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Built2Spec

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D3.14 Acoustic methodology

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Executive summary

The Deliverable D3.14 entitled “Acoustic methodology” is a public document delivered in the context of WP3, Task 3.3: Acoustic performance

This work is part of the project on Tools for the 21st Century Construction Worksite (BUILT2SPEC) and is financed by the European Union under the Horizon 2020 Program.

The deliverable 3.14 is related with subtask 3.3.1 *Evaluation of the use of mobile devices as an alternative to class 1 microphones for acoustic measurements*. This subtask evaluates the use of mobile devices for airborne sound insulation measurements and develops a methodology for the application of these devices.

This document provides details about the different parts of the methodology:
- Calibration
- Sound field generation
- Microphone positions
- Background noise
- Source and receiver room location
- Reverberation time
- Regulation requirements in European countries
- Airborne sound insulation descriptors calculation

1 Table of Contents

Abbreviations

B2S = Built to Specifications

DOA = Description of Action;

CS = Communication Strategy;

SPL = Sound Pressure Level

FFT= Fast Fourier Transform

WP = Work Package.

1 Introduction

The deliverable 3.14 is related with subtask 3.3.1 *Evaluation of the use of mobile devices as an alternative to class 1 microphones for acoustic measurements*. This subtask evaluates the use of mobile devices for airborne sound insulation measurements and develops a methodology for the application of this devices.

The methodology will be based on the UNE-EN ISO 1628-1 regulation, which specifies the requirements to perform in situ airborne sound insulation measurement in buildings. This methodology will be adapted to the Built2Spec app.

2 Calibration

Each time that a new device or a new microphone is used, is mandatory to perform a calibration of the system. The calibration is done by an expert user and saved in the device. The details of the calibration algorithm are explained in D3.13 and its procedure in D3.9

3 Sound field generation

Any loudspeaker used for airborne sound insulation measurements has to accomplish the following directivity requirements:

- The location and directivity of the loudspeaker has to ensure that the acoustic direct radiation is not the dominant.
- The noise generated in the room has to be stable and to have a continuous spectrum in all the frequency range
- The acoustic radiation directivity has to be approximately uniform, omnidirectional. To check the loudspeaker directivity, an averaged sound pressure level in a complete circle has to be recorded (L_{360^a}). For each angle interval, $L_{30,i}$ values are measured for each angle interval i and averaged over 30º around the central angle. The directivity indexes are , then , obtained with the following relation:

$$DI_i = L_{360º} - L_{30,i}$$

In our case, these requirements will be checked for the Omnidirectional Parametric Loudspeaker during the characterization stage. The results obtained, as well as a comparison with actual loudspeaker will be reported in D.3.10

Apart from the sound generation requirements, there are also location requirements that must be accomplished when performing sound insulation measurements. The next guidelines must be followed:

- Distance between the loudspeaker and any of the room walls , floor or ceiling must be equal or higher than 0.5 meters
- Distance between the loudspeaker and the separation wall to be measured must be equal or higher than 1 meter
- Between loudspeaker different locations must be at least a distance of 0.7 meters

These requirements will be summarized in a user guide for the non-trained personnel.

4 Microphone positions

In order to obtain the sound insulation measurement, at least five different positions of the microphone should be used. In our case, the device application will guide the user through all the different steps needed to make the measurement, indicating which microphone position is measuring at each time.

Considering that we have multiple loudspeaker positions and multiple microphone positions, the Sound Pressure Level Difference is obtained as:

$$D_{nT} = -10\log\frac{1}{m}\sum_{j=1}^{m}10^{-D_{nT,j}/10}$$

Whew

- m is the different positions of the loudspeaker
- j is the different positions of the microphone

As well as with the loudspeaker, there are some requirements with the locations of the microphones that has to be taken into account:

- There must be 0.7 meters between two microphone measurement positions
- There must be 0.5 meters between any microphone position and any wall, floor or ceiling of the room
- There must be 1 meter between any microphone position and any loudspeaker position

The mobile application app will ensure that the average time of each measurement is correct. By default, an average time of 6 seconds will be used. This time could be not enough for low frequency measurements. However, the calibration stage suggested that we might not be able to measure at low frequencies due to the limitations of the internal mobile device microphones. More accurately information will be obtained from the pilot testing measurements.

5 Background noise

Background noise is a very important issue to take into account when performing acoustic measurements. First of all, background noise measurements must be done to guarantee that the noise level in the room is not affected by the background noise. Noise from outside the measurement room, electric noise or any kind of unwanted noise can distort the measurements. Once the background noise measurements are obtained, they will be compared with the rest of the measurements obtained (in particular, the noise level measurements in the receiver room) and the following actions should be taken:

- **If the noise level is less than 6 dB louder than the measured background noise:** Then, a 1.3dB will be corrected in each frequency band where that occurs. That will be logged in the outputs results file.
- **If the noise level is more than 10 dB louder than the background noise level:** Then, the background noise won't affect the measurement and no correction is needed
- **If the noise level is between 6 dB and 10 dB above the background level:** Then , the background level will have a little influence in the results and the following correction must be used:

$$L = 10\log(10^{\frac{L_{sb}}{10}} - 10^{\frac{L_b}{10}})$$

Where

- L : is the noise level in dB with the correction applied
- L_{sb} is the noise level recorded with the loudspeaker on
- L_b: is the background level recorded previously

The previous steps will be done automatically by the mobile application software.

However, when measuring, the user must be aware if there is any other noise than the one generated by the loudspeaker. If that is the case, the measurement done should be rejected. This can be done just after the measurement by pressing **reject** button in the mobile application screen.

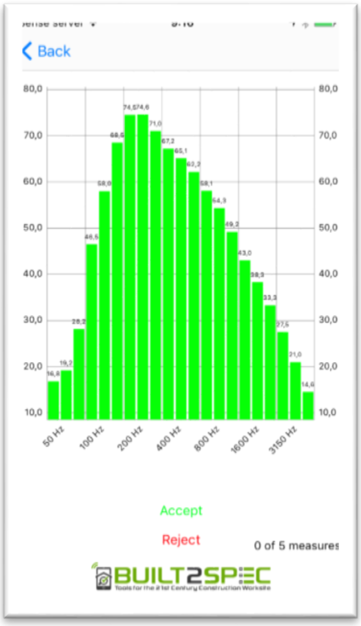

Figure 1Mobile application options after performing a measurement

6 Source and receiver room selection

Some guidelines that are recommended to follow when choosing the rooms to be measured are:

- By default, the source room should be the one with a bigger volume. Except when:
  A) In horizontal measurements (in the same floor), when a room has a simple defined volume and the other not, this room should be used as a receiver, even when it had a bigger volume.
  B) In vertical measurements, the upper room can only be used as a source room if the loudspeaker is far enough from the floor (more than 1 meter)

Special room cases:

- If we have rooms with high acoustic absorption: In the receiver room, the locations with a sound level pressure difference of more than 6 dB will be neglected. In the source room, the source has to be a as near as possible to the floor/wall to be measured (in compliance with the requirements indicated in section 3.
- If the rooms are located in different planes (moved from each other). The positions of the loudspeaker and microphones should be near the partition.

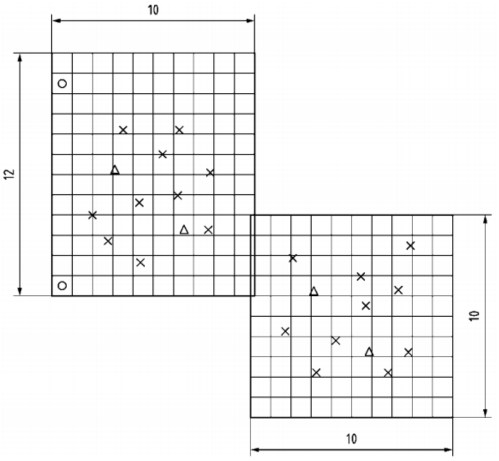

Figure 2 Microphone (X) and Loudspeaker (Δ) positions example in ISO 16283

7 Reverberation time

Reverberation time is the time needed to reduce in 60 dB (T60) the sound pressure of a room. Additional reverberation times can be calculated for 30 dB reduction (T30) and 20 dB reduction (T20).

Reverberation time is used to calculate the equivalent absorption area

$$A = \frac{0.16V}{T}$$

Where

T is the reverberation time of the receiver room

V is the volume of the receiver room

The equivalent absorption area is necessary to compute the sound reduction index from the level difference index

$$R' = D + 10\log(S/A)$$

Where

- D is the level differenc index in dB for each frequency band
- S is the surface of the separation wall or floor
- A is the equivalent absorption area in each frequency band

Reverberation time may range from 0.1 seconds (or less) in anechoic chambers, to 10 or more seconds in large public spaces, and could vary between positions in a room. Then, at least five different positions must be taken in the sound insulation measurements.

There are two methods available to successfully measure reverberation time: impulsive excitation (Schroeder method), such as from a pistol or balloon burst, or interrupted noise method, which records the moment when a loudspeaker stops generating noise.

In our case, only the interrupted noise method will be used. The application will indicate the user to stop the loudspeaker and then the algorithm will detect when the noise level is decreasing and start the reverberation time measurement.

This measurement will be performed in third octave bands and used to compute the sound reduction index.

8 Regulation requirements in European countries

One of the main problems when comparing acoustic measurements and acoustic material performances between countries is that the acoustic descriptor used is different. In the next table, we can see that there several acoustic descriptors for airborne sound insulations

Country	Descriptor
France	D_{nTw}+C
Germany	R’$_{w}$
Ireland	D_{nTw}
Italy	R’$_{w}$
Netherlands	R’$_{w}$ +C
Spain	D_{nTw}+C
Switzerland	D_{nTw}+C
United Kingdom	D_{nTw}+C_{tr}

Figure 3Acoustic descriptors for airborne sound insulation in European countries

Fortunately, these descriptors can be obtained from the raw data of the acoustic measurement without changing the measurement method. In the next section the methodology to obtain each of the descriptor is presented

In any case, during the airborne sound insulation measurement tests, the application will allow the user to choose which descriptor/country wants to select to view the results.

9 Airborne sound insulation descriptors calculation

Once all the steps given by the mobile application have been carried out, we have the following results for each third octave frequency band:

1) L_1 : Sound pressure level averaged in time and space of the source room
2) $L_{2:}$ Sound pressure level averaged in time and space of the receiver room
3) T: Reverberation time of the receiver room

Where, the averaged sound pressure level is obtained from:

$$L = 10\log\left(\frac{1}{T}\right)\int_0^T \frac{p^2(t)}{p_0^2}$$

Being p(t) the sound pressure at instant t and p_0 the reference pressure ($2\cdot10^{-5}$ Pa).

From the sound pressure level, the sound pressure level difference can be obtained

$$D = L_1 - L_2$$

This result will depend on the absorptive material from the receiving room.

To normalize the level difference we must us the reverberation time recorded in the receiver room.

The level difference, D, is then *standardized* using a reference value for the reverberation time, or *normalized* using a reference value for the absorption area.

- normalized level difference as $D_n = D - 10\log\left(\frac{A}{A_0}\right)$, where $A_0 = 10\ m^2$
- standardized level difference as $D_{nT} = D - 10\log\left(\frac{T}{T_0}\right)$, where $T_0 = 0.5\ s$

Besides, if we want to take into account the surface of the wall or floor that we are measuring, then the apparent acoustic reduction index must be used

$$R' = D - 10\log\left(\frac{S}{A}\right)$$

All these descriptors are obtained in third-octave frequency bands. However, regulatory requirements for buildings are often set using single-number quantities calculated according to the UNE EN ISO 717-1. To obtain the single-number quantity, a weighting is performed comparing the measured spectrum with a reference curve. The reference curve is moved in 1 dB steps while the unfavorable deviations is less than 32 dBs. The final value of the curve at 500 Hz is the weighted level (R_w, D_w, D_{nTw}).

To account for the relative loudness perceived by the human ear, some countries add a coefficient C to the weighted level. The resulting index is approximately equal to the A-weighted level.

10 Measurement workflow

The methodology described in this document will be applied to the general workflow of the acoustic measurement. In this case, two different workflows have been described and implemented for two different user cases: with and without the indoor positioning method