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PERFORMANCE OF FRAMES AND FACADES: MAPPING OF REQUIREMENTS, TESTS, AND INDICATORS

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Abstract: The performance of window frames and facades is one of the fundamental pillars of the quality and efficiency of contemporary buildings, directly impacting the thermal and acoustic comfort, airtightness, and durability of constructions. This article presents a systematic review of the literature, with the aim of mapping the main requirements, tests, and normative indicators applicable to the Brazilian context and proposing a hierarchical framework of indicators. The research covered the ABNT NBR 15575, NBR 10821, NBR 15220, and NBR 6123 standards, as well as technical reports from IPT, CBIC, and LabEEE/UFSC. The results show significant advances in the standardization of the sector, but also point to methodological fragmentation and a lack of standardization in the communication of results. The proposed framework organizes the indicators into levels and provides a basis for comparability, certification, and digital integration via BIM/PLM. The main contribution of this work is to consolidate a systemic and replicable performance evaluation structure, promoting technical interoperability and the advancement of sustainable civil construction in Brazil.
Keywords: Construction performance, Window frames, Facades, Indicators, Tests, ABNT.

Introduction

At first glance, it is not uncommon for window frames and facades to be given a secondary role in civil construction. However, the performance of buildings depends heavily on the quality and behavior of the envelope—a set of walls, roofs, window frames, and facades that acts as an interface between the internal environment and the external environment.

In the Brazilian context, characterized by wide climatic diversity and growing urbanization, the adequacy of the envelope takes on strategic importance. Recent studies by EPE (2023) indicate that the civil construction sector accounts for a significant portion of national electricity consumption and that improving the thermal and acoustic performance of facades and window frames can reduce air conditioning consumption. In addition, the search for more sustainable buildings with low environmental impact requires the use of materials and construction systems capable of simultaneously meeting the requirements of comfort, durability, and efficiency.

In this scenario, ABNT performance standards—especially NBR 15575, NBR 10821, NBR 15220, and NBR 6123—have consolidated a regulatory framework that guides the design, manufacture, and evaluation of window frames and facades in Brazil. These standards define minimum parameters and testing methods that ensure the habitability and safety of buildings, contributing to a culture of technical quality in the construction sector.

Theoretical Reference

The concept of building performance is associated with the ability of a construction system to meet functional, technical, and comfort requirements during its useful life. According to ABNT NBR 15575:2021, performance is evaluated based on objective criteria that encompass safety, habitability, and sustainability, considering the behavior of construction systems under normal conditions of use and maintenance.

The envelope—a set formed by facades, window frames, roofs, and floors—acts as a barrier between the external environment and the internal environment, playing a decisive role in the thermal, acoustic, and lighting behavior of buildings. For Lamberts, Dutra, and Pereira (2014), the envelope is the physical element that regulates energy and mass exchanges between the external and internal environments, directly influencing energy efficiency and environmental comfort.

In the Brazilian context, the importance of the envelope is related to the great climatic diversity, ranging from areas of high solar radiation and humidity to regions with low temperatures. This variability reinforces the need for regionalized performance criteria, such as those defined by NBR 15220, which establishes the bioclimatic zoning of Brazil and guides the dimensioning of openings and sealing materials according to the local climate type.

Brazilian regulatory framework: The national regulatory system for window frames and facades is comprehensive and interconnected. The main standards applicable to this topic include:

- ABNT NBR 15575 (Residential Buildings – Performance): establishes performance levels (minimum, intermediate, and superior) for vertical sealing systems, window frames, and facades, covering requirements for thermal and acoustic comfort, airtightness, and durability (ABNT, 2021).
- ABNT NBR 10821 (Window and Door Frames for Buildings): defines requirements, test methods, and performance evaluation criteria for external window and door frames, covering aspects of air permeability, water tightness, wind load resistance, thermal and acoustic performance, and efficiency labeling (ABNT, 2017).
- ABNT NBR 6123:2023 (Wind forces on buildings): provides the basis for the structural design of facades and window frames, considering positive and negative wind pressures as a function of height, roughness, and topography (ABNT, 2023).
- ABNT NBR 15220 (Thermal performance and bioclimatic zoning): provides guidance on the calculation of thermal transmittance (U), solar heat gain coefficient (SHGC), and light transmittance (T_v), adapting thermal performance limits according to Brazilian bioclimatic zones.
- ABNT NBR 7199:2025 (Glass in civil construction): deals with the safe use of glass in frames and facades, considering criteria of impact and temperature resistance.

When applied in an integrated manner, these standards constitute a solid technical basis for evaluating the overall performance of facades, allowing for the correlation of design requirements, testing methods, and performance indicators. However, as discussed by CBIC (2021) and IPT (2020), the lack of standardization between laboratories and manufacturers still results in significant differences in the way results are expressed, which makes it difficult to directly compare products.

The performance of window frames and facades is evaluated using physical and quantitative indicators that reflect the behavior of each construction system in relation to a specific requirement. These indicators,

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defined by ABNT standards and technical literature, can be grouped into five main areas: thermal, acoustic, watertightness, structural, and durability.

Thermal performance: relates to the ability of the window frame or facade to reduce heat transfer between environments. The main indicators are:

- Thermal transmittance (U): expressed in W/m²·K, represents the heat flow through the material; the lower the value, the greater the insulation;
- Solar heat gain coefficient (SHGC): measures the fraction of total solar energy that passes through the glass-frame assembly;
- Light transmittance (T_v): indicates the amount of natural light transmitted.

According to NBR 10821-4, these indicators are used in thermal performance labeling, with a rating from A (best performance) to E (worst performance), according to the bioclimatic zone (NBR 15220). Studies by the LabEEE/UFSC ( ) (2022) show that high-performance windows (U ≤ 3.0 W/m²·K) reduce air conditioning energy consumption by up to 20%.

Thermal performance is determined by the ability of the window frame or facade to limit heat transfer and contribute to internal thermal comfort. The main indicators and regulatory parameters are presented in Table 1.

Acoustic performance: the main acoustic indicator is the weighted sound reduction index (Rw), expressed in decibels (dB), calculated according to NBR 15575-4 and NBR 10821-4.

According to IPT (2020), facades with Rw ≥ 30 dB, Table 2, are considered suitable for urban areas with moderate noise levels. Elements such as laminated glass, double joints, and frames with continuous sealing contribute significantly to sound attenuation.

Air and water tightness: measured by the frame's ability to prevent infiltration under differential pressures. The main indicators are:

- Air permeability (Q): expressed in m³/h·m², evaluates the volume of air that passes through the system under constant pressure;
- Water tightness pressure (P_v): measured in Pascal (Pa), represents the point at which the first water leak occurs.

NBR 10821-3 classifies the results into levels M (minimum), I (intermediate), and S (superior). Tests carried out by the Construction Technology Institute (ITEC, 2021) indicate that class S systems can withstand pressures greater than 450 Pa without infiltration, Table 3.

Structural performance: the structural resistance of frames and facades is determined by wind pressure tests in accordance with NBR 6123:2023 and the deformation limits specified in NBR 10821-3. The indicator used is the maximum deflection (L/x), with L/175, table 4, commonly used as the permissible limit. This verification ensures the integrity and proper functioning of the systems under dynamic wind loads.

Table 1 – Thermal performance indicators for window frames and facades

Indicator	Symbol	Unit	Method/ Standard	Description	Class / Threshold
Thermal transmittance	U	W/m²·K	NBR 10821-4 / NBR 15220	Quantifies heat flow between media with ΔT	A (≤3.0), B (3.0–4.0), C (≥4.0)
Solar factor	SHGC	Dimensionless	NBR 10821-4	Fraction of total solar energy transmitted	≤0.35 for hot zones
Light transmittance	TV	%	NBR 10821-4/ NBR 15220	Percentage of natural light transmitted	≥40% (minimum)
Thermal conductivity of glass	λ	W/m·K	NBR 15220	Related to glass type and thickness	0.8–1.2 (single glazing)

Table 2 – Acoustic performance indicators

Indicator	Symbol	Unit	Method/ Standard	Description	Class / Threshold
Weighted sound reduction index	Rw	dB	NBR 10821-4 / NBR 15575-4	Measures the ability to attenuate airborne noise	25–30 (minimum), ≥35 (maximum)
Sound transmission index	STC	dB	ASTM E413 / NBR 15575-4	International equivalent of Rw	Comparable to Rw
Residual internal noise	LAeq	dB(A)	NBR 10151 / NBR 15575-4	Weighted average of internal sound level	≤45 dB(A) in bedrooms

Table 3 – Air and water tightness indicators

Indicator	Symbol	Unit	Standard	Description	Class / Threshold
Air flow per pressure	Q	m³/h·m²	NBR 10821-3	Air volume passing through the system under ΔP	≤1.5 (class S)
Water tightness pressure	Pv	Pa	NBR 10821-3	Pressure at which the first leak occurs	200 (minimum), 450 (maximum)
Test time	t	min	NBR 10821-3	Duration of simulated rain exposure test	15–30 min

Table 4 – Structural performance indicators

Indicator	Symbol	Unit	Standard	Description	Class / Threshold
Wind design pressure	P	Pa	NBR 6123:2023	Design pressure according to height and wind zone	500–1500 Pa
Maximum permissible deflection	L/x	Dimensionless	NBR 10821-3	Maximum permissible deformation	L/175 to L/200
Natural frequency	“ f	Hz	IPT (2019)	Evaluates stiffness and dynamic behavior	≥10 Hz (recommended)

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Table 5 – Durability indicators for window frames and facades

Indicator	Symbol	Unit	Standard/ Source	Description	Criterion / Threshold
Operating cycles	N	cycles	NBR 10821-3	Number of openings and closings before failure	≥10,000 cycles
Corrosion test (salt spray)	—	h	NBR 8094 / ABAL (2020)	Evaluates the resistance of profiles and hardware	≥480 h without corrosion
Color change (ΔE)	ΔE	—	ISO 7724 / NBR 10821-3	Color variation after UV exposure	ΔE ≤ 3.0
Reference service life	VUR	years	NBR 15575-1	Expected performance maintenance time	13–50 years

Durability and maintenance: Durability is the system's ability to maintain its initial performance throughout its service life. The main tests required by NBR 10821-3 include:

- Operating cycles (opening and closing);
- Salt spray chamber (evaluates corrosion of metal profiles and hardware);
- Color change (ΔE) after UV exposure;
- Impact and abrasion tests.

According to CBIC (2021), the durability of a window frame is directly related to the quality of the materials, surface protection (anodizing or painting), and periodic maintenance, which must be documented in a manual provided to the end user, Table 5.

Integration of performance domains: performance domains are not independent, but mutually interconnected. Improvement in one requirement may affect another—for example, increased sound insulation tends to reduce natural ventilation, impacting thermal comfort. According to Lamberts et al. (2014) and CBIC (2021), the contemporary challenge is to harmonize evaluation criteria that allow different performance dimensions to be integrated into a comparable model.

However, there is still a lack of standardization in the presentation of results, a lack of metrological uncertainty statements, and a scarcity of protocols for field testing. This gap justifies the need to develop a framework of indicators that brings together requirements, testing methods, and metrics in a coherent manner applicable to the Brazilian reality.

Theoretical gaps and the need for an integrative framework: Analysis of national standards and publications reveals that, although the technical framework is robust and comprehensive, there is fragmentation of data and metrics, a lack of cross-validation between laboratories, and insufficient reporting of result uncertainties.

IPT (2020) emphasizes that the adoption of unified and comparable indicators would facilitate project decision-making, as well as product certification and integration with BIM/PLM systems. The development of a structured and hierarchical indicator framework will allow for the synthesis of information from different domains, contributing to a more transparent, standardized system that is aligned with the construction sector's demands for efficiency and quality.

Discussion

The integrated analysis of standards and publications revealed significant progress in the standardization and consolidation of the concept of performance applied to window frames and facades in Brazil, especially since the enactment of ABNT NBR 15575 (2013–2021). This standard consolidated a systemic view of the building, considering the behavior of its subsystems—including the envelope—in relation to criteria of habitability, safety, and durability.

The results indicate that standards NBR 10821, NBR 15220, and NBR 6123 form the technical basis for the evaluation of window frames and facades, with direct interfaces with NBR 7199 (glass) and NBR 14037 (user and maintenance manuals). However, it was observed that the application of these documents still occurs in a fragmented manner among manufacturers, designers, and laboratories, which compromises the comparability of tests and the interoperability of technical reports.

There is consensus in the literature (CBIC, 2021; IPT, 2020; LABEEE/UFSC, 2022) that the current challenge is no longer the absence of standards, but the integration of performance indicators and the creation of unified benchmarks that allow the correlation of requirements, test methods, and quantitative results.

The review showed a high degree of convergence between Brazilian standards and international practices (ASTM, ISO, and EN). The main points of consistency are:

- Thermal domain: consensus on the use of U ($W/m^2 \cdot K$) and SHGC indicators as fundamental parameters of thermal comfort. The Brazilian method, based on NBR 10821-4, is compatible with the tests described in ISO 15099 and ASTM C1363, presenting equivalent results.
- Acoustic domain: the equivalence between Rw (NBR 10821-4) and STC (ASTM E413) ensures international compatibility of sound reduction data, facilitating product comparisons and certifications.
- Air tightness and wind resistance: NBR 10821-3 harmonizes test procedures with European standards EN 1026/1027, adopting the same pressure ranges and air tightness criteria.
- Durability: the inclusion of operating cycle, salt spray corrosion, and UV exposure tests brings the Brazilian model closer to the methodologies of ISO 9227 and ISO 16474.

These convergences show that the Brazilian regulatory framework is technically robust, although practical application depends on the standardization of reports and the consistent use of quantitative indicators.

Based on the review summary and regulatory convergence, a **minimum set of comparable indicators** was developed, divided into three hierarchical levels. This set of indicators aims to guide designers and manufacturers as well as regulators and performance evaluators, Table 6.

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Table 6 – Minimum panel of comparable indicators

Level	Domain	Main indicators	Reference standard	Purpose
Level 1 – Core (mandatory)	Thermal, Acoustic, Air Tightness, Structural	U (W/m²·K); SHGC; Rw (dB); Q (m³/h·m²); Pv (Pa); L/175	NBR 10821-3 and 4 / NBR 6123 / NBR 15220	Basis for comparison between products and certification
Level 2 – Contextual (conditional)	Durability and Maintenance	ΔE; Operating cycles; Corrosion (salt spray); LCC	NBR 10821-3 / NBR 15575-1	Lifetime performance evaluation
Level 3 – Project-specific	Safety and Sustainability	Impact resistance; Fire behavior; Vapor permeability	NBR 7199 / ISO 3008 / CBIC 2021	Additional criteria according to building type and use

The framework proposed in this study is based on the principle that the performance of window frames and facades should be understood as a multidimensional system, composed of normative requirements, test methods, and interrelated quantitative indicators. The model was constructed based on the results of the systematic review and the gaps identified in the previous chapters, adopting as fundamentals:

- Hierarchization of indicators according to their technical function and applicability;
- Integration between performance domains (thermal, acoustic, airtightness, structural, and durability);
- Compatibility with ABNT standards and correlation with international standards (ISO, ASTM, EN);
- Simplicity and replicability — the model must be applicable by manufacturers, designers, and evaluators;
- Digital interoperability — the framework was designed for future integration with BIM (Building Information Modeling) and PLM (Product Lifecycle Management) platforms.

The framework organizes the indicators into three hierarchical levels, according to their essentiality, context of application, and project specificity.

This hierarchy allows essential metrics to be differentiated from complementary and specific metrics, adapting the rigor of the assessment according to the function of the building and the environmental context.

- Level 1 forms the minimum comparative panel, essential for certification and public tenders;
- Level 2 expands the analysis of durability and life cycle cost;
- Level 3 covers specific or sustainability requirements.

The operationalization of the framework requires the adoption of standardized measurement protocols and uniform formatting of results. It is recommended that technical reports present:

This structure allows indicators to be integrated into performance databases compatible with digital building management systems (BIM/PLM).

Example of practical application: to demonstrate the applicability of the framework, two comparative scenarios of glazed facades were simulated in different Brazilian bioclimatic zones (NBR 15220).

Parameter	**Facade Type A (zone 1 – hot and humid)**	**Facade Type B (zone 8 – cold and dry)**
U (W/m²·K)	3.0	1.80
SHGC	0.32	0.55
Rw (dB)	28.0	35.0
P_v (Pa)	350.00	450.00
ΔE	2.50	1.00
Cycles (operation)	15,000.00	12,000.00

Facade Type A, with lower SHGC and greater airtightness, offers better energy performance in hot, humid climates (Belém, Manaus). Facade Type B, with greater thermal insulation (U = 1.8) and acoustic insulation (Rw = 35 dB), is more suitable for cold and dry regions (Curitiba, São Joaquim). This example reinforces the potential of the framework for multi-criteria analysis and for the rational choice of facade systems based on objective data, rather than just declarative construction characteristics.

The adoption of the framework brings benefits in multiple dimensions:

- Technical: standardization of indicators and elimination of ambiguities between reports;
- Economic: reduction of rework costs and increased efficiency in public procurement;
- Environmental: better correlation between thermal performance and energy efficiency;
- Regulatory: strengthening traceability and technical transparency;
- Scientific: creation of an interoperable database for future comparative studies.
- Thus, the framework is consolidated as an instrument of technical governance and a basis for quality and sustainability public policies in civil construction.

Although the framework has high applicability, its effectiveness depends on:

- Standardization of technical terminology between laboratories and manufacturers;
- Inclusion of metrological uncertainty parameters in all reports;
- Expansion to complementary domains, such as lightweight seals and shading systems;
- Development of open digital interfaces (API) for direct integration with thermal and acoustic simulation software.

Final considerations

This article concludes that the performance of window frames and facades should be treated not only as a set of isolated technical tests, but as an integrated system of requirements, indicators, and decisions that spans all stages of a building's life cycle—from design to maintenance.

The Hierarchical Indicator Framework proposal represents a methodological and operational advance toward national standardization of performance criteria, offering a bridge between scientific research, technical regulation, and professional practice.

By systematizing available knowledge and proposing an integration structure, this work contributes to consolidating a new paradigm: that of evidence-based, transparent, comparable, and digitally interoperable performance evaluation — essential for the modernization and sustainability of civil construction in Brazil.

References

ABAL – Associação Brasileira do Alumínio. Manual Técnico de Perfis e Tratamentos Superficiais. São Paulo, 2020.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM). ASTM C1363-19: Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus. West Conshohocken, PA: ASTM International, 2019.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM). ASTM E413-16: Classification for Rating Sound Insulation. West Conshohocken, PA: ASTM International, 2016.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 6123:1988 — Forças devidas ao vento em edificações. Rio de Janeiro: ABNT, 1988.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 7199:2025 — Aplicações de vidros na construção civil — Requisitos. Rio de Janeiro: ABNT, 2025.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 8094: corrosão por exposição à névoa salina. Rio de Janeiro: ABNT, 1983.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 10821:2017 — Esquadrias para edificações — Janelas, portas e fachadas-cortina — Parte 1 a 6. Rio de Janeiro: ABNT, 2017.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 15220:2024 — Desempenho térmico de edificações — Parte 1 a 5. Rio de Janeiro: ABNT, 2024.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 15575:2021 — Edificações habitacionais — Desempenho. Rio de Janeiro: ABNT, 2013.

CBIC – Câmara Brasileira da Indústria da Construção. GUIA ORIENTATIVO DE BOAS PRÁTICAS PARA CÓDIGOS DE OBRAS E EDIFICAÇÕES. Brasília, 2021.

EPE – Empresa de Pesquisa Energética. Atlas Brasil 2023 (rev. set. 2024). Brasília: EPE, 2024. Disponível em: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-788/Atlas_Brasil_2023_PT_rev_set2024.pdf. Acesso em: 07/10/2025.

LABEEE/UFSC. Relatórios técnicos de desempenho térmico e etiquetagem de esquadrias. Florianópolis, 2022.

LAMBERTS, R.; DUTRA, L.; PEREIRA, F. O. R. Eficiência Energética na Arquitetura. 3. ed. Rio de Janeiro: Eletrobras/PROCEL, 2014.

IPT – Instituto de Pesquisas Tecnológicas. Relatórios de ensaio e publicações técnicas sobre fachadas e esquadrias. São Paulo, 2019–2023.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO). ISO 9227: Corrosion tests in artificial atmospheres — Salt spray tests. Geneva: ISO, 2017.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO). ISO 15099: Thermal performance of windows, doors and shading devices — Detailed calculations. Geneva: ISO, 2003.

ITEC – Instituto Tecnológico da Construção. Ensaios de estanqueidade e resistência estrutural de esquadrias. São Paulo, 2021.