DOI: 10.61782/fa.2025.0082

FORUM ACUSTICUM EURONOISE 2025

ACOUSTIC PERFORMANCE OF THE JUNCTION BETWEEN FAÇADES WITH ETICS AND THE JOINERY

Lieven De Geetere[1*]
[1] Buildwise, Kleine Kloosterstraat 23, 1932 Zaventem, Belgium

ABSTRACT

Due to the use of lightweight and often rigid insulation materials in External Thermal Insulation Composite Systems (ETICS), the risk of sound leaks at the junction with the external joinery is real. However, detailed knowledge of the acoustic performance of common connection methods is lacking. Therefore, an acoustic measurement campaign was set up in the acoustic laboratory of Buildwise in Belgium to measure the acoustic insulation performance of the junction $R_{s,Atr}$ $(= R_{s,w} + C_{tr})$ (standardized in ISO 10140-1) for a large number of common connection methods. From this dataset, interesting trends are observed and guidelines for the applicability of the different junction types with respect to the required façade sound insulation are deduced.

Keywords: *ETICS, façades, sound leaks, joinery, junction*

1. INTRODUCTION

External Thermal Insulation Composite Systems (ETICS) are frequently used to improve the energy efficiency and sustainability of buildings, both new and existing. They basically comprise an insulating layer and an external rendering. The insulating layer consists of panels that can be glued or mechanically fixed to the structural façade. These are either made up of fibrous materials (like mineral wool, wood fibers,…) or are foam-based (like EPS, XPS, PU, …). They usually increase the direct façade sound insulation R_{Atr}, but can also lower it, especially when relatively thin and stiff insulation layers are combined with lightweight renderings (see EN ISO 12354-1 [1], Annex D.2.3 for design values of ΔR_{Atr}).

Further, due to their light and stiff character, they are prone to cause sound leaks at the junction with the external joinery. Whether these sound leaks will determine the overall in-situ sound insulation of a composed façade pane, will depend on the (opaque) façade composition, the window composition, the way of mounting the window to the façade, the way of connecting the ETICS to the window and the finishing of the internal reveal. The acoustic performance of the junction can be quantified by the so-called sound reduction index of joints or slits R_s, which is defined in EN ISO 12354-3 [2] and which will be called junction sound reduction index throughout this paper. It represents the sound reduction index that would be measured for a perfectly insulating panel with area of 1 m² in which a joint with a length of 1 m is applied. For façades, the spectral adaptation term C_{tr} (defined in ISO 717-1 [3]) is usually applied to obtain a single number rating representative for urban traffic noise $R_{s,Atr}$ $(= R_{s,w} + C_{tr})$.
Since experimental data on this important junction sound reduction index is hard to find, a laboratory measurement campaign was set up to study a large number of common connection methods used in Belgium.

2. MEASUREMENT SETUP

The measurement method to measure the sound reduction index of joints or slits is standardized in ISO 10140-1 [4], Annex J. Since this method is mainly intended for simple joints filled with fillers or seals, it is not directly applicable to more complicated junctions of ETICS façades with the external joinery. Therefore, a dedicated measurement setup was built, however keeping the same measurement methodology.

Corresponding author: lieven.de.geetere@buildwise.be.

In a standard 10 m² laboratory measurement opening, first a façade wall with an ETICS is constructed. This wall is made up of 19 cm thick massive concrete blocks, plastered on the indoor side. On the outdoor side, the insulating layer is made up of 20 cm thick EPS insulation panels that are glued to the base wall. For practical reasons, the exterior rendering is represented by a 9.5 mm gypsum board lining glued to the insulation panels. The sound reduction index of this ETICS wall is called R_{wall}. By comparing the measured spectra of the wall with and without the ETICS, the mass-spring-mass resonance frequency of the ETICS is estimated to be in the 250 Hz third-octave band.

Secondly, a highly insulating dummy window is assembled. It is made up of a 7 cm thick heavy timber peripheral frame, completely filled with mineral wool. On both sides, it is closed by a composite layer of two 2 mm thick steel plates glued together with a 3 mm thick bituminous layer in between (see Fig. 1). The sound reduction index of this dummy window is measured in the laboratory in a standardized small-sized test opening and called R_{dummy}.

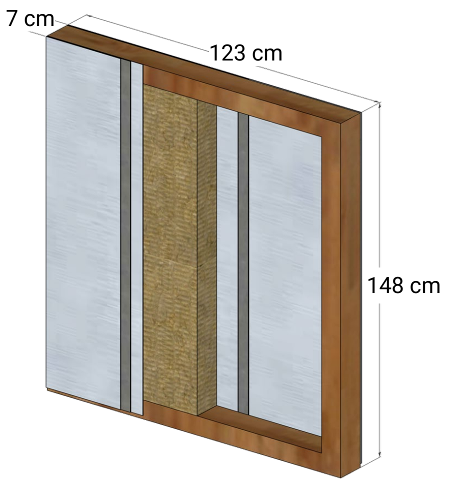


Figure 1. Dummy window.

Finally, an opening is made in the façade wall to host a concrete precast frame to which the dummy window can be mounted using the connection methods to be investigated. Four concrete frames with different opening dimensions make it possible to control the mounting gap width between concrete frame and dummy window very precisely to respectively 0, 2, 4 and 8 cm (see Fig. 2 and Fig. 4, nr. 6). The measured sound reduction index of this composed wall is called R_{tot}.

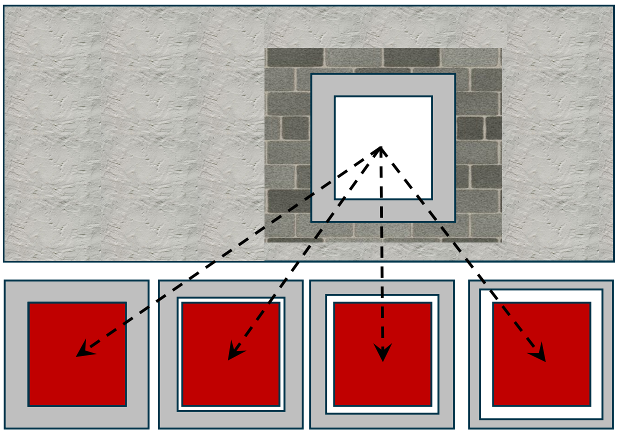


Figure 2. Principle to ensure controlled gap widths of 0, 2, 4 and 8 cm between window and façade wall by using precast concrete frames to mount the dummy window (red).

This total sound reduction index can be calculated by Eqn. (1):

$$R_{tot} = -10log\left\{\frac{1}{S_{tot}}\left[\begin{array}{c} S_{wall}\cdot 10^{\left(\frac{-R_{wall}}{10}\right)}\ldots \\ +S_{dummy}\cdot 10^{\left(\frac{-R_{dummy}}{10}\right)}\ldots \\ +1\cdot l_S 10^{\left(\frac{-R_S}{10}\right)} \end{array}\right]\right\} \quad (1)$$

in which S_{tot} is the area of the laboratory measurement opening, S_{wall} is the area of the façade wall excluding the window opening, S_{dummy} is the area of the dummy window, l_s is the perimeter of the window opening. Here it is supposed that the junction type is the same for all 4 sides of the window panel.

From that equation and the previously measured spectra for R_{wall} and R_{dummy}, the junction sound reduction index can be estimated by Eqn. (2):

$$R_s = -10log\left\{\frac{1}{l_s}\left[\begin{array}{c} S_{tot}\cdot 10^{\left(\frac{-R_{tot}}{10}\right)}\ldots \\ -S_{wall}\cdot 10^{\left(\frac{-R_{wall}}{10}\right)}\ldots \\ -S_{dummy}\cdot 10^{\left(\frac{-R_{dummy}}{10}\right)} \end{array}\right]\right\} \quad (2)$$

In the ideal case where there is no sound leakage across the window junctions, the maximum total sound reduction index can be calculated by omitting the green term in Eqn. (1). It can be seen from Fig. 3 that this ideal sound reduction index is determined by the performance of the façade wall at low frequencies and by the performance of the dummy window at high frequencies.

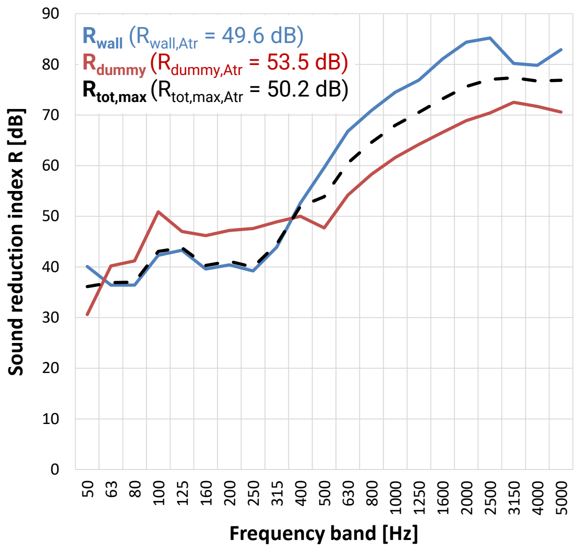


Figure 3. Measured sound reduction index for the façade wall and the dummy window and calculated maximum total sound reduction index.

3. TESTED CONFIGURATIONS

In the Buildwise acoustic lab in Limelette, Belgium, a large number of variants of typical mountings of exterior joinery in an ETICS wall were tested (Fig. 4), both in flush (a) and eccentric (b-f) mounting. Anchoring methods using dowels or angle brackets (a-c), positioning frames (i.e. first attached to the structural wall) (d-e) and installation frames (i.e. first attached to the window) (e-f) were combined with interior finishes made of plasterboard, either fixed directly in the reveal (c) or via mounting blocks where the remaining space between the reveal and the plasterboards is completely filled with standard PU spray foam (a, b, f), or glued on XPS reveal boards (d-e).

4. STUDIED EFFECTS

4.1 General remarks

In the following graphs, a selection of the measured junction sound reduction index spectra R_s are presented. The single number values mentioned in the graphs are $R_{s,Atr}$ values. When some curves are lacking data, it means that the values in these frequency bands could not be calculated by Eqn. (2) because in these bands the measured R_{tot} was higher than the $R_{tot,max}$.

Since the single number value $R_{s,Atr}$ is in most cases largely determined by the value of R_s around the mass-spring-mass resonance frequency of the ETICS, mounting alternatives that give large variations in the 250 Hz band will also reflect large variations in the single number value. Inversely, mounting variations that cause variations only at higher frequencies can show uncorrelated changes in the single number value due to usual statistical variations within the expected measurement uncertainty at 250 Hz.

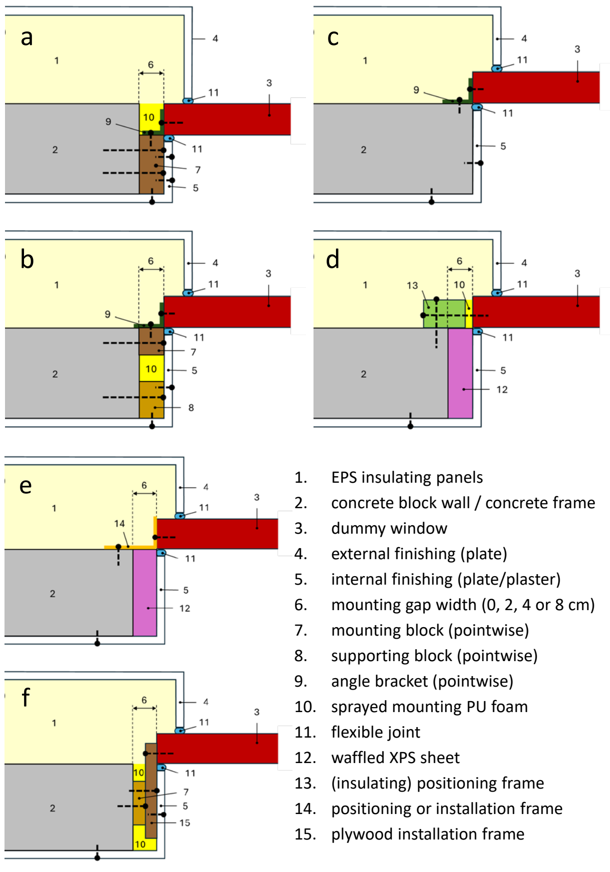


Figure 4. Examples of tested mounting variations.

4.2 Mounting gap width

The mounting gap width (see Fig. 4, nr. 6) is an important parameter, especially when the window is mounted pointwise by dowels or angle brackets, which is illustrated in Fig. 5 and Fig. 6. A mountain gap width of 4 cm or 8 cm lowers the $R_{s,Atr}$ value by 4 respectively 9 dB compared to the case where no mounting gap was present.

Figure 5. Example of a (partial) mounting using angle brackets on mounting blocks with a mounting gap of 8 cm (exterior side).

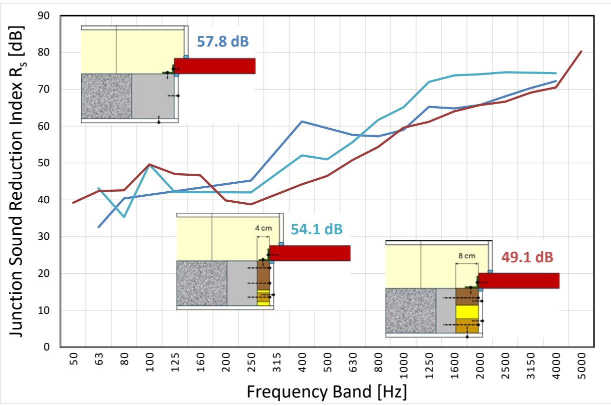


Figure 6. Influence of the mounting gap width.

4.3 Interior finishing

For the cases with spray foamed interior reveals in combination with a pointwise connection of the window panel (Fig. 8), adding an extra gypsum board at the interior side, gives an average gain in $R_{s,Atr}$ of about 1 dB.
However, when in these cases, the sprayed PU foam on the interior reveal is replaced by rigid XPS insulating panels, a large wideband drop of about 9 dB is observed (Fig. 7). This was found to be due to remaining thin air gaps between these insulating panels and the reveal and between the insulating panels themselves.

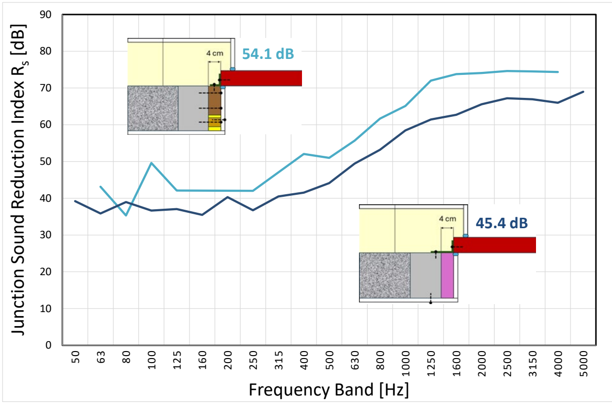


Figure 7. Influence of replacing the PU spray foam at the interior side by rigid XPS insulating panels (case with pointwise mounted windows).

Figure 8. Example of a (partial) mounting using angle brackets on mounting blocks with a mounting gap of 8 cm and spray foamed interior reveals (interior side).

4.4 Flush versus eccentric mounting

When switching from a flush to an eccentric mounting in the case of pointwise mounted windows, the $R_{s,Atr}$ value drops about 2.5 dB and 1 dB in the case of respectively a 4 cm and 8 cm mounting gap. This drop is mainly due to the behaviour in the 250 Hz band and since both curves remain similar in each case, this difference is more likely to be determined by the measurement uncertainty in this band (Fig. 9).

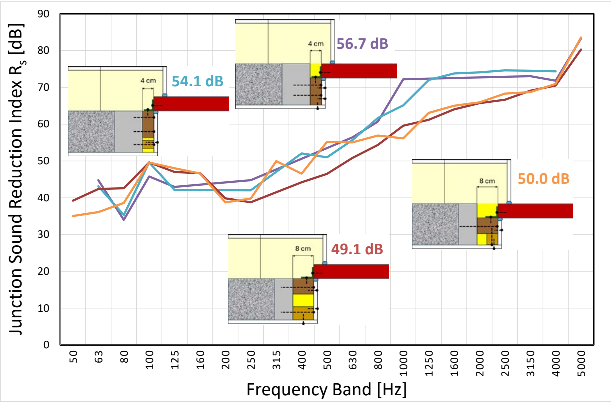


Figure 9. Influence of the mounting depth of the window: flush mounting versus eccentric mounting.

4.5 Installation frame type

Installation frames are commonly used in eccentric mountings to laterally extend the window chassis to enable fixing it to the structural façade while completely covering the mounting gap. They can be made of different materials. However, comparing 60x60 mm² heavy timber battens with L-shaped frames made of a 8 mm thick PES fiberglass composite (Fig. 4e) did not show significant performance differences.

4.6 Plywood installation frame

Another common technique in Belgium to install windows while ensuring airtightness is to apply a plywood installation frame to the window before it is being installed. This installation frame is mounted pointwise on the structural façade wall using mounting blocks. The remaining space between the installation frame and the reveal is then filled with sprayed PU foam (Fig. 4f). No considerable changes in performance are observed compared to pointwise connection methods without installation frame (Fig. 4b), as long as the mounting gap width is comparable.

4.7 Positioning frame density

The insulating positioning frames in Fig. 4d are made of compacted EPS battens with nominal densities of 100, 200 and 400 kg/m³. They have been tested for a mounting gap width of 4 cm and show no remarkable change in performance between these 3 densities.

4.8 Positioning frame filler type

The levelling clearance between the compacted EPS positioning frames and the window panel was filled either by a self-expanding foam tape or by a sprayed PU foam. In all cases, the PU foam performed considerably better (an improvement of about 3 dB in $R_{s,Atr}$) and is additionally more practical to apply (Fig. 10).

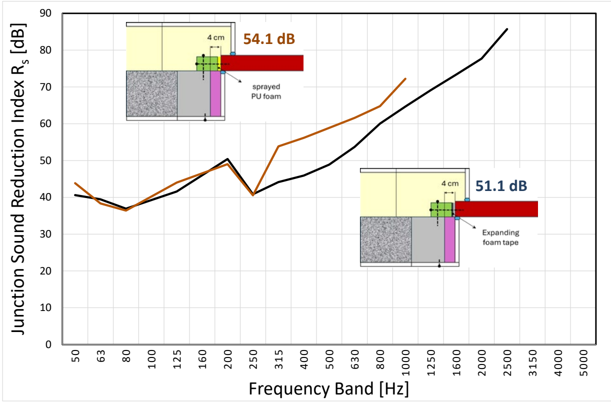


Figure 10. Influence of the filler type for the levelling clearance between positioning frame and window.

4.9 Sealing joints

Sealing joints between the interior and exterior finishings and the window are important to achieve a good air- and rain tightness. They also play an acoustic role at higher frequencies as can be seen in Fig. 11. The influence on the $R_{s,Atr}$ value however remains rather small (1 to 2 dB per joint), since the behavior around the mass-spring-mass resonance frequency of the ETICS remains unaffected.

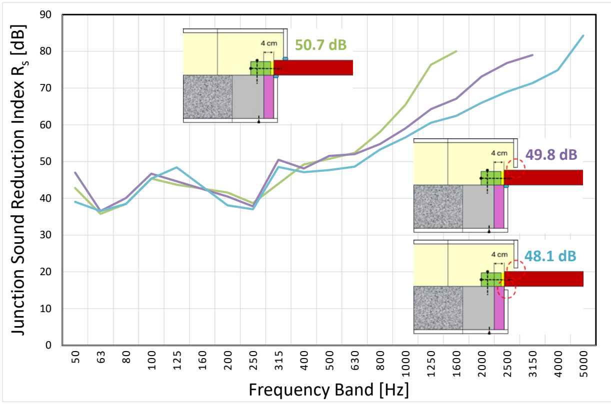


Figure 11. Influence of the sealing joints.

4.10 Exterior and interior finishing

For practical reasons, the external rendering and interior reveal finishing used in-situ were replaced during the laboratory measurements by acoustically equivalent plasterboards. Although not reflecting good practices but interesting from a scientific point of view, the effect of locally removing these lining plates was additionally studied (Fig. 12). Gradually removing these lining boards lowered the junction sound reduction index systematically in the frequency region above the mass-spring-mass resonance frequency of the ETICS. However, no systematic changes were observed around and below this resonance frequency. Since the $R_{s,Atr}$ value becomes more and more dominated by the spectral values at higher frequencies, a gradual decrease of 3 to 5 dB with each step was measured.

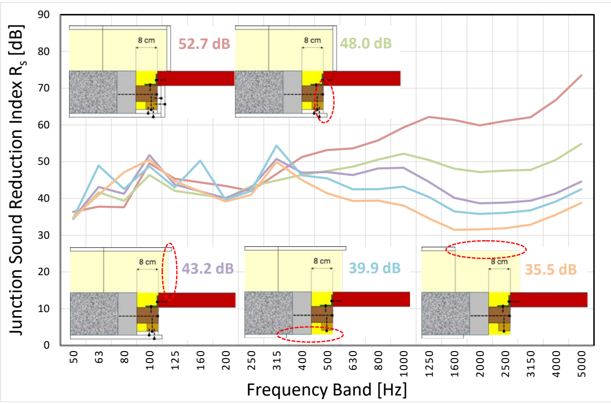


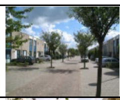
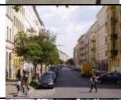
Figure 12. Effect of gradually removing exterior and interior lining boards.

5. APPLICABILITY OF THE TESTED JUNCTIONS IN DIFFERENT OUTDOOR NOISE CLASSES

5.1 Façade insulation requirements

The façade sound insulation requirements in Belgium are specified in the building acoustical standards series NBN S 01-400-x. Four outdoor noise classes are defined, going from a quiet rural environment or quiet residential area (Class 1) to very busy urban traffic (Class 4). For each class, a reference outdoor sound pressure level L_{Aref} is set. For dwellings, most strict requirements are for bedrooms during night. If there are no structural frequent loud passages of vehicles during night along bedrooms, the requirements, expressed in D_{Atr} $(= D_{2m,nT} + C_{tr})$ for façade panes, are summarized in Table 1.

Table 1. Belgian façade sound insulation requirements.

Outdoor noise class		Day spaces		Night spaces	
		$L_{Aref, day}$	D_{Atr}	$L_{Aref, night}$	D_{Atr}
1		60 dB	≥ 28 dB	55 dB	≥ 28 dB
2		65 dB	≥ 31 dB	60 dB	≥ 32 dB
3		70 dB	≥ 36 dB	65 dB	≥ 37 dB
4		≥ 77 dB	≥ 43 dB	≥ 72 dB	≥ 44 dB

5.2 Use case

To verify what mounting methods can be used in each of the outdoor noise classes, an acoustically rather unfavourable situation of a small bedroom with a large total junction length between the ETICS wall and the joinery is considered (Fig. 13). We assume that the ETICS wall has an $R_{Atr,wall}$ of at least 48 dB. The in-situ façade sound insulation can be calculated according to [2]:

$$D_{Atr,tot} \cong R_{Atr,tot} + 10lg\left(\frac{V}{3S_{tot}}\right), \tag{3}$$

in which $R_{Atr,tot}$ is the traffic-noise related single number value of the sound reduction index of the composed façade pane, that can be calculated using Eqn. (1) in which R_{dummy} is replaced by R_{window}.

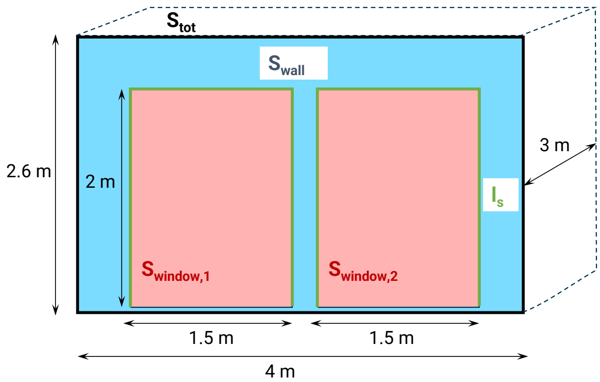


Figure 13. Use case of a small bedroom with S_{tot} = 10.4 m², S_{wall} = 4.4 m², S_{window} = 6 m² and l_s = 11 m.

Since the composed façade sound reduction index $R_{Atr,tot}$ will be largely determined by the sound transmitted through the windows and the junction, the choice of an appropriate window type is quite important. We first need to make a deliberate choice of the glazing, appropriate for the different outdoor noise classes. Then we make the necessary corrections described in EN 14351-1 [5] to estimate the chosen $R_{Atr,window}$ (Table 2).

Table 2. Choice of appropriate windows for the outdoor noise classes 2-4 for the selected use case.

Outdoor noise class	$R_{Atr,\ glazing}$	Area correction [5]	Frame correction [5]	$R_{Atr,\ window}$
2	30 dB	-1 dB	+1 dB	30 dB
3	40 dB	-1 dB	-3 dB	36 dB
4	47 dB	-1 dB	-3 dB	43 dB

5.3 Junction sound reduction index requirements

With these choices for $R_{Atr,wall}$ and $R_{Atr,window}$, the minimum required values for the junction sound reduction index $R_{s,Atr}$ to fulfill the D_{Atr} requirements for the bedroom in Table 1 can be calculated by combining Eqn. (3) and Eqn. (2) in which R_{dummy} is replaced by R_{window}. For classes 2, 3 and 4 this results in minimum $R_{s,Atr}$ values of 42.9, 43.3 and 53.6 dB respectively. Important to note is that in these cases, the fraction of sound energy passing through the windows is quite substantial: 90%, 72% and 72% respectively, while the fraction passing through the junction remains small: 9%, 25% and 11% respectively. This shows that the choice of an appropriate window is of prime importance.

5.4 Eligible junction solutions

From this simple use case, it follows that for the outdoor noise classes 1-3, all studied connecting methods are possible since all measured $R_{s,Atr}$ values were larger than 45 dB. In class 4 however, only the following junction types are eligible:

- connection methods where there is no mounting gap between the chassis and the reveal opening;
- installation methods with positioning frames: the clearance between the positioning frame and chassis must be limited to 1 cm and must be filled with spray foam (swelling strips are not recommended from both a practical and acoustic point of view);
- plywood installation frames in combination with a maximum of 2 cm wide spray foam;
- angle brackets or dowels in combination with a plasterboard interior lining and a max. 4 cm wide spray foam.

6. ACKNOWLEDGMENTS

Buildwise wants to thank all companies that made this research possible by supplying components to build the laboratory setups, in particular Knauf, Buildtechnics and Staduco.

7. REFERENCES

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