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PROPOSAL FOR A METHODOLOGY AND CALCULATION TO APPLY IN THE SOUND INSULATION MEASUREMENT OF CORNER FAÇADES USING ISO 16283-3 STANDARD

Trujillo Gallego, Jose Alberto[1*] **Romero Fernández, Amelia**[2]
[1] Laboratorio de Ensayos Acústicos (Labenac) - Universidad Politécnica de Madrid, Spain
[2] Instituto de la Construcción Eduardo Torroja (CSIC), Madrid, Spain.

ABSTRACT

The measurement methodology described in ISO 16283-3:2015 for façade sound insulation allows the use of a loudspeaker as a substitute for real noise sources (road, railway, or aircraft traffic). Using this source, the sound insulation tests of multi-wall façades are conducted wall by wall. The method requires positioning the loudspeaker at an angle of sound incidence of 45°, which, for ground-floor façades necessitates placing the sound source off-center, toward one of the two lateral edges of the wall under test. This situation becomes particularly critical for corner façades with two walls, where the side to which the sound source is shifted may lead to significantly different results due to potential indirect noise transmission into the interior space via the opposite wall. Furthermore, the mathematical approach used to calculate the final sound insulation value does not accurately reflect a real situation.

This study proposes a more appropriate positioning and calculation method to achieve repeatable and representative results under realistic conditions, demonstrated through an example in a real scenario.

Keywords: *ISO 16283-3; façade sound insulation, corner façade, field measurements, repeatability.*

1. INTRODUCTION

The current standard for façade sound insulation, ISO 16283-3 [1], defines a field measurement and calculation method to determine the acoustic insulation of whole façades (global methods). The specified test method is general, meaning that in specific cases, it may lack precision or fail to provide representative results.
This paper studies the specific case of a corner façade with two walls exposed to outdoor noise and how standard testing procedures can yield different results depending on their application. Additionally, it evaluates how the current calculation method may not accurately reflect real conditions in this scenario of a corner façade.

2. SCENARIO

Figure 1 illustrates a typical scenario of a corner façade with two walls on the ground floor.

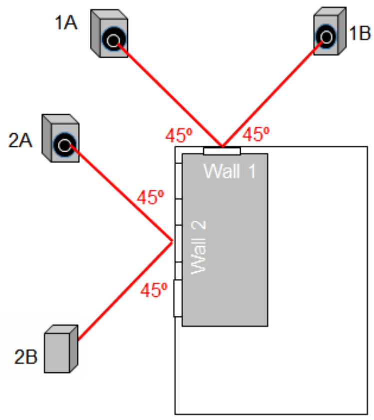


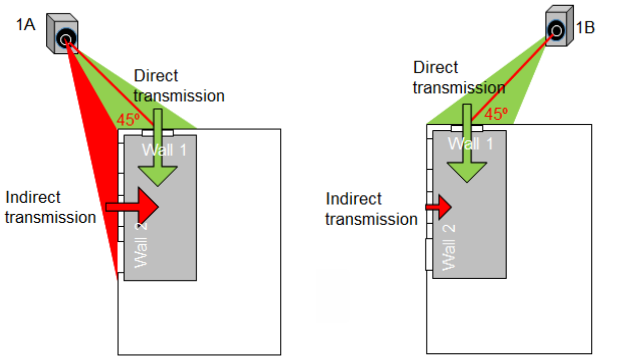
Figure 1. Possible sound source positions per wall.

*Corresponding author: jtrujillo@labenac.es.

According to the measurement standard, when using the global loudspeaker method, each façade wall must be tested separately. To ensure an angle of sound incidence equal to 45°±5° on the wall, the noise source must be laterally displaced from the façade centre. The standard allows for two possible loudspeaker positions: either towards the corner or in the opposite direction (Fig. 1).

2.1 Insulation procedure for Wall 1

For measuring the sound insulation of Wall 1, two noise source positions are possible: 1A, with the source shifted towards the corner (Fig. 2a), and 1B, shifted in the opposite direction (Fig. 2b).



(a) (b)

Figure 2. (a) Noise transmission for 1A sound source position. (b) Noise transmission for 1B sound source position.

For source position 1A, due to the small length of Wall 1, the noise source has a direct line of sight to both tested walls. As a result, although the source is directed at Wall 1 (direct transmission), part of the sound beam directly reaches Wall 2. This means that the indoor noise level (L_2) consists of contributions from both the tested wall ($L_{2,W1}$) and the adjacent wall ($L_{2,W2}$), making it impossible to isolate the contribution of Wall 2 in the overall measured levels, without any other additional and specific studies.

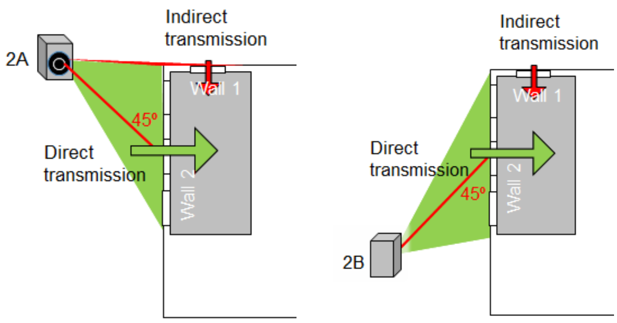
$$L_2 = 10Log(10^{(0,1*L_{2,W1})} + 10^{(0,1*L_{2,W2})}) \quad (1)$$

Consequently, the partial insulation of Wall 1 ($D_{nT,W1}$) may be underestimated. However, using source position 1B ensures that most of the loudspeaker's sound beam is transmitted through Wall 1, with significantly lower and negligible indirect transmission through Wall 2. Thus, in this configuration, $L_{2,W1} >> L_{2,W2}$, and consequently, $L_2 \approx L_{2,W1}$.

In conclusion, selecting source position 1B provides a result closer to the real sound insulation of the wall.

2.2 Insulation procedure for Wall 2

As in the previous case, two source positions can be used to characterize the sound insulation of Wall 2: 2A, with the source shifted towards the corner (Fig. 3a), and 2B, shifted in the opposite direction (Fig. 3b).



(a) (b)

Figure 3. (a) Noise transmission for 2A sound source position. (b) Noise transmission for 2B sound source position.

Due to the greater length of Wall 2, in the least favorable position (2A, near the corner), there is hardly any direct view of Wall 1. Therefore, regardless of whether 2A or 2B is chosen, the direct transmission through Wall 2 will be significantly higher than the indirect transmission through Wall 1 ($L_{2,W2} >> L_{2,W1}$). This means that, in this case, the source position is less critical, and the partial insulation result of Wall 2 ($D_{nT,W2}$) is expected to be similar for both source positions.

2.3 Conclusions on sound source position

Since the measurement procedure in ISO 16283-3 standard [1] requires that façades with multiple walls be tested independently (wall by wall), it is essential to ensure that the measured insulation corresponds exclusively to the tested wall, avoiding noise transmission into the room through the adjacent corner wall. Source positions shifted towards the façade corner may lead to lower-than-actual partial insulation values due to indirect noise transmission, with deviations that cannot be precisely quantified. These deviations depend on factors such as source position, coverage beam, and wall dimensions.

Therefore, to minimize this situation, the best approach is to locate the source away from the façade centre, as far as possible, always in the direction opposite to the corner.
Other authors [2] have also studied the influence of the source position on the final results of the façade insulation of corner rooms, additionally considering the acoustic attenuation due to corner diffraction.

3. ON THE CALCULATION METODOLOGY

ISO 16283-3 [1] allows the use of road traffic (see Fig. 4), railway traffic, and even aircraft noise as sound sources. Conducting tests with these sources provides insulation values that reflect real façade performance under actual noise exposure. However, using traffic noise requires very specific conditions, making the global loudspeaker method the preferred option due to its simplicity and independence from external sources.
The standard's calculation method evaluates each façade wall separately, determining a partial insulation index ($D_{2m,i}$) for each. The final insulation value is then obtained by averaging the individual results, as expressed in Eqn. (2):

$$D_{2m} = -10Log(\frac{1}{n}\sum_{i=1}^{n}(10^{(0,1*D_{2m,i})})) \qquad (2)$$

3.1 Comparison of road traffic and loudspeaker global methods

Next, a theoretical case of a corner façade is evaluated using both global methods: road traffic noise and the loudspeaker.

3.1.1 Theoretical considerations

For the development of this example, the following considerations will be taken into account:

- To simplify the analysis, the examples will use global values rather than one-third octave band frequency spectra.
- The two walls forming the façade are identical in both dimensions and construction characteristics. Each wall provides a sound insulation level of D = 35 dB.
- In both the road traffic noise method and the loudspeaker method, the external measurement point receives the same noise level in all cases: $L_{1,2m}$ = 85 dB.

3.1.2 Test 1. Sound insulation measurement using loudspeaker global method

As mentioned in the previous section, the loudspeaker positions farthest from the corner are selected to avoid indirect transmissions that could affect the results (Fig. 4).

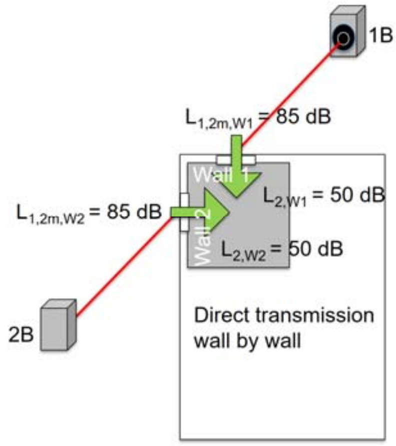


Figure 4. Façade sound insulation calculation using a loudspeaker as a sound source.

As specified by the standard's procedure, each wall is tested separately. For Wall 1, with an outdoor noise level $L_{1,2m}$ = 85 dB and a sound insulation value D = 35 dB, the indoor noise level will be 50 dB ($L_{2,W1}$). Since indirect transmission is negligible, it follows that $L_2 \approx L_{2,W1}$ = 50 dB.
Given that both walls have identical properties, their partial insulation values are:

$$D_{ls,2m,W1} = D_{ls,2m,W2} = 85\text{ dB} - 50\text{ dB} = 35\text{ dB} \qquad (3)$$

Finally, applying Eqn. (2), the overall insulation is $\mathbf{D_{ls,2m}}$ = **35 dB**.

3.1.3 Test 1. Sound insulation measurement using road traffic global method

As previously mentioned, the insulation test must be performed separately for each wall. However, in this case, it is important to consider that outdoor noise enters the indoor space simultaneously through both façade walls.
Since both walls are identical and exposed to the same outdoor noise levels, the insulation calculation for Wall 1 ($D_{tr,2m,W1}$) is also valid for Wall 2 ($D_{tr,2m,W2}$), giving the same result.

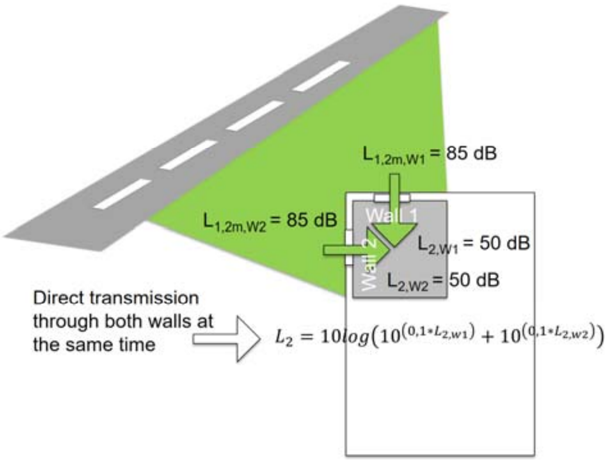


Figure 5. Façade sound insulation calculation using road traffic noise.

For Wall 1, with an outdoor noise level of $L_{2m,W1}$ = 85 dB and a known insulation value $D_{tr,2m}$ = 35 dB, the noise reaching the interior through this wall is 50 dB. However, as the traffic noise excites both walls equally, an additional 50 dB also enters through Wall 2. Therefore, the total indoor noise level (L_2) can be calculated as:

$$L_2 = 10Log(10^{(0,1*L_{2,W1})} + 10^{(0,1*L_{2,W2})}) \quad (4)$$

Resulting in L_2 = 53 dB (Fig. 5).
Thus, the partial insulation values for both walls are:

$$D_{tr,2m,W1} = D_{tr,2m,W2} = 85 \text{ dB} - 53 \text{ dB} = 32 \text{ dB} \quad (5)$$

Finally, applying Eqn. (2), the overall insulation value is **$D_{tr,2m}$ = 32 dB**.

3.2 Conclusions on the calculation method

Therefore, as reflected in the previous theoretical discussion, for the same façade and identical outdoor noise conditions, there is a 3 dB deviation between the traffic noise insulation procedure and the loudspeaker method, despite using the same testing methodology and calculation approach.
The key difference lies in the fact that, during traffic noise insulation measurements, outdoor noise enters through both façade walls simultaneously, regardless of which wall is being tested at a given moment. This results in a higher interior noise level and, consequently, a lower insulation value compared to the loudspeaker method.
Considering that traffic noise insulation measurement better represents real-world conditions and should therefore be used as a reference, two alternative adaptations of the loudspeaker method are proposed to achieve similar results:

Option 1: Modification of the testing method: This approach requires using two identical loudspeakers, each directed towards the centre of one wall, positioned to minimize indirect transmission (Fig. 6), away from the corner. The testing procedure follows the standard method, assessing the partial insulation of each wall. The only difference is that, during the test of each wall, both loudspeakers (sound sources S_1 and S_2) will emit the same noise simultaneously at the same intensity.

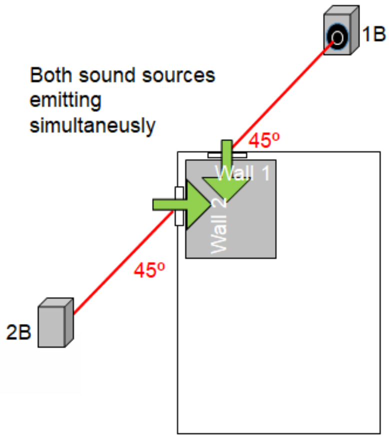


Figure 4. Façade sound insulation measurement using two loudspeakers simultaneously as sound sources.

Option 2. Modification of the Calculation Method: In this case, the standard procedure remains unchanged: each wall is tested separately using a single noise source, positioned sequentially; first for Wall 1 to calculate its partial insulation, then for Wall 2.
To determine the overall insulation, the standard Eqn. (2) is replaced with a new equation that sums the partial insulation values instead of averaging them:

$$D_{2m} = -10Log(\sum_{i=1}^{n}(10^{(0,1*D_{2m,i})})) \quad (6)$$

4. PRACTICAL CASE

To validate the previous findings, a sound insulation test was conducted on a corner façade. Two identical loudspeakers were positioned to excite both façade walls, with their locations shifted away from the corner to reduce indirect transmissions.

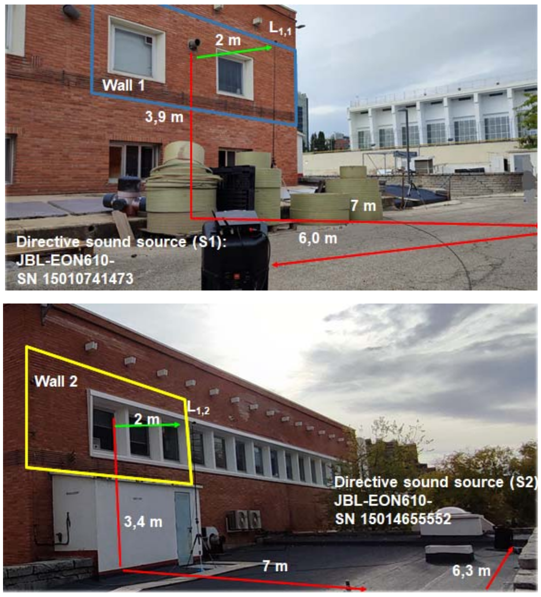


Figure 5. Measurement scenario. Outdoor microphone and sound source positions per wall.

4.1 Measurements

The following tests were performed according to ISO 16283-3 [1]:

- Test 1: "Real-World Scenario". Both noise sources emitted simultaneously during the testing of each wall.
- Test 2: Standard Procedure. Sound insulation measured separately per wall.
- Control Tests: Outdoor measurements taken 2m from Wall 1 while testing Wall 2, and vice versa, to check for indirect transmission.

4.2 Instrumentation

The following equipment was used for the tests:

- Brüel & Kjaer model 2270 dual-channel sound level meter and one-third octave band analyzer.
- Brüel & Kjaer model 2260 dual-channel sound level meter and one-third octave band analyzer.
- Brüel&Kjaer model 4231acoustic calibrator.
- Two JBL model EON610 directive sound sources.
- AKG dual-channel RF transmitter.

5. RESULTS AND DISCUSSION

5.1 Outdoor noise level results

Next, the outdoor results are presented according to

- $L_{1,W1\ (S1\&S2)}$: Outdoor noise level 2m in front of wall 1. Sound sources S1 and S2 emitting simultaneously.
- $L_{1,W1\ (S1)}$: Outdoor noise level 2m in front of wall 1. Only emitting sound source S1.
- $L_{1,W2\ (S1\&S2)}$: Outdoor noise level 2m in front of wall 2. Sound sources S1 and S2 emitting simultaneously.
- $L_{1,W2\ (S2)}$: Outdoor noise level 2m in front of wall 2. Only emitting sound source S2.
- $L_{1,W1\ (S2)}$: Outdoor noise level 2m in front of wall 1. Only emitting sound source S2 (control measurement).
- $L_{1,W2\ (S1)}$: Outdoor noise level 2m in front of wall 2. Only emitting sound source S1 (control measurement).

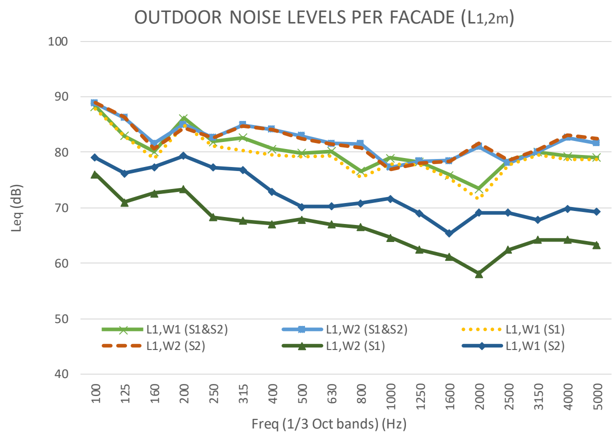


Figure 6. Outdoor levels.

For each wall, the noise spectrum measured at 2m remains similar, whether both sources operate simultaneously or only the one exciting the measured wall is active. This confirms that, with the selected source positioning, the influence of the secondary source on the measured wall is negligible. This effect is particularly evident for Wall 2, where the measured spectra closely align in both test conditions, reinforcing the validity of the experimental setup.

5.2 Indoor noise levels results

The following results were obtained indoors:

- $L_{sb(S1\&S2)}$: Indoor noise level when S1 and S2 emitting simultaneously.
- $L_{sb\ (S1)}$: Indoor noise level when S1 emitting.
- $L_{sb\ (S2)}$: Indoor noise level when S2 emitting.
- L_b: Indoor background noise level.

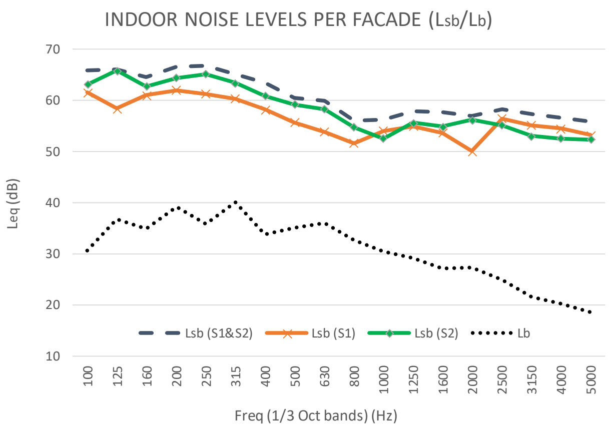


Figure 7. Indoor levels.

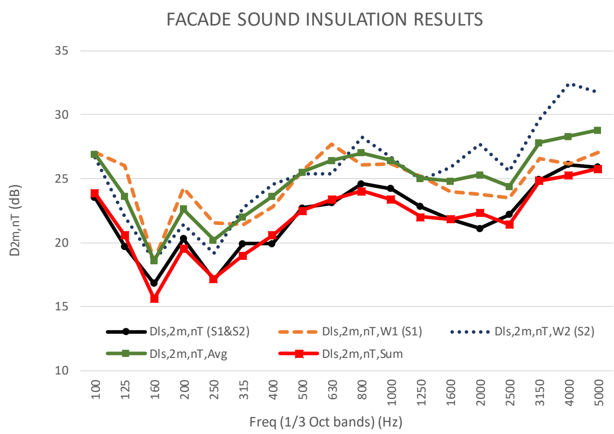


Figure 8. Standardized level difference.

The results confirm no significant background noise influence. As expected, indoor noise levels are higher when both façade walls are excited simultaneously, replicating real-world conditions.

5.3 Standardized level difference ($D_{ls,2m,nT}$)

Graph in Fig. 10 presents the results:

- $D_{ls,2m,nT\ (S1\&S2)}$: Final standardized level difference calculated using Eqn. (2), for sound insulation descriptor $D_{ls,2m,nT}$. when both sound sources are emitting simultaneously.
- $D_{ls,2m,nT,W1\ (S1)}$: Partial standardized level difference for Wall 1 (with only sound source 1 emitting).
- $D_{ls,2m,nT,W2\ (S2)}$: Partial standardized level difference for Wall 2 (with only sound source 2 emitting).
- $D_{ls,2m,nT,Avg}$: Final standardized level difference level calculated using Eqn. (2) based on the partial results $D_{ls,2m,nT,W1\ (S1)}$ and $D_{ls,2m,nT,W2\ (S2)}$.
- $D_{ls,2m,nT,Sum}$: Final standardized level difference calculated using Eqn. (6), summing the partial results $D_{ls,2m,nT,W1\ (S1)}$ and $D_{ls,2m,nT,W2\ (S2)}$.

Considering that the sound insulation curve $D_{ls,2m,nT\ (S1\&S2)}$ represents a real-life scenario (e.g., road traffic noise exciting both walls simultaneously), it can be observed that this curve closely matches the $D_{ls,2m,nT,Sum}$ curve, obtained by summing the partial insulation values using Eqn. (6). This differs from Eqn. (2), currently in the standard, which averages these partial insulation values.
Thus, applying Eqn. (2) to calculate the final insulation from partial insulation values ($D_{ls,2m,nT,Avg}$) results in higher insulation levels across all frequency bands than those observed in a real scenario.
All findings are validated when applying the calculation method for obtaining weighted values according to ISO 717-1 [3], as shown in Table 1.

Table 1. Weighted standardized level difference.

Freq. range (Hz)	$D_{ls,2m,nT,w}$ (C; C_{tr}) (dB)		
	$S_1\&S_2$ simultaneously	Eqn. (2)	Eqn. (6)
Weighted	23	26	23
100-3150	(-1;-1)	(-1;-1)	(-1;-1)
100-5000	(0;-1)	(0;-1)	(0;-1)
50-3150	(-1;-2)	(-1;-2)	(-1;-2)
50-5000	(0;-2)	(0;-2)	(0;-2)

6. CONCLUSIONS

Based on the findings presented in this study, it is concluded that testing façades with two corner walls is a complex process influenced by multiple factors. Additionally, the mathematical approach currently applied in the standard to compute the final insulation from partial insulation values may not be adequate or representative of real conditions. Therefore, the following recommendations are proposed:

- When using the loudspeaker method, the noise source should be positioned in a way that minimizes indirect transmissions through the adjacent wall while measuring the insulation of the tested wall.
- Whenever possible, the sound source should be placed away from the façade's centre, in the opposite direction of the corner. In some cases, achieving this may require increasing the source-to-façade distance.
- Positioning the source too close to the corner can lead to an underestimated insulation value for the tested wall. Moreover, in such cases, it becomes difficult to quantify the impact of indirect transmissions, as they depend on uncontrollable factors such as façade length, direct visibility of the other wall, and placement of façade elements on the untested wall.

Furthermore, the study confirms that the calculation equation currently used in the standard, Eqn. (2) does not accurately reflect real-world conditions and often leads to an overestimation of façade insulation. Instead, a more appropriate approach is to sum the partial insulation values rather than averaging them, as proposed in Eqn. (6). If indirect transmissions are properly controlled, this equation yields results that are representative of real conditions.

This approach aligns with the calculation methodology of ISO 12354, Part 3 [4], which states that the apparent sound reduction index of a façade is obtained by summing the acoustic power transmitted through each of its components.

Indirectly, similar considerations are already reflected in some European national regulations, such as the Belgian standard NBN S 01-400-1 [5], which establishes sound insulation requirements for residential buildings. In cases of corner façades with elements on both walls, this standard increases the sound insulation requirement by 3 dB.

7. REFERENCES

[1] ISO 16283-3:2016. *Acoustics — Field measurement of sound insulation in buildings and of building elements — Part 3: Façade sound insulation.* International Organization for Standardization, 2016.

[2] N. Granzotto, E. Alessio, "Evaluation method for façade acoustic insulation for a corner room: discussion on the results obtained as a function of the source position", *Applied Sciencies*, vol. 10, no. 21, 7434, 2020. doi:10.3390/app10217434

[3] ISO 717-1:2020. *Acoustics – Rating os sound insulation in buildings and of building elements. Part 1: Airborne sound insulation.* International Organization for Standardization, 2020.

[4] ISO 12354-3:2017. *Building Acoustics – Estimation of acoustic performance of buildings from the performance of elements. Part 3: Airborne sound insulation against outdoor sound.* International Organization for Standardization, 2017.

[5] NBN. NBN S 01-400-1:2022. *Acoustics – Acoustic performance of buildings – Part 1: Dwellings.* Belgian Bureau for Standardization (NBN), 2022.