Airnorne sound insulation of vertical partitions in an apartment in Maceió - AL - Brazil

Maria Lúcia Gondim da Rosa Oiticica
Department of Architecture and Urbanism, Federal University of Alagoas, Maceió-AL, Brazil.
Rafaella Cristina Teixeira Penedo
Department of Architecture and Urbanism, Federal University of Alagoas, Maceió-AL, Brazil.

Summary
In response to the diffusion of technological innovations, brazilian architecture has brought changes in the techniques and construction materials with several reflections on the quality of buildings. Regarding the quality of sound insulation of dwellings, these reflections, in general, are negative and user complaints are increasing. In this context, further compounded by the lack of regulations and laws with parameters and criteria for the assessment of the acoustic performance of homes, in 2013 the Performance Standard - Dwellings, NBR 15575 (ABNT, 2013) came into force establishing mandatory minimum requirements for the various elements of construction in favor of the performance of buildings, including the acoustic performance. It serves as a benchmark for builders and buyers for the analysis and quality assurance of their homes. The objective of this study is to evaluate the sound insulation airborne noise of vertical partitions in an apartment of a multifamily building in Maceió-AL - Brazil. As evaluation method, the field measurements were carried out to know the degree of sound insulation of facades of dormitories and internal vertical partitions that make up the housing unit under study. The results showed that the soundproofing was not satisfactory, since the values for the airborne noise, mostly, were below the minimum levels required by the performance standard NBR 15575 (ABNT, 2013). A qualitative assessment of the object, taking into account the design strategies, techniques and materials adopted in its construction and the impact on quality of airborne sound insulation was even made. It is evident, therefore, a need, not just the assessment and control of noise performance, but also of major concern to design strategies and constructive interventions that provide users with adequate conditions of comfort and privacy.

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1. Introduction

The Brazilian architecture presented, in response to the diffusion of technological innovations, a number of changes in techniques and construction materials with many reflections on the quality of buildings. In terms of quality of sound insulation of dwellings, these reflections, in general, have been negative [1].
This proves the importance of evaluating the design solutions adopted, in order to identify the inadequacies and to propose strategies that have better acoustic performance and provide privacy for users. Discomfort and health problems caused by exposure to noise affect users ante they, without evaluation parameters of sound insulation of the components of the buildings, buy houses permeable to noise, only realizing the problem during the occupation.
The designer have to plan ahead to avoid possible conflicts generated by external noise (from the vehicle traffic, shopping and leisure facilities, buildings, neighboring apartments and common areas to the building, for example). It is essential that investments in better acoustic performance solutions are made in the design phase, since late acoustic projects are much more expensive than those in the initial phase [1].
In Brazil, in recent years, users are considering more and more the noise levels at the time of purchase, so low levels of noise become a differential from manufacturer to offer your product in the market.
It was in this context that, in 2013, entered into force in Brazil the "performance standard of housing," the NBR 15575 [2], which deals with

criteria for assessing performance in dwellings. Among the various parameters discussed is the acoustic performance.

With the "Performance Standard" requirements, builders end up being forced to test their constructions and components to know its performance in order to enable the management of their building techniques and their improvement.

This study, on these justifications, intends, through field measurements, to verify if the chosen residence is appropriate for the existing requirements in relation to airborne sound insulation of the vertical partitions.

1.1. Aims

The aim of this study is to evaluate the airborne sound insulation of vertical partitions in an apartment in Maceió-AL-Brazil, in order to obtain data to characterize their acoustic performance and improve the quality of life of users.

2. Materials and methods

The procedures performed are presented in the following steps.

2.1. Selection of the object

The object of study fits within a few criteria for evaluation: apartment ready; still unoccupied and unfurnished; and located on the first floor, making easier the measurement of the insulation of facades.The selected building is in the city of Maceió-AL, in the northeastern Brazilian coast, with hot and humid weather and temperatures between 17 ° C and 32 ° C (Figure 1).

Figure 1. Map of Brazil highlighting the state of Alagoas and the location of the capital, Maceió

The selected apartment (104) is on the first floor of a building situated in Gustavo Paiva Avenue, that links the north coast to the city center, in Mangabeiras neighborhood, and is close to a shopping center and to a viaduct that connects the lower town to the higher (Figure 2).

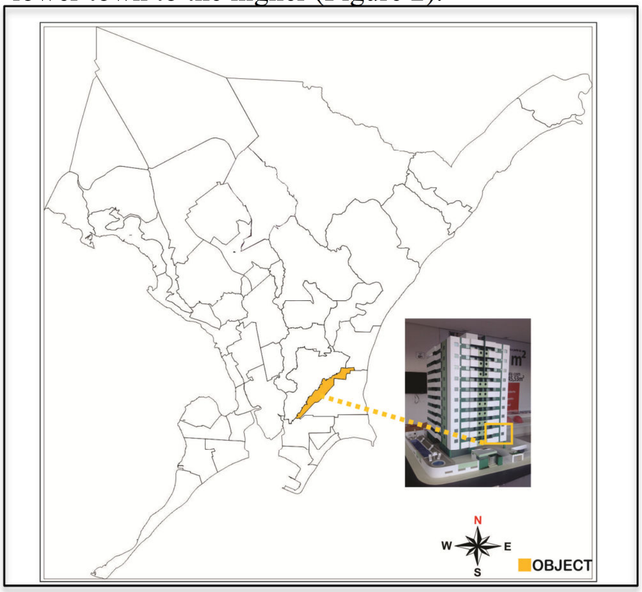


Figure 2. Map of Maceió indicating the location of the object under study

2.1.1. Data collection: the environment and the physical characteristics

According to the NBR 15575 [2], facades are characterized by three groups of noise. The object of study was classified as noise class III of Part 4: "Housing exposed to intense noise from transportation and other nature, provided it is in accordance with the law".

The building has nine floors with six apartments each (Figure 3), and one floor on the top with four flats. Its leisure area has playground, party room, open game room, fitness area, adult and children's pool and barbecue area.

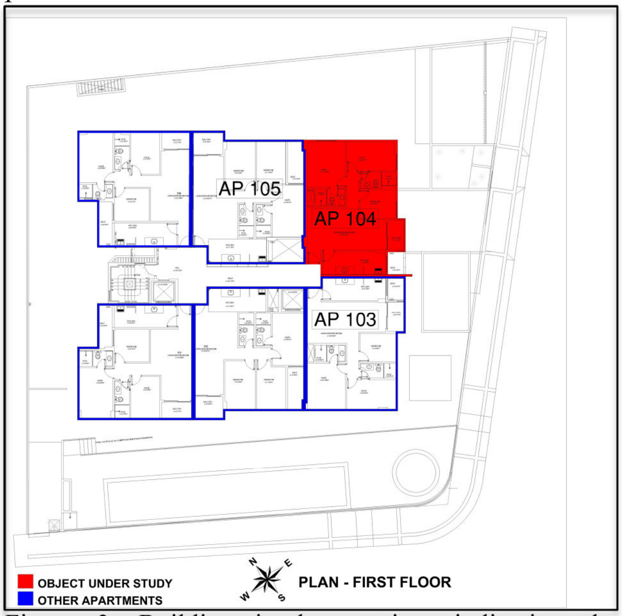
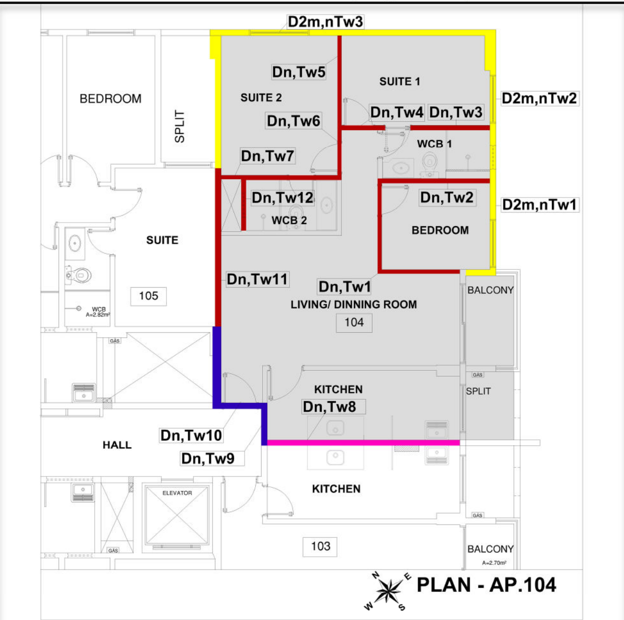


Figure 3. Building implementation, indicating the location of the apartment under study

The apartment has 66,30m² of area and consists of: two bedrooms with bathroom inside (suite); one bedroom (without bathroom); living / dining room with a balcony; and integrated kitchen to the service area (Figure 4).



LEGEND:

Wall between autonomous housing units (twinning wall) in situations with no bedrooms

Wall between autonomous housing units (twinning wall) in the case of at least one bedroom invoved

Blind wall rooms and kitchens from a housing unit and possible traffic areas such as hallways and staircases

External sealing - housing subject to intense noise from transportation and other nature, provided it is in accordance with the law - Class III

Figure 4 – Plan of the object of study with the analysed partitions divided in groups according to the classification of NBR 15575 [2]

The building has a construction system that consists of columns, beams and slabs in reinforced concrete. Different size ceramic bricks were used to build the walls:

- Bricks of 8 holes (11,5x19x19cm) – in the masonry of facades and of the walls between the object of study and the external hall and the neighboring apartments;
- Bricks of 8 holes (9x19x19cm) – internal walls with pipes (water and sewer) inside;
- Bricks of 4 holes (7x19x19cm) - internal walls without pipes (water and sewer) inside;

The partitions of the facades are coated with ceramic applied to roughcast and plaster. Internal walls and the internal faces of the facades are coated with painting on race plaster mass, except for the inner walls of the bathrooms and the kitchen that are tiled with ceramic.

The kitchen window, that faces the outside of the apartment, and the balcony door are sliding and made of aluminum with ordinary glass 4 mm. The windows of the rooms are also sliding and made of aluminum and they received a treatment to improve its sound insulation. The glass was replaced by ordinary laminated glass 6 (3 + 3) mm. In addition, the aluminum structure was filled with rock wool and they used in the sliding system expanded polyurethane brushes. The manufacturer did not perform tests to establish the Weighted Sound Reduction Index (Rw) of these adapted windows, but, according to the manufacturer, the index for the same type of window without the adjustments and ordinary glass 6 mm is 20 dB [3].

2.2. Measurements

For measurements of airborne sound insulation of partitions was adopted the "classic" method, a reference according to NBR 15575 [2].

2.2.1. Equipment used

The equipment used in the measurements was the Sound Level Meter 01dB, model SOLO, Class 1, which was configured to operate coupled via a USB cable to the notebook (slave mode), so that the results were automatically transferred to the software dBBati32.

2.2.2. Measuring procedures

Measuring procedures were performed according to standards: ISO 140-4 [4], which specifies field methods for measuring the airborne soud insulation properties of interior walls; ISO 140-5 [5] with procedures for the measurements of airborne sound insulation of facades; ISO 717-1 [6], with rules for determining single-number quantities from the results of measurements; and ISO 3382 [7] that presents methods for measuring the reverberation time. These international standards are recommended by NBR 15575 [2].

For airborne sound insulation measurements between enclosures and facades was adopted white noise, which has a constant level for all spectrum band. For the reverberation time measurements, the noise used was produced by the bursting of rubber balloons (the method of the impulse response). The background noise measurements were made with the source off. The adopted frequency range was the 1/3 octave bands and the set measuring average time was six seconds for each microphone position.

Standards that deal with acoustic insulation of houses are focused on the partitions between a dwelling and its surroundings, both externally, in the case of the facades of dormitories, and internally, as the neighboring apartments and common areas of the building, by example. Nevertheless, it was decided to include in the review internal walls that divide two rooms, with, at least, one of them, a bedroom. For this situation, the same performance level recommended for walls between autonomous housing units with at least one bed being environments was adopted.

2.2.2.1 Airborne sound insulation measurements between enclosures

The airborne sound insulation measurements between enclosures were performed according to ISO 140-4 [4] recommendations, adopting general requirements of the engineering method (Figure 5). However, to the measurements in bathrooms, adjustments had to be made in positioning the equipment, since the reduced dimensions of these rooms did not allow the placement of equipment in five points, respecting the distances set out in the standard.

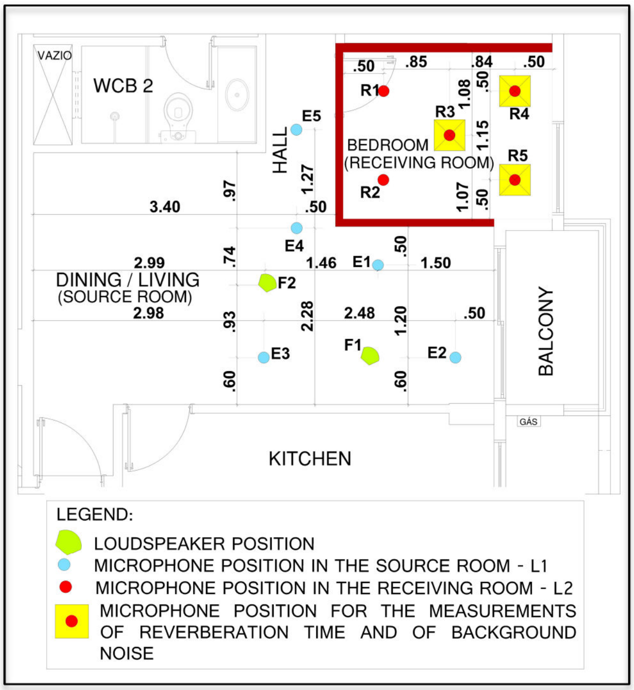


Figure 5. Positions of the loudspeaker and the sound level meter in the measurements of sound insulation between the dining/living room and the bedroom

For the sound pressure level at the source room (L1), measurements were made with the source in operation, positioning it at two points of source room (F), and the sound level meter in five positions in the same room (E) (Figure 5). Then, to obtain the sound pressure level in the receiving room (L2), the procedure was repeated by placing, however, the microphone in five points in the receiving room (R). This routine was repeated for each of the airborne sound insulation measurements between enclosures.

For the measurement of reverberation time (Tr) rubber balloons were blown maintaining a minimum distance of 1,2m from the microphone (Figure 5). For each of the three measuring positions were made three bursts.

The background noise (B2) defined by Gerges [8] as any secondary sources of noise reaching the microphone, the receiver position has been measured in the receiving rooms, turning off the source and measuring in three positions (Figure 5).

2.2.2.2 Airborne sound insulation measurements of facades

The method for measuring airborne sound insulation of facades is described in ISO 140-5 [5].The first step was to generate an external sound field, using white noise and with the loudspeaker positioned at an angle of 45° from the normal of the facade. Each measurement lasted for 6 seconds. For each situation the source was positioned at two different points on the outside. For each position of the source, the microphone was positioned at three points two meters away from the facade, to obtain L1, then, at five points within the receiving room (Figure 6).

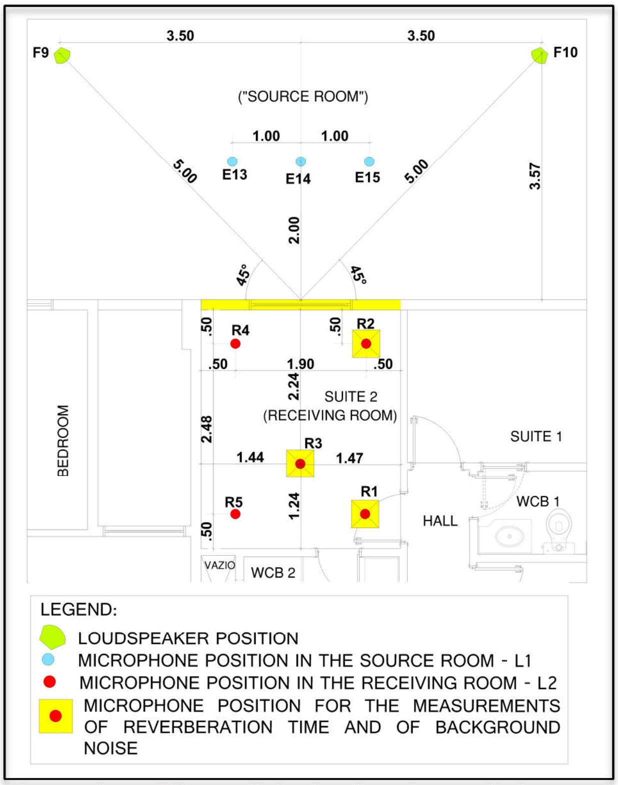


Figure 6. Positions of the loudspeaker and the sound level meter in the measurements of sound insulation of the façade of the suite 2

For the measurements in the source room, so that the microphone could be positioned two meters away from the facade, it was attached to a tripod and suspended by the balcony or the window. Then, measurements were carried out in the receiving room (Figure 6) in three steps:

- Step 1: Measure the sound pressure level (L2) with source (loudspeaker) in operation in two positions (F) and the sound level meter in five different points (R);
- Step 2: Background noise measurement (B2) with three positions of the sound level meter and the source off;
- Step 3: Reverberation time measurement (Tr), with the bursting of rubber balloons as a source and three microphone positions, with three bursts for each position.

2.2.3. Measuring points

For the evaluation of airborne sound insulation of the object of study, fifteen measurements were performed, twelve evaluating partitions (seven internal, two between the apartment 104 and the hall and three in neighboring apartments) and three facades (the bedroom and of the two suites).

3. Analysis and diagnosis

With the systematization of the results and the application of them in the equations determined by standards in order to obtain the single-number quantities used in quantitative analysis, we obtained the first conclusions on the acoustic performance of the apartment.

The next step, qualitative analysis, deals with the effects of the design of the apartment, of the materials and construction techniques of the apartment under study on the airborne sound insulation of its vertical partitions.

3.1. Quantitative analysis

For each partition, we calculated the arithmetic average of the obtained values for each parameter (L1, L2, B2 and Tr), and then the results were entered into the equations for calculating the Weighted Standardized Level Difference ($D_{nT,\ w}$) and Weighted Standardized Level Difference, 2 meters ($D_{2M,\ nT,\ w}$) of each wall evaluated. The results were organized in spreadsheets and systematized to facilitate analysis.

For each situation, the first step was to assess the need to apply the correction for background noise, according to ISO 140-4 [4]. Then, with the values of Leq1 and Tr, the Standardized Level Difference (D_{nT}) was calculated. And, using the ISO 717-1 [6] method, the single-number quantities, $D_{nT,w}$, were obtained. The same procedure was applied to obtain the Standardized Level Difference 2 meters ($D_{2m,nT}$) and the Weighted Standardized Level Difference, 2 meters ($D_{2m,nT,w}$). Table II presents the results of the acoustic performance of the object of study.

Table II– Results of the Weighted Standardized Level Difference (D_{nTw}) and for Weighted Standardized Level Difference, 2 meters (e $D_{2m,nTw}$) of the object of study indicating their acordance to acoustic performance estabilished by the NBR 15575 [2]

Acoustic parameters	D2m,nTw/ DnTw (dB)	Limit (M) NBR 15575 (dB)	Reached the limit (M) of NBR 15575
$D_{2m,nT}$ 1	21	≥30	NO
$D_{2m,nT}$ 2	19	≥30	NO
$D_{2m,nT}$ 3	20	≥30	NO
D_{nT} 1	19	45 a 49	NO
D_{nT}, 2	46	45 a 49	YES
D_{nT}, 3	20	45 a 49	NO
D_{nT}, 4	18	45 a 49	NO
D_{nT}, 5	32	45 a 49	NO
D_{nT}, 6	17	45 a 49	NO
D_{nT}, 7	22	45 a 49	NO
D_{nT} 11	42	45 a 49	NO
D_{nT} 12	49	45 a 49	YES
D_{nT} 8	38	40 a 44	NO
D_{nT} 9	38	30 a 34	YES
D_{nT} 10	24	30 a 34	NO

3.2. Qualitative analysis

The qualitative analysis took into account design strategies, techniques and materials adopted for the construction.

The suite 1 was located in a more remote area of the living room, protected by the bedroom and by the bathroom. The designer positioned the bathrooms on the wall opposite to that which divides suite 1 and its bathroom. The suite 2, and the other, was separated from the room by a bathroom, and from the bedroom and from the neighbor's apartment by a shaft. The designer also took care not to place pipes (water and sewer) in the partition between the suite 2 and its bathroom.

However, the room was still very exposed to noise from outside, from the balcony and from the living room. Although pipes (water and sewer) have been installed in the wall dividing the suite 1 and the bathroom, the type of ceramic bricks adopted improved the acoustic performance of the partition, reaching the minimum required by the "Performance Standard".

The designer specified for the external walls (partitions of the hall between the apartments and partitions between neighboring apartments) ceramic bricks with higher density, so they reached performance levels very close to the minimum required in NBR 15575 [2]. The performance of the partition between the hall and the kitchen was higher than the minimum required.

The choice of masonry with denser ceramic bricks was not enough for the facades of the rooms, as they didn't reach the minimum performance required by Part 4 of the NBR 15575 [2], even with the acoustic treatment performed on the windows.

The inner walls, made of ceramic bricks with reduced dimensions, together with the "honeycomb" wood doors, resulted in partitions with low levels of sound insulation.

The contact between the apartments 103 and 104 is done through a wall without openings separating the kitchens of the two units, so that the noises generated cause fewer bother than would be if the kitchen confronted with the living/dining room, by an example. In addition, the wall and the kitchen door reduce the passage of undesirable sounds of home appliances to the living/dining room.

The object of study is bordered by one of the suites of apartment 105 through two rooms: a living/dining room and the bathroom of suite 2. The denser ceramic brick used in the wall of the living/dining room attenuated the sound insulation problem of this partition so that, though not reaching the minimum performance standard, came very close to it. The insulation between the bathroom 2 and the suite of apartment 105 was improved by placing a shaft between them, enabling the measurement results indicate intermediate performance, even with the existence of a type of window with a permanent ventilation opening, which makes the noise pass easily. Another shaft separates the living room of apartment 104 and 105 of the kitchen, but without openings.

4. Conclusions

This study evaluated the airborne sound insulation of vertical, internal and external partitions, of an apartment in a multifamily building in Maceió-AL, through field measurements, comparing results obtained with the requirements of the "Performance Standard", NBR 15575 [2]. The results of the measurements showed that most partitions analyzed does not reach the minimum requirements set by NBR 15575 [2].

As the object of study was built before the adoption of the NBR 15575 [2], it does not have the obligation to conform to the levels that it sets, but the evaluation is important to show the builder the need for adjustments in future projects for their next ventures, so they will present acoustic performance as standard requirements.

There are several alternatives that can be adopted to suit new housing developments. It is a job that must be done together. The designer must take design strategies, as to put noisy areas more away from other rooms, for example, and specify materials that are more resistant to noise. Manufacturers must perform tests and insert in its catalogs the performance results of its products, in order to assist and guide the designer in the specification. Finally, builders must evaluate the acoustic performance of its most recent constructions in order to get a diagnosis that will guide interventions in the next buildings; and ensure that its engineers follow the installation instructions of materials and construction systems, so that the acoustic performance of the construction is not damaged by errors in execution.

The designer has the challenge of studying techniques and building materials that improve the acoustic performance of dwellings without affecting the other variables related to the comfort of users, as thermal comfort, for example.

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