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Technical Notes

EVALUATION OF PERFORMANCE OF ACOUSTIC MATERIALS – A CASE STUDY IN BRAZILIAN CIVIL CONSTRUCTION

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Urban noises are emitted simultaneously by a wide variety of sources, such as, transportation and activities encountered in large cities. Many studies show that traffic noise followed by noise produced by neighbours are the main disturbing sources. Considering that both traffic and neighbour noise upset people inside their homes, it is possible to conclude that these homes do not display good performance of one of their purposes, which is the one of providing acoustic comfort. This fact is critical in Brazilian homes, as opposed to countries such as Germany and the USA, since these countries have specific rules for acoustic properties of materials used in civil construction, and Brazil does not. The goal of the present study is to show the acoustic performance of materials routinely used in Brazilian civil construction. Measurement procedures both *in situ* and in the laboratory are presented to determine acoustic performance of the materials, such as: insulation coefficient for air propagation. The results have shown that the acoustic performance of Brazilian constructions, are under international standard.

Key words: sound insulation, acoustic comfort, civil construction, urban noise, insulation coefficient.

1. Introduction

Noise pollution is nowadays, right after air and water pollution, the environmental problem that affects most people. Noise has been causing increasing levels of annoyance and harm in the great urban centers around the globe. People are obviously especially sensitive to noise during leisure time. That is precisely the problem with urban noise. It upsets and annoys people also when they are not working, during nighttime.

Urban noises are emitted simultaneously by a wide variety of sources, such as industry, transportation and activities encountered in large cities. Several researchers have been trying to characterize urban noise, and to study how it affects city inhabitants.

These studies show that traffic noise followed by noise produced by neighbours are the main disturbing sources.

Considering that both traffic and neighbor noise upset people inside their homes, it is possible to conclude that these homes do not perform well one of their purposes, which is the one of providing acoustic comfort to its inhabitants. This fact is critical in Brazilian homes, as opposed to countries such as France, Germany, England, and the USA, since these countries have specific rules for the acoustic insulation properties of materials used in civil construction, and Brazil does not.

2. Discussions

When sound waves reach a wall, their energy is partially reflected and partially absorbed by it [1, 2]. The paths of sound transmission are: 1) the direct transmission, through the elements of separation between rooms; and 2) indirect transmission, through the lateral walls, through the ceiling and floor. These two components sum up to yield the total sound energy transferred from one room to the other [2, 3]. For walls made of homogeneous materials of constant width, the level of insulation is a function of the mass of the element and of the frequency of the sound that hits the wall.

One theory vastly used to predict the coefficient of sound insulation in simple walls is the law of mass, which shows good performance according to several authors such as BERANECK [4], HECKL [5] and SILVA [6]. There are also other methods to predict the insulation factor of simple walls, like those of Feshbach, Cremer, Josse, Brüel, Savioli, Meisser, and the Statistical Energy Analysis. These methods have been evaluated by LARANJA [7], through the confrontation of measured and simulated results. As a result of this study he has concluded that, depending on the material studied and the frequency to be analyse, different methods may yield different results. The method shown to be the most efficient for all materials and frequencies evaluated was Patamar's Method [1].

When a high loss of transmission is desirable, without massive walls, the use of double or triple walls is the best option. BATISTA [8] states that the main factors that determine the quality of a double wall are: 1) the type of material, 2) the system of assembly of the walls, 3) the width of the air layer, and 4) the coefficient of absorption of the material placed in the air chamber to lower resonance. In order to assure the efficiency of this type of composition, several authors [1–5] suggest materials of different mass and rigidity, in order to guarantee that the walls will not display the same critical frequency. Sound transmission in this kind of structure is very difficult to be mathematically formulated through a simple expression, as it depends on different mechanisms of transmission. In order to evaluate the phenomenon of sound transmission, some simplified and limited models have been proposed, such as those of London, Goesele, Josse, Craik and Wilson, Sharp and Meisser. In order to estimate the insulation coefficients in this kind of structure, LIPS [9] suggests the use of expression (1), which was obtained empirically:

$$R'_w = R^*_w + (100.d.n.c), \tag{1}$$

where R'_w – coefficient of sound insulation of the double wall; R^*_w – coefficient of sound insulation of the simple wall; d – distance between the two walls [m]; n – type of coupling between the walls ($n = 1$ if coupling is rigid; $n = 1.5$ if coupling is elastic; $n = 2$ if the walls are not connected); c – Type of material that fills the space between the walls ($c = 0.8$ if air chamber; $c = 1$ if the chamber is filled with absorptive material).

In Brazilian civil construction, the material most often used for walls are bricks. The bricks are perforated ceramic blocks 15 cm-wide. Concrete blocks are also used, as well as Dry Wall. SILVA [6] has evaluated the acoustic insulation by walls built with these materials. This evaluation has been carried out through laboratory measurements, according to ISO 140-3 [10]. The results have been obtained in frequency bands of 1/3 of octave, and afterwards, following the standard ISO 717-1 [11] converted to weighted apparent sound reduction index. The results of this evaluation are displayed in Table 1 [6].

Table 1. Sound insulation measured in the laboratory for the walls built with materials routinely used in Brazilian civil construction. R_w is the weighted sound reduction index, conform ISO 140-3 and ISO 717-1.

Wall	R_w [dB]
Plain brick wall	41
Covered brick wall	44
Plain concrete block	37
Covered concrete block	43
Dry Wall without fiber glass	34
Dry Wall with fiber glass	42

In FERREIRA [12] and in FERREIRA *et al.* [13], the performance of Brazilian construction materials is studied, when used for home building. In his work Ferreira performed *in situ* measurements of the insulation between the rooms (Table 2) and the façade insulation (Table 3) of eleven homes built with the usual materials of Brazilian civil construction. These evaluations have been performed according to standards ISO 140–4 [14] and ISO 140-5 [15].

Table 2. Sound insulation measured between rooms – *in situ* measurements R'_w is the weighted apparent sound reduction index conform ISO 140-4 and ISO 717-1.

Wall material	Door relative area with respect to the wall [%]	R'_w [dB]
Wood	13–16	20–25
Brick wall	8–20	25–31
Concrete block	11–18	25–26
Dry Wall	13–20	27–29

Table 2 [12, 13] and Table 3 [12, 13] show the results through the single number quantities of airborne sound insulation in buildings obtained according to standard ISO 717-1. The results are displayed in bands that include all the values measured in residences, as a function of the materials used to build the walls.

Table 3. Sound insulation of façades $R'_{tr,s,w}$ is the weighted apparent sound reduction index conform ISO 140-5 and ISO 717-1.

Wall material	Window relative area with respect to the wall [%]	External noise at the measurement site L_{eq} in dB(A)	$R'_{tr,s,w}$ [dB]
Wood	18	69	16
Brick wall	14–26	66–72	19–23
Concrete block	16–22	68–70	20–21

The German standard DIN 4109 [16] recommends for the weighted apparent sound reduction index between rooms, a minimum value of $R'_w = 47$ dB. The German standard VDI 4100 recommends for the weighted apparent sound reduction index between rooms as a function of the desired comfort, the values between 36 and 51 dB [17].

For sound insulation from façades, the DIN 4109 sets the limits displayed in Table 4. The insulation values in Table 4 are established with respect to the level of external noise. The insulation levels measured, presented in Tables 2 and 3, are all below the levels recommended by DIN 4109 and VDI 4100. This leads to the conclusion that Brazilian residences do not meet one of their purposes, that of providing acoustic comfort to its inhabitants. Consequences of the detected lack of acoustic protection against urban noise are immediately apparent.

Table 4. Sound insulation for façades as a function of the external sound level as demanded by DIN 4109.

External noise	Living rooms, bedrooms, classrooms, etc.
L_{eq} dB(A)	$R'_{tr,s,w}$ [dB]
Until 55	30
56 to 60	30
61 to 65	35
66 to 70	40
71 to 75	45
76 to 80	50

A social survey conducted in the city of Curitiba [18] with 860 people interviewed pointed to traffic noise (72%) and noise by neighbors (38%) as the main sources of annoyance by noise. Figure 1 [18] displays the main effects of noise in the evaluated population. Data in Fig. 1 demonstrates how noise affects quality of life in the urban environment, leading to the need for acoustic quality of the built environment. The acoustic quality of the built environment is intimately related to the sound insulation capacity of the materials employed.

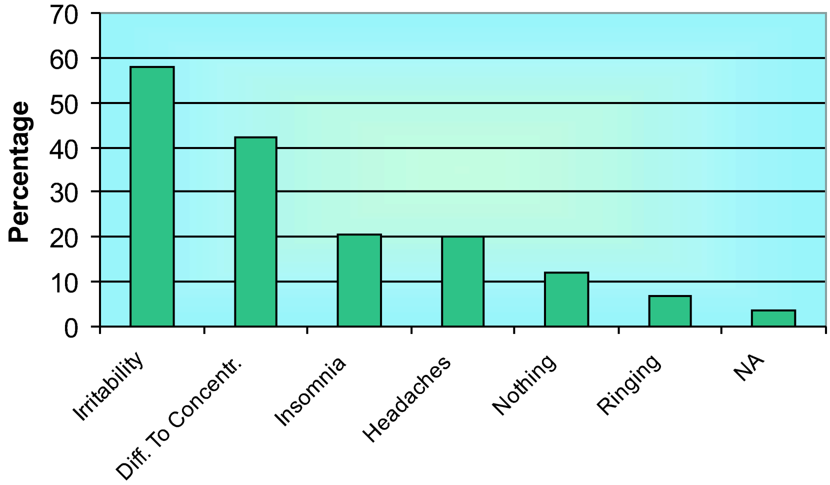

Fig. 1. Annoyance trough urban noise.

The low levels of insulation found in the evaluated residences may be a consequence of the poor acoustic insulation quality of doors and windows used. The doors commonly used in Brazil present a weighted apparent sound reduction index R'_w within the range of 10 to 20 dB. According to LIPS [9], doors with such sound insulation values are inadequate for dormitories.

Furthermore, comparing the Brazilian measured sound insulation by windows (Table 5) to the levels recommended by German standard (Table 6) VDI 2719 [19], it is clear that Brazilian windows present poor acoustic performance.

The measurement of sound insulation by windows is an *in situ* measurement.

Table 5. *In situ* sound insulation measured for windows.

Product assayed	Characteristics	R'_w [dB]
Wood window	Simple 3 mm-glass, without jealousy	19.1
Aluminum window	Simple 3 mm-glass, without jealousy	17.8
Iron window	Simple 3 mm-glass, without jealousy	21.1
PVC window	Simple 3 mm-glass, without jealousy	20

As can be observed in Table 1, the materials used for the walls, individually, display high levels of sound insulation index. The main route for sound transmission through doors is through the gap below, of 1 cm [6]. As a consequence, the weighted apparent sound reduction index will not be over 20 to 25 dB, whichever the material it is made of. For improvement in performance, special doors should be used, the so-called acoustic doors.

The windows should also be improved, as they are the weak point to sound transmission in the façades. The windows thus define the insulation coefficient for external noise. Studies performed by SANTOS [20], BARING [21] and RECCHIA [22] shown that the main factors responsible for the low levels of insulation are the frames of the windows, and not the glass, as most people guess. Therefore, there is a common mistake of supposing that the substitution of single glass by double glass would solve the acoustic problem. BARING [21] *in situ*, SANTOS [20] and RECCHIA [22] in the laboratory have evaluated several types of windows. They have demonstrated that the models mostly used in Brazil do not display a satisfactory performance in sound insulation capacity. The values these authors have found for the weighted apparent sound reduction index for façades are well below the values reported in countries such as Germany, France, Spain, and the USA. These countries have rules and standards that establish the minimum values of sound insulation in buildings.

Table 6. Categories of windows conform VDI 2719.

Noise Control Categories	Insulation Coefficient *In situ* measurement R'_w	Insulation Coefficient Laboratory measurement R_w
1	25 to 29	≥ 27
2	30 to 34	≥ 32
3	35 to 39	≥ 37
4	40 to 44	≥ 42
5	45 to 49	≥ 47
6	≥ 50	≥ 52

3. Conclusions

It has been observed that Brazilian residences display less than acceptable values of the weighted apparent sound reduction index between rooms, when compared with the values demanded by international standards, such as DIN 4109 and VDI 4100. It has also been detected, in the evaluated residences, that the values of the weighted apparent sound reduction index from façades are also below those demanded by DIN 4109.

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References

[1] FASOLD W., VEREZ E., *Schallschutz und Raumakustik in der Praxis*, 2 ed., Verlag für Bauwesen, p. 422, Berlin 2003.

[2] MEISSER M., *Acustica de los Edificios*, ed. Barcelona 1973.

[3] METZEN A. H., *Bastian the building acoustics planning system – user manual*, p. 178, Saint-Gobain Isover, Berlin 2002.

[4] BERANECK L. L., *Noise reduction*, 1 ed., p. 758, McGraw-Hill, New York 1960.

[5] HECKL M., *The tenth Sir Richard Fairey memorial lecture: sound transmission in buildings*, Journal of Sound and Vibration, **70**, 137–153 (1980).

[6] SILVA D. T., *Estudo da Isolação Sonora em Paredes Divisórias de Diversas Naturezas*, Dissertação – Universidade Federal de Santa Maria, p. 140, Santa Maria 2000.

[7] LARANJA R. A. C., *Métodos e Modelos de Predição Sonora por Paredes e Atenuação por Barreiras*, Dissertação – UFRGS, p. 152, Porto Alegre 2000.

[8] BATISTA N. N., *Importância do Projeto Acústico Como um dos Parâmetros para a Obtenção da Qualidade dos Espaços Edificados*, Dissertação – UFRJ, Rio de Janeiro 1998.

[9] LIPS W., *Lärmbekämpfung in der Haustechnik*, Berlin: Expert-Verlag, p.404, 1999.

[10] International Organization Standartization ISO 140-3: Acoustic – Part 3: Laboratory measurements of airborne sound insulation of building elements, Geneva 1998.

[11] International Organization Standardization ISO 717-1: Acoustic – Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation, Geneva 1996.

[12] FERREIRA JAC., *Avaliação Acústica de Residências: Resultados Medidos e Simulados*, Dissertação – UFPR, Curitiba 2004.

[13] FERREIRA J. A, DINIZ F. B., FERREIRA A., ZANNIN P. H. T., *Evaluation of acoustical parameters of a Brazilian popular housing model*, Archives of Acoustics, **29**, 1, 123–127 (2004).

[14] International Organization Standardization ISO 140-4: Acoustic – Part 4: Field measurements of airborne sound insulation between rooms, Geneva 1998.

[15] International Organization Standardization ISO 140-5: Acoustic Part 5: Field measurements of airborne sound of façade elements and façades, Geneva 1998.

[16] Deutsches Institut für Normung DIN 4109: Schallschutz im Hochbau, Deutschland 1989.

[17] Verein Deutscher Ingenieure – VDI 4100 – Schallschutz von Wohnungen – Kriterien für Planung und Beurteilung, Düsseldorf 1994.

[18] ZANNIN P. H. T., DINIZ F. B., FERREIRA J. A., *A survey of urban noise annoyance in a large Brazilian city: the importance of a subjective analysis in conjunction with an objective analysis*, Environmental Impact Assessment Review, **23**, 245–255 (2003).

[19] Verein Deutscher Ingenieure – VDI 2719 – Schalldämmung von Fenstern und deren Zusatzeinrichtungen, Düsseldorf 1987.

[20] SANTOS J. L. P., PAIXÃO D. X., *Qualidade acústica de janelas: realidade e perspectiva*, Porto Alegre 1991.

[21] BARING J. G. A., *Isolação Sonora de Paredes e Divisórias*, [in:] Tecnologia das edificações, pp. 429–434, Instituto de Pesquisas Tecnológicas do Estado de São Paulo – IPT/SP, São Paulo 1998.

[22] RECCHIA C., *Estudo do Desempenho Acústico dos Elementos Construtivos que Compõe a Fachada*, Dissertação – UFSM, p. 108, Santa Maria 2001.