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ACOUSTIC PERFORMANCE OF ALUMINUM WINDOW FRAMES IN THE CONTEXT OF NBR 15575: SYSTEMIC INNOVATION AND A CASE STUDY IN A CLASS III NOISE ZONE

Gustavo Medeiros Lyra

Civil Engineer, with a bachelor's degree from the Federal University of Rio Grande do Norte (UFRN). He holds a master's degree in Aluminum Engineering and Glazed Facades from Anhanguera University



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ABSTRACT: The intensification of urbanization in Brazilian cities has raised environmental noise levels, making the acoustic performance of facades an essential requirement in residential buildings. In this context, window and door frames play a decisive role, especially in light of the requirements established by ABNT NBR 15575. This study analyzes recent developments in the acoustic performance of aluminum window and door frames, highlighting the influence of standardization on technological innovation in the sector and presenting a case study applied to a residential development located in an area classified as Noise Class III. The research adopted a qualitative-quantitative approach, conducting a field test to determine the $D_{2m,nT,w}$ index of the facade. The technical solution developed combined 25 mm profiles with optimized geometry, multiple sealing systems, pressure-controlled locking, and laminated glass with PVB interlayers. The result obtained was 37 dB, meeting regulatory criteria and exceeding typical values reported for systems of the same dimensional range. It is concluded that acoustic performance is associated with the integrated design of the system, and not exclusively with increased mass, highlighting the technical and economic feasibility of rationalized solutions.

KEYWORDS: acoustic performance; aluminum window and door frames; NBR 15575; sound insulation; facades.

1. INTRODUCTION

The intensification of the urbanization process in medium and large Brazilian cities has led to a significant increase in environmental noise levels, resulting mainly from road traffic, the verticalization of buildings, and the concentration of commercial acti-

vities. Urban noise has established itself as one of the main sources of environmental discomfort in contemporary cities, directly impacting the quality of life and health of building occupants. In this context, acoustic comfort has ceased to be a secondary attribute and has become a core component of the essential performance requirements for residential buildings.

Rohden and Lima (2019) note that window and door frames represent one of the main points of failure in the acoustic performance of facades, especially when there are manufacturing or installation deficiencies, and can become the primary entry point for noise into the building. This finding reinforces the understanding that the acoustic performance of the facade does not depend exclusively on the opaque systems of the external envelope, but finds its most sensitive point of vulnerability in the window and door frames.

Similarly, Ferrarese, Amario, and Stolz (2024) highlight that, within the facade assembly, window and door frames tend to be the least insulating elements in an acoustic context, particularly when there are no adequate technical specifications or quality control during installation. This situation is associated with lower relative mass, the presence of moving parts, and susceptibility to leaks.

The publication of ABNT NBR 15575 in 2013 and its revision in 2021 consolidated the concept of performance as the cornerstone of residential building quality. Lopes *et al.* (2021) note that the standard articulates user expectations regarding the requirements that building systems must meet, promoting the transition from a prescriptive approach to a logic based on measurable performance.

Following the implementation of the standard, significant progress was observed in the sector. Giner *et al.* (2023) demonstrate, based on a database comprising over 700 acoustic tests conducted between 2013 and 2022, that there was an average increase of approximately 7 dB in the acoustic performance of internal vertical systems, in addition to a significant rise in the commissioning of acoustic tests by construction companies. This data shows that standardization has acted as a driver of technological innovation and technical maturation in the market.

At the same time, the aluminum window and door frame sector has undergone a significant technical transformation. Although historically acoustic performance has been associated with increased mass—a principle based on the so-called law of mass—in the current context, it is evident that the acoustic efficiency of window and door frames depends on a systemic set of factors, such as typology, sealing system, closing mechanisms, and glass configuration.

Oliveira Júnior (2021) argues that acoustic performance is not linked exclusively to the structural material of the window frame, but to the design of the system as a whole, including the typology adopted and the glass specifications. Similarly, Ferrarese, Amario, and Stolz (2024) state that it was not possible to establish unequivocal acoustic superiority between aluminum and PVC, emphasizing that performance is associated with the technical solution employed and not merely with the base material used.

Given this scenario, this study aims to analyze the recent evolution of the acoustic performance of aluminum window frames, discussing the influence of technical standards on the innovation process and presenting technical evidence demonstrating the

possibility of achieving high levels of sound attenuation through the rational use of materials and economic viability.

2. RECENT EVOLUTION OF SOUND ATTENUATION IN ALUMINUM WINDOW FRAMES

2.1. Technological Advances in the Window and Door Frame Sector

Historically, the acoustic performance of window and door frames has been associated with increased mass, through the use of thicker profiles and thicker glass. Oliveira Júnior (2021) explains that the application of the law of mass assumes that an increase in the surface density of the structural element contributes to greater sound reduction. However, this approach has proven limited when applied to systems with structural discontinuities, such as sliding windows.

Recent experimental studies show that the acoustic performance of window frames is strongly influenced by airtightness and sealing systems. Pires *et al.* (2025) demonstrate that window frames equipped with elastomeric gaskets, laminated glass, and cremone-type closures tend to exhibit higher values of the Weighted Sound Reduction Index (R_w), while systems with simple brushes and thin monolithic glass fall into the lower performance classes.

Furthermore, it was found that minor installation flaws can result in significant losses in acoustic performance, even outweighing any gains resulting from specific modifications to the shutter box (ROHDEN; LIMA, 2019). Thus, airtightness is established as a determining factor in the system's final performance.

Additionally, Bento, Foiato, and Carrelli (2021) demonstrated that different glass configurations substantially alter the acoustic performance of window frames, potentially achieving reductions exceeding 30 dB in certain types. Thus, the evidence shows that system optimization does not necessarily require an indiscriminate increase in the structural cross-section, but rather an appropriate combination of components.

This paradigm shift enables the rational use of aluminum, reconciling high acoustic performance with cost control, even in social housing projects.

2.2. Contributions from Leading System Manufacturers

Technological evolution is also evident in the solutions offered by the domestic market. Zonta (2024) analyzed aluminum window and door frames installed in a condominium located on a major thoroughfare and found that sliding windows with 3 mm float glass and lift-and-slide windows with 3+3 mm laminated glass met the regulatory performance criteria for noise classes I, II, and III. The author concludes that it is possible to combine technical quality with moderate cost in window and door specifications.

Lyra (2025) argues that the performance of window and door frames should be analyzed systematically, taking into account the integration of criteria, laboratory tests, and performance indicators. This perspective reinforces the trend toward technical evaluation based on measurable and comparable performance.

The data presented by Giner *et al.* (2023) indicate a consistent increase in the sound insulation ratings of Brazilian residential buildings, demonstrating that the market has adopted regulatory requirements and begun to invest in more efficient solutions aimed at improving the comfort of new residential buildings.

3. INFLUENCE OF TECHNICAL STANDARDS

3.1. ABNT NBR 15575 (Brazilian Standard for the Performance of Residential Buildings)

ABNT NBR 15575 established, within the Brazilian context, the concept of performance as the cornerstone of residential building quality. The revision of the standard, published in 2021, introduced a significant advancement by reinforcing the need for a contextualized assessment of the acoustic performance of facades, classifying buildings according to three surrounding noise classes (I, II, and III). This classification imposes progressively stricter levels of sound insulation based on the intensity of the incident noise.

Unlike traditional prescriptive standards, the Performance Standard establishes criteria based on the actual behavior of building systems throughout the building's service life, including requirements related to safety, habitability, and environmental comfort. Giner *et al.* (2023) show that, following the implementation of the standard, there was an approximately 1,800% increase in the commissioning of acoustic tests by construction companies, indicating a structural transformation of the sector and greater technical maturity.

In the field of acoustics, the standard defines objective parameters for external noise insulation, linking the performance of facades to the actual sound exposure conditions of the surrounding environment. Lopes *et al.* (2021) emphasize that NBR 15575 translates user requirements into measurable technical criteria, expanding the responsibility of the agents involved in the civil construction production chain. This approach shifts the focus from mere formal compliance to the effective verification of in-use performance.

The case study presented by Zonta (2024) demonstrates the practical application of this classification in a development located on a major thoroughfare, showing that the correct definition of the noise class is critical for the proper specification of window and door frames. In addition to reinforcing the need for regulatory compliance, which depends on the compatibility between the design, choice of glass, and sealing system.

The consolidation of this regulatory model has also contributed to increased technical oversight in the sector. Thus, the standard has expanded the technical responsibility of designers, builders, and window manufacturers, requiring solutions compatible with the specific acoustic context of each project (LYRA, 2025).

3.2. Market and Regulation as Drivers of Development

The requirement for sound insulation levels between 30 dB and 40 dB, depending on the surrounding noise class, placed direct pressure on the market for technically more efficient solutions. Lyra (2025) points out that the consolidation of regulatory requirements has contributed to greater technical

standardization. This regulatory demand has driven investments in research and development, particularly in the geometric refinement of profiles, the evolution of closure and sealing systems, and the more rigorous specification of glass. Furthermore, in the studies by Pires *et al.* (2025), it can be concluded that the evolution of the acoustic performance is not exclusively associated with an increase in mass, but with the engineering employed in the system as a whole.

Since it had already been established that acoustic performance is associated with the typology, sealing system, and glass specifications, this enabled the promotion of innovation in thinner profiles with high performance (FERRARESE; AMARIO; STOLZ, 2024).

Complementarily, Berardi, Ivona, and Stasi (2025) point out that construction precision and installation quality directly influence the weighted sound reduction index (R_w), potentially generating variations of up to 4 dB. The authors indicate that specific interventions in the sealing system can result in measurable performance gains, reinforcing the importance of technical detailing.

In the domestic market, it is observed that window and door frame lines with thicknesses exceeding 30 mm have been improved or developed to meet the requirements imposed by NBR 15575, reflecting the need to balance acoustic performance with economic viability.

In this context, innovation is no longer an optional differentiator but has become an essential requirement for remaining competitive in the market, especially in developments located in densely populated urban areas, where stricter noise classes impose more rigorous technical requirements.

4. METHODOLOGY

This research is characterized as an applied case study, employing a quantitative and qualitative approach, based on the analysis of façade acoustic performance under real-world conditions. The methodological choice aligns with the performance evaluation recommendations set forth in ABNT NBR 15575, which prioritizes verifying the actual behavior of the installed system over exclusively laboratory-based analyses. Lopes *et al.* (2021) highlight that the logic of the standard is based on verifying in-service performance, requiring technical validation through measurements and tests.

The adopted methodology was structured into four integrated stages: characterization of the acoustic environment, analysis of the construction solution, field testing to determine the $D_{2m,nT,w}$ index and comparison with market reference data.

Regarding the testing, the procedure adopted involved *on-site* measurement of the standardized sound level difference of the facade ($D_{2m,nT,w}$), the recommended indicator for evaluating the actual performance of the building envelope. This scenario is a result of the growing use of field tests following the implementation of NBR 15575, which has contributed to greater precision in evaluating the actual performance of buildings (GINER *et al.*, 2023).

Thus, the adopted methodology allowed for the evaluation not only of the profile's efficiency but also of the integrated behavior of the frame–glass–seal–installation system, aligning with the article's central thesis that acoustic performance is the result of the engineering of the assembly and not merely the mass of the system.

5. CASE STUDY – VISTAMAR DEVELOPMENT

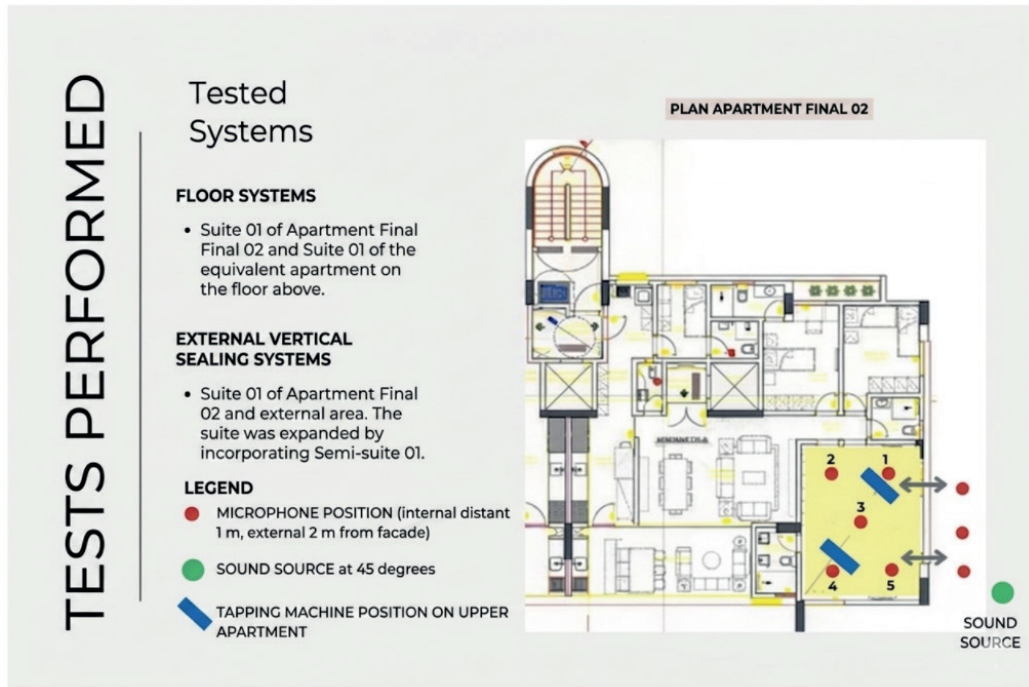
The Vistamar development consists of a residential building with 40 housing units, distributed across a 20-story tower, located in Natal, Rio Grande do Norte, within an area classified as Noise Class III. In this category, the standard establishes stricter requirements for the acoustic insulation of facades, especially in bedrooms.

In this category, the standard establishes a minimum requirement of over 30 dB of sound attenuation, imposing stricter criteria on the performance of facades, especially in bedroom environments, as shown in Figure 1.

The supply and installation of the window frames and metal components for the project were carried out by a specialized company in the sector, covering both the main building and the common areas. The solutions adopted prioritized technical criteria related to durability, airtightness, acoustic performance, and aesthetic compatibility with the architectural design, including an electrostatic paint finish.

The main challenge was to meet the minimum and intermediate acoustic performance requirements established by ABNT NBR 15575 for building facades, focusing on Suite 01 of the apartments on the second floor, whose facade is simultaneously exposed to traffic noise and a continuous point source of noise from air conditioning condensing units in an adjacent building, as indicated at the top of Figure 2. The literature shows that noises with tonal or continuous content tend to generate a higher perception of annoyance than noises with a broader spectrum, even when the overall weighted sound pressure levels meet the li-

Figure 1 – Floor plan of the final apartment 2



Source: Adapted from Araújo (2024)

Figure 2 – Facade of the Vistamar development



Source: Author's collection (2024)

mits established by the standards. Studies indicate that the presence of tonal components intensifies the sensation of annoyance, suggesting the need for complementary indicators beyond the LAeq level in urban acoustic comfort analyses (RADOSZ *et al.*, 2021).

6. RESULTS AND DISCUSSION

The developed solution was based on technical expertise accumulated over more than two decades of experience in the aluminum window and door frame sector. The decision was made to develop new profiles, combined with the design of an unprecedented combination of distinct profile lines with a nominal thickness of 25 mm, strategically selected based on their geometric characteristics, sealing performance, and potential for systemic integration.

In addition to using the new profiles, customized adjustments were made to ensure system compatibility, including the incorporation of elastomeric gaskets at the mullion joints and side joint covers, the use of multiple sealing brushes with interlayers, and the application of PVC gaskets at the interface between the frame and counterframe. Additionally, a central locking system was adopted capable of applying controlled pressure from the sash against the frame, significantly reducing the effective gaps in the assembly and ensuring continuous contact between the sealing elements. This condition directly contributed to improved acoustic performance, increased airtightness, and the maintenance of the system's geometric stability and architectural aesthetics. The inclusion of multiple brushes with interlayers, PVC gaskets at the interfaces,

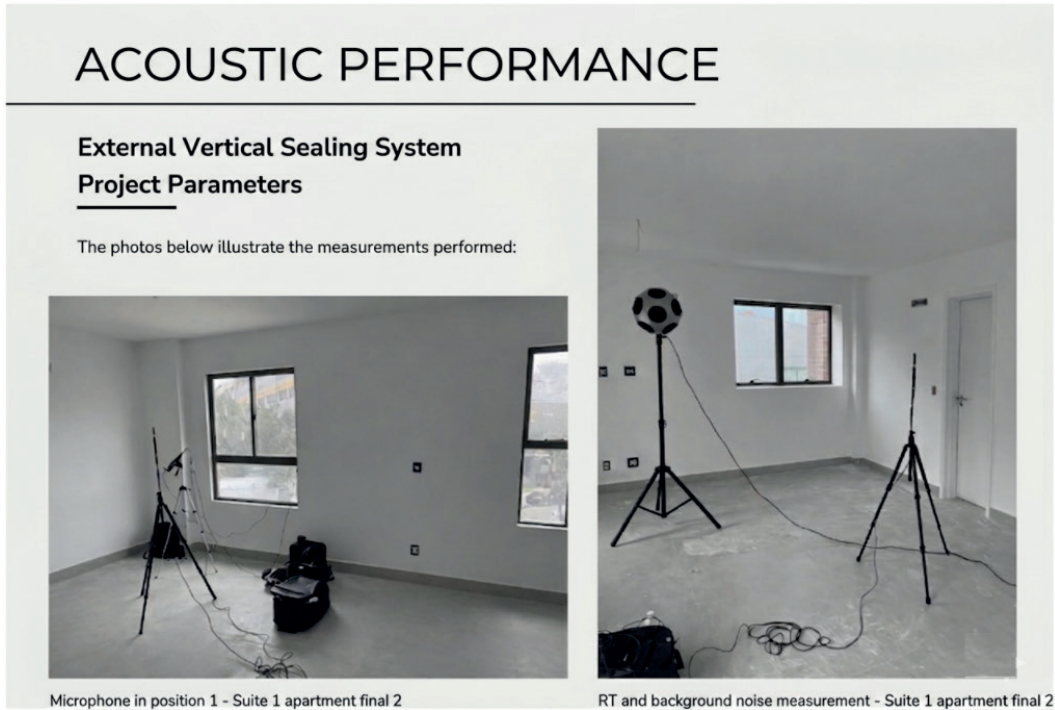
and continuous-pressure locking reduced the effective gaps in the assembly—a critical factor for the acoustic performance of movable systems.

The integration with clear laminated glass, with PVB (polyvinyl butyral) interlayers, completed the adopted solution, promoting a balance between mass, structural rigidity and structural strength, and sound energy dissipation, in line with the acoustic performance requirements established for the facade. Bento, Foiato, and Carelli (2021) demonstrate that laminated configurations offer significant improvements in insulation compared to monolithic glass.

Field tests, conducted in accordance with ABNT NBR 15575 by Araújo (2024), as shown in Figure 3, indicated a result of $D_{2m,nT,w} = 37$ dB for the facade of the analyzed suite. This value meets the minimum and intermediate performance criteria required for the site's noise class. The value exceeds the minimum required for Class III and demonstrates performance superior to standard market benchmarks.

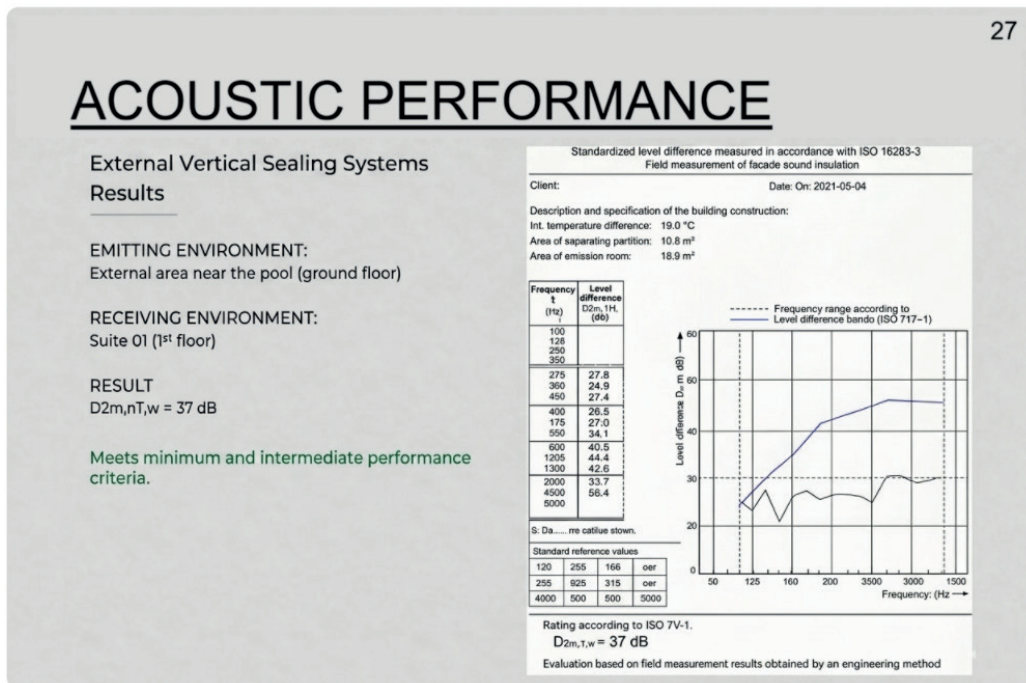
It is observed that commercial solutions of the same dimensional range (25 mm), frequently associated with systems featuring single brushes and conventional locking mechanisms, typically exhibit insulation values ranging from 19 dB to 27 dB in laboratory tests. The comparison indicates that the performance obtained in this study does not result from increased thickness or mass, but from the system's integrated design, with an emphasis on reducing effective gaps, ensuring seal continuity, and using appropriately specified glass. This difference reinforces the argument that the performance achieved stems from the integrated system design, rather than an increase in nominal thickness, as shown in Figure 4.

Figure 3 – On-site Acoustic Measurements



Source: Author's collection (2024)

Figure 4 – Acoustic measurement data



Source: Araujo (2024)

Additionally, an approximate 14% reduction in aluminum consumption was observed compared to more robust lines on the market, which would have acoustic and e y performance similar to the system used in the Vistamar Development. This aspect aligns with the trend toward material rationalization pointed out by Lyra (2025), who relates technical performance to systemic efficiency.

7. FINAL CONSIDERATIONS

The evolution of the acoustic performance of aluminum window frames reflects the convergence of regulatory advancements, technical maturity in the sector, and systemic innovation, with ABNT NBR 15575 serving as a structuring vector for this process.

The case study demonstrates that it is possible to achieve superior performance (37 dB) with 25 mm profiles, outperforming conventional solutions with greater mass. This result confirms that acoustic insulation is not necessarily linked to increased thickness, but rather to the integrated design of the solution.

The combination of optimized profile geometry, continuous sealing, a pressure-controlled locking system, and the use of laminated glass proved decisive for the final performance observed. In this vein, Pires *et al.* (2025) also highlight the direct influence of sealing and locking systems on the sound reduction index. It is also in line with Rohden and Lima (2019), who demonstrate the significant impact of effective gaps and installation quality on overall acoustic performance. Finally, in a complementary manner, Bento, Foiato, and Carelli (2021) show that glass configuration contributes significantly to increased sound insulation in facades.

Trends point toward the integration of hybrid materials and a greater emphasis on field validation tests, with a consistent increase in testing following the latest revision of the standard, indicating the consolidation of a culture of measurable performance.

Another under-explored aspect concerns low-frequency behavior, which is particularly relevant in areas with heavy traffic and continuous equipment noise. Regarding low-frequency behavior, recent studies indicate that the structural stiffness of the movable pane and resonance control directly influence acoustic performance (BERARDI; IVONA; STASI, 2025).

Material optimization combined with geometric improvements to profiles is becoming the dominant strategy, balancing performance, sustainability, and competitiveness. It is concluded that applied engineering, coupled with material optimization, enables the achievement of high acoustic performance with economic viability, establishing aluminum window frames as a strategic element for acoustic comfort in contemporary buildings.

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