In-situ Measurement of the Sound Insulation of Building Elements

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Abstract

The verification of the sound insulation of façades and individual building elements, such as windows, is typically carried out in accordance with EN ISO 16283 - 3. However, in the presence of traffic noise or in the case of complex façade structures, such measurements are often difficult and require considerable effort.
This paper therefore presents an adapted measurement method based on sound intensity, following the principles of EN ISO 15186-2. The two methods are compared in terms of their applicability and accuracy.
Furthermore, specific challenges associated with large rooms and with building elements exhibiting high sound insulation values are discussed.

Keywords: *Sound Insulation, EN ISO 16283-3, EN ISO 15186-2*

1. Introduction

The sound intensity probe is a measuring instrument that enables a wide range of applications. Firstly, it can be used to measure sound intensity. When scanning a structure, the sound intensity can be localized, which allows the acoustic properties of the various components to be distinguished. This enables, for example, defects to be detected. This article focuses specifically on the inspection of building components such as windows and façades.
The aim is first to compare the different methods

- Measurement using a sound level meter in accordance with EN ISO 16283-3 [1]
- Measurement based on sound intensity in accordance with EN ISO 15186-2 [2]

A proposed method for determining the sound insulation of façades and windows, especially in large rooms is illustrated using examples.

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2. Measurement of sound insulation

2.1 EN ISO 16283 – Element method

In this method, sound is emitted from a loudspeaker positioned at an angle of 45° to the building element at a distance of at least 3.5 m. The sending level L1, s is measured on the sending side near the surface of the building element at 3–10 positions. In the receiving room, the average level L2 and the reverberation time T20 are determined. The sound insulation of the component is calculated using the following formulas:

$$R'_{45°} = L_{1,s} – L_2 + 10 \lg \frac{S}{A} - 1{,}5 \tag{1}$$

$$A = 0{,}16 \frac{V}{T20} \tag{2}$$

Here, S is the element area, A is the equivalent absorption area and V is the volume of the receiving room.

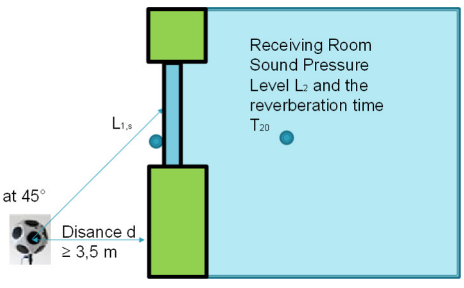


Figure 1. Measurement of a window using the element method

2.2 EN ISO 16283 – Global method

This method is used to determine the sound insulation of a façade, including windows. Sound is also incident at an angle of 45° to the component, but at a distance of at least 5 m from the wall. The source sound level L1, 2m is measured at a distance of 2 m from the façade. In the receiving room, the average level L2 and the reverberation time T20 are determined. The sound insulation of the building element is calculated using the following formulae:

$$D_{2m,nT} = L_{1,\,2m} - L_2 + 10\,\lg\frac{T20}{T0} \qquad (3)$$

$$R'_{res} = D_{2m,nT} - 10\,\lg\frac{V}{6T0\;S} + 4.5 \qquad (4)$$

T0 is the reference reverberation time of 0.5 s.

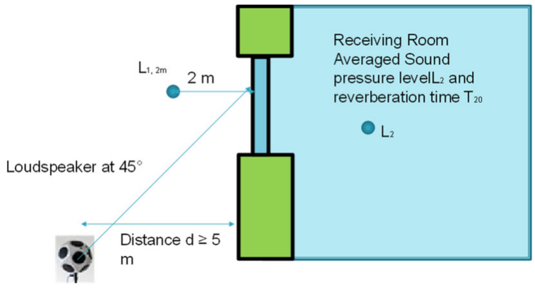


Figure 2. Measurement of a façade using the global method

2.3 EN ISO 15186-2 Building sound intensity insulation index

In this adapted method, the sound source is positioned within the room, the source room. The average level L_1 in the source room is determined by sweeping the probe. Outside, the sound intensity $L_{I,n}$, which passes through the building element with area S, is measured at the measurement surface S_m using a sound intensity probe. The measurement surface forms a closed envelope around the building element to be measured. The sound intensity probe is swept across the measurement surface twice in a meandering pattern. The direction of measurement is perpendicular to the measurement surface.
In the source room there is in a diffuse field, as it is assumed in all conventional building acoustics measurements. Outside, a free field is generally present. The building sound intensity insulation index is calculated as follows:

$$R'_I = L_1 - 6 - L_{I,n} + 10\,\lg\frac{S}{Sm} \qquad (5)$$

The following figure shows a schematic representation of a measurement of a window. The recess is used to define the lateral boundary.

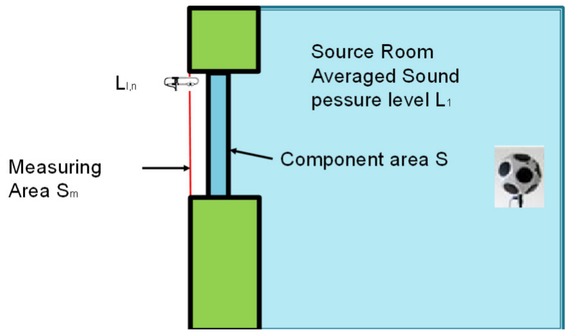


Figure 3. Measurement of a window using the sound intensity method

2.4 Specific issues measuring in large rooms

If the source room is a big room, then there is almost no diffuse field. The sound from the loudspeaker is mainly direct sound and a little echo. Figure 4 shows a setup with extra loudspeakers.

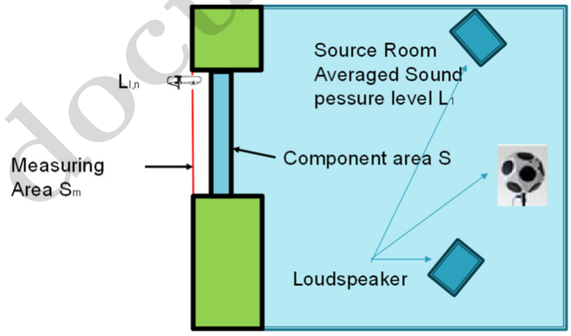


Figure 4. Setup in a large source room with extra loudspeaker

To verify a high sound insulation index, it is also useful to use extra loudspeakers to get a higher Sound pressure level in the source room.

3. Examples

3.1 Practical measurement situations

The following examples illustrate situations in which it is difficult to apply the standard method in accordance with EN ISO 16283-3 [1]. Balconies and parapet walls often make it impossible to direct sound at the building element at an angle of 45°.

In the example in Figure 7, it is practically impossible to apply sound at an angle of 45° from below.

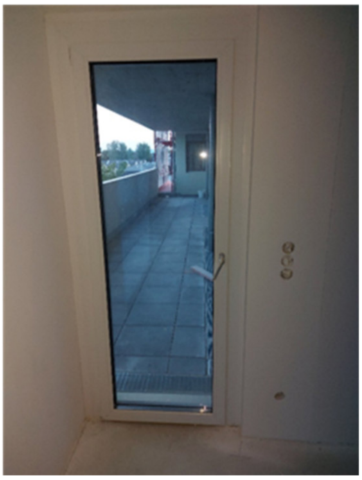


Figure 5. Example of a balcony door with a balcony and parapet wall

Figure 6. Example of a bungalow, small façade with a recess

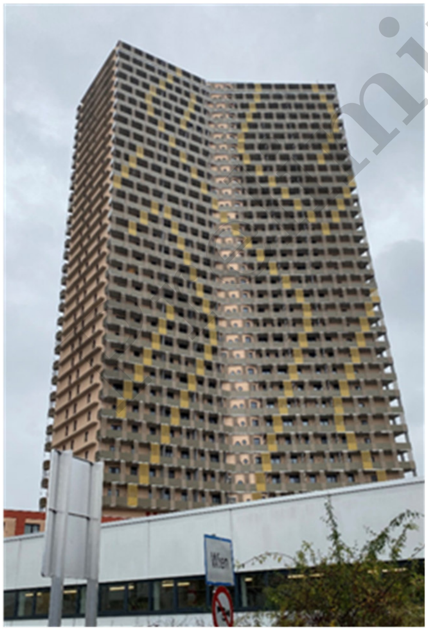


Figure 7. Example of a high-rise building with balconies

3.2 Bungalow – Comparison of methods

In the following example, complaints were made about the noise from passing vehicles in the bedroom. The task was to determine whether the noise is coming mainly through the windows or through the façade, and whether the building elements met the requirements. The following image shows an extract from the plan and schematically illustrates the position of the loudspeaker during façade and building element measurements. The wall is a brick wall with an external thermal insulation composite system. In order to measure the wall as a building element in accordance with EN ISO 16283-3 [1], it is necessary to seal off the window.

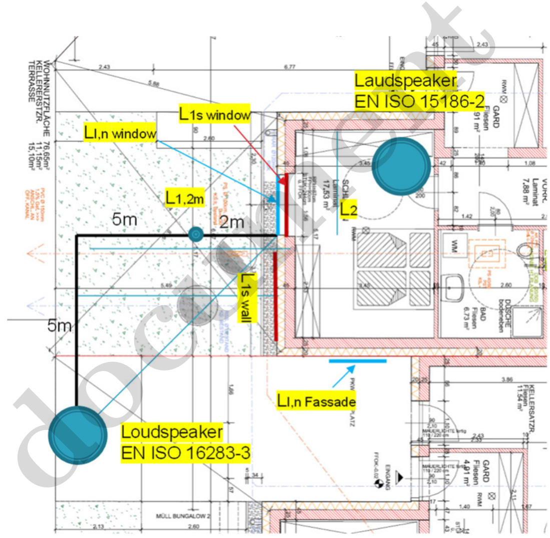


Figure 8. Example of measurements at a bungalow

Measuring based on EN ISO 15186-2 [2] with the sound intensity probe, the sound source is positioned in the bedroom and the sound pressure averaged is in the room. Outside the measurement is taken, either at the window recess or on the side of the façade.

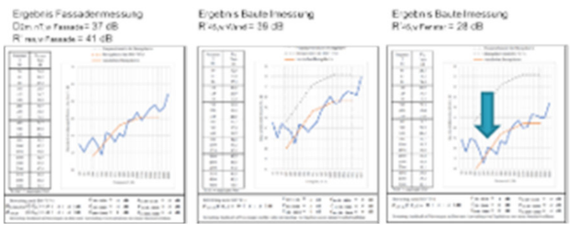


Figure 9. Result in accordance with EN ISO 16283-3 [1]

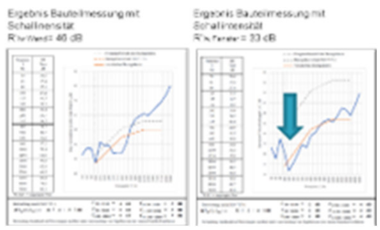


Figure 10. Result according to EN ISO 15186-2 [2]

The results show that the window, specifically the glazing, is responsible for the low sound insulation performance with Rw~ 12 dB at 125 Hz. During the component measurement of the window in accordance with EN ISO 16283-3 [1], the sound pressure was measured at three points in the vicinity of the panes. As the panes, or rather their installation within the window, were the cause of the low sound insulation values, the value for the window, R'45,w window= 28 dB – measured at the pane – is lower than the measurement for the entire window, which is R'I,w window= 33 dB. The advantage of measuring sound insulation based on sound intensity is, that the recess, which is often present, can be used as a boundary. A further advantage is that a diffuse field prevails in the source room, thus providing conditions similar to those on the test bench.

3.3 Example of glass facade measurements

The following example shows a setup of a glass façade measurement at the new departure hall at the airport in Frankfurt. The departure hall has an area of ~12700 m^2 and a height of ~12 m. The sound field is far away from being diffuse. Therefore, extra loudspeaker simulate sound from more directions.

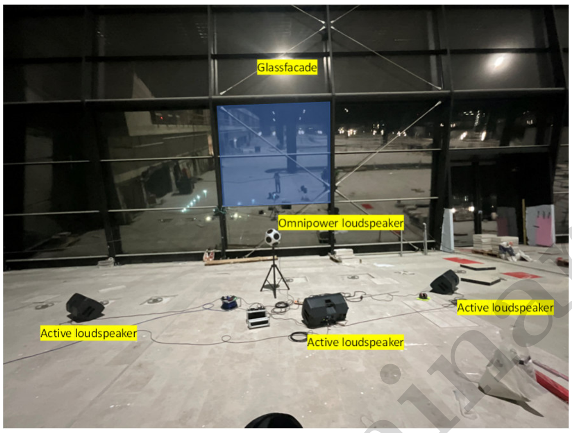
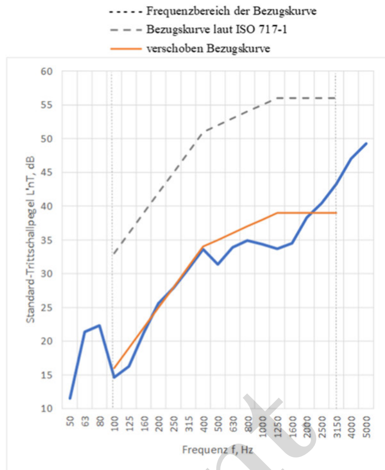


Figure 11. Setup at Airport in Frankfurt

In the Source room the sound pressure level is measured close to the surface, around 1 m away. Outside the averaged Sound Intensity of an element is measured by scanning the surface.

Frequenz f Hz	R'I Terz dB
50	11,5
63	21,4
80	22,3
100	14,6
125	16,3
160	21,2
200	25,6
250	27,9
315	30,7
400	33,6
500	31,4
630	33,9
800	34,9
1000	34,4
1250	33,7
1600	34,5
2000	38,3
2500	40,4
3150	43,3
4000	47,0
5000	49,3

*B: R' >= angezeigter Wert



Bewertung nach ISO 717-1

$R'I_w(C; C_{tr})$ = **35 (-2 ; -6)dB**

$C_{50-3150}$ = **-2 dB** $C_{tr,50-3150}$ = **-7 d**

$C_{50-5000}$ = **-1 dB** $C_{tr,50-5000}$ = **-7 d**

$C_{100-5000}$ = **-1 dB** $C_{tr,100-5000}$ = **-6 d**

Bewertung beruhend auf Messungen am Bau unter Anwendung von Ergebnissen aus einem Standardverfahren

Figure 12. Result of the glass façade measurement

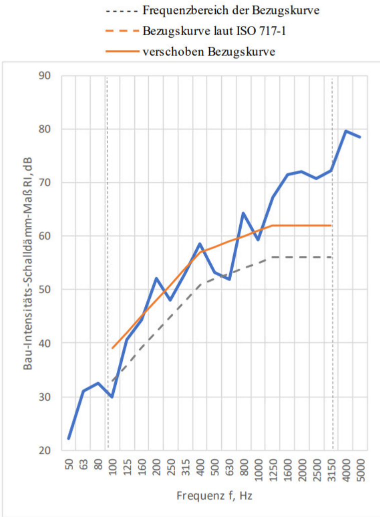
3.4 Example of a boxtype window

The following example shows a measurement of a boxtype window. A sound insulation index of R'w = 60 dB +0, -2 dB should be in-situ verified. Due to the big size of the room and the high sound insulation requirements, a high sound pressure level inside the source room is necessary, to avoide a negative impact of ambient moise outside.

A boxtype window consists of 2 windows, one inside and one outside. Between is an air cushion of ~ 25 cm. Normally the inner window is fully sealed and the outer window is not fully sealed, to avoide negative impact due to humidity.
Measurements were made with both windows fully sealed and the outer windor not fully sealed.

Frequenz f Hz	R'I Terz dB
50	22,2
63	31,1
80	32,6
100	29,9
125	40,6
160	44,4
200	52,1
250	48,1
315	53,0
400	58,5
500	53,2
630	52,0
800	64,3
1000	59,4
1250	67,3
1600	71,5
2000	72,0
2500	70,8
3150	72,3
4000	79,7
5000	78,6

*B: DnT >= angezeigter Wert



Bewertung nach ISO 717-1

$R'I_w(C;C_{tr})$ = 58 (-3 ; -9 dB

$C_{50-3150}$ = -4 dB $C_{tr,50-3150}$ = -14

$C_{50-5000}$ = -3 dB $C_{tr,50-5000}$ = -14

$C_{100-5000}$ = -2 dB $C_{tr,100-5000}$ = -9

Figure 12. Result of the boxtype window measurement

The R'Iw is 58 dB and is reaching the requirements. In case of unsealed outer window, the result is between 48 dB and 50 dB.

The quality of the sealing of the windows with the essential mass- air- mass resonance of the boxtype window has a major impact on the sound insulation.

This example shows, that very high sound insulation indexes can be measured and verified in-situ.

References

[1] EN ISO 16283-3 Acoustics — Field measurement of sound insulation in buildings and of building elements Part 3: Façade sound insulation.

[2] EN ISO 15186-2 Acoustics – Measurement of sound insulation in buildings and of building elements using sound intensity – Part 2 Field Measurements