LABORATORY MEASUREMENTS OF SOUND INSULATION OF COMERCIAL DOORS

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Abstract. *Some laboratory measurements have been made to observe the acoustic insulation of doors. This concern is happening due to increasing requirements of better acoustic insulation results in recent Brazilian buildings. A study group on the subject have been discussing various standard projects for up to five floor high buildings, including some with the acoustic performance that indicates the use of ISO-140-3 and 717-1. In this experiment results for the weighted sound reduction index (R_w) varied from 23 dB to 35 dB. This paper not only presents the R_w but brings up some issues on the data such as the reverberation time and the sound level difference. The studied doors were made by PRODESIVO Industria e Comércio Ltda. The tests were run in the Laboratory of Technology of the Constructed Environment of FURNAS CENTRAIS ELÉTRICAS S.A.*

Keywords*: laboratory measurement, acoustic insulation, doors.*

1. INTRODUCTION

With the industrial revolution, the environmental working conditions were improved so to increase productivity. However, little attention was given to the workers resting environment. It is true that a worker produces less with improper environmental conditions. Thus to create a comfortable constructed ambience is economically beneficial and more comfortable both for the workers and the surrounding community.

Recently in Brazil, these habitation conditions are being evaluated so to guarantee quality in the built constructed environment. One of the actions comes from the ABNT (Brazilian Association of Technical Standards) with a standard project regarding the performance criteria for residential building of up to five stories. In this work, the part 4 of the norm, referring to façades and internal walls (ABNT, 2006), will be discussed in face of the acoustics insulation performance of three doors.

A door, like a window, is an integrating element of an enclosed wall. In this way, its performance reflects on the global result for the building set. A door can reduce the acoustical insulation dramatically in 30% relating to a blind wall (Gerges, 1992).

Laboratory measurement results for the calculus of the weighted sound reduction index, R_w of three doors are presented. The results include the variables of sound level difference measured between the source and the receiving room respectively, L1 – L2, and the reverberation time in the receiving room, T2 (ISO, 1995).

2. METHODOLOGY

The methodology applied to the tests followed the third serie of the ISO 140 named "laboratory measurements of airborne sound insulation of building elements" (ISO, 1995). The measurement product is the sound reduction index, R presented at Eq. (1). This result is led by a weighting process determined in the ISO 717-1 (ISO, 1996) to achieve the weighted sound reduction index, R_w.

$$R = L1 - L2 + 10\log\left(S/A\right) \quad (1)$$

Were S is equal to the specimen area and A is the equivalent sound absorption area in the receiving room derived from the reverberation time measured during the test and extracted by Eq. (2).

$$T = 0.163 \left(V / A \right) \qquad (2)$$

Where, V is the volume of the receiving room.

The measurement took place at the technology laboratory of the constructed environment, LASC, of Furnas Centrais Elétricas SA, one of the few Brazilian laboratories with infrastructure for this kind of measurement. The variables, L1, L2 and T2 were measured at the points A to F represented in Fig. 1.

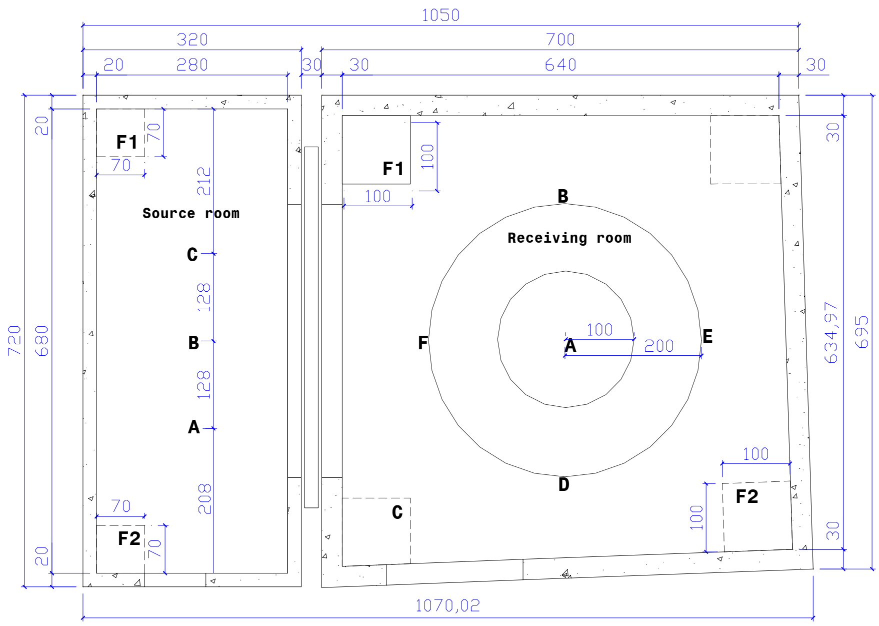

Figure 1. Ground point view of collecting point in laboratory site.

2.1. Specimen:

The specimens are Door 1, Door 2, and Door 3. The first two doors are made of 30 mm Medium Density Fiberboard, MDF, and 35 mm solid pine wood. Door 1 is formed by a single door leaf covered with a wood panel, weights 95 kg, and has an automatic door sealing system close to the floor, Fig. 2.

Figure 2. Views of Door 1, automatic door sealing system (a) and double door frame (b)

Door 2 has two leaves with 5 mm carpet panel opening one to each side of the wall and weights 180 kg (Fig. 3).

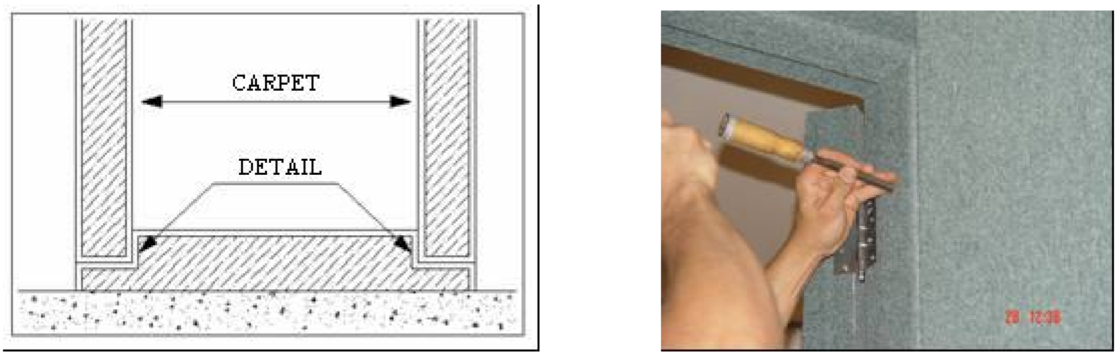

Figure 3. Door 2, drawing of the two leaf doors (a) and door's installation (b)

Door 3 is made of 3 mm common wood, has internal lath wood structure, is covered by wood panel, and weights 51 kg (Fig. 4).

Figure 4. Installed view of Door 3.

3. RESULTS

3.1. Sound reduction index, R, and weighted sound reduction index, R_w:

Table 1. Experimental results for all three doors, numeric values for Sound Reduction Index in decibel versus Frequency in hertz.

	DOOR 1		**DOOR 2**		**DOOR 3**
Hz	**R 1.1**	**R 1.2**	**R 2.1**	**R 2.2**	**R 3**
100	21	25	24	31	14
125	27	30	25	32	21
160	24	28	27	32	19
200	21	24	25	32	17
250	22	24	23	30	16
315	22	25	22	28	17
400	24	27	23	26	18
500	24	26	23	28	17
630	24	25	24	32	18
800	23	26	24	34	18
1000	22	25	24	36	19
1250	19	23	24	36	20
1600	15	19	26	37	20
2000	17	21	29	40	19
2500	20	23	31	42	16
3150	18	22	32	44	14
4000	19	24	35	43	16
5000	19	26	37	41	17

The detailed results for R and R_w were presented in a previous article (Carvalho *et al.*, 2006). Table 1 resumes the sound reduction index for all three doors.

Door 1 had two evaluations for R. Initially, the door was tested as originally manufactured, R 1.1. The weighted sound reduction index, R_w, was calculated according to the ISO 717-1 and the single-number quantity for Door 1 at 500 Hz resulted in 19 dB. Suggestions to improve slits were applied to the door frame and new tests were made, R 1.2. The single-number R_w increased to 23 dB.

Door 2 also had two evaluations, one with an open door, R 2.1, and another with both doors closed, R 2.2. The single-number R_w for the first situation was 26 dB and for the second 35 dB.

Door 3 was analyzed only to make a comparison with the others. Results for the sound reduction index are represented as R 3 and the single-number R_w was 18 dB.

3.2. Sound level difference, L1-L2, and reverberation time, T2:

The results for the sound level difference and reverberation time of Door 1 before, 1.1, and after, 1.2, revisions and improved slits are presented at Fig. 5 and 6 respectively. The thick colored line represents the average from 10 tested points during measurement. The thin black lines are the values for each test point.

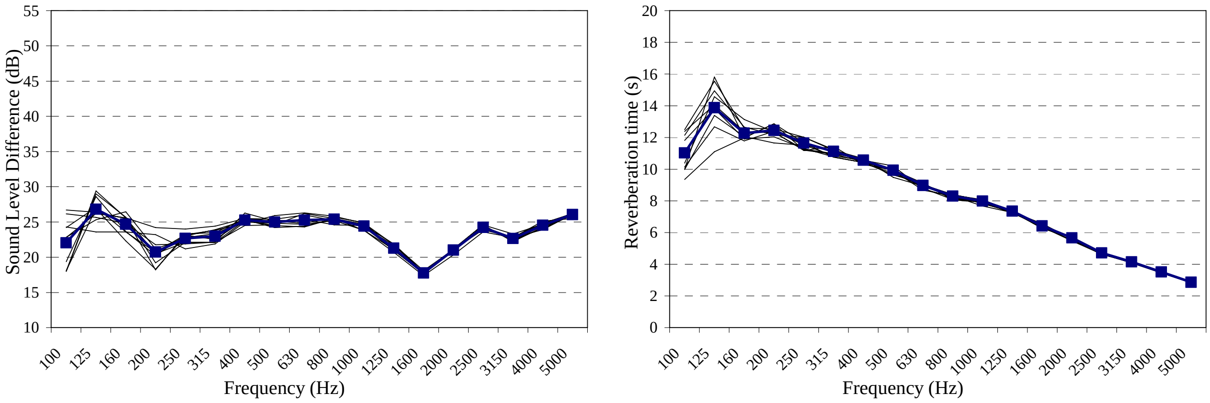

Figure 5. Sound Level Difference in decibel versus Frequency in hertz (a)
and Reverberation Time in seconds versus Frequency in hertz (b) for Door 1.1 before changes.

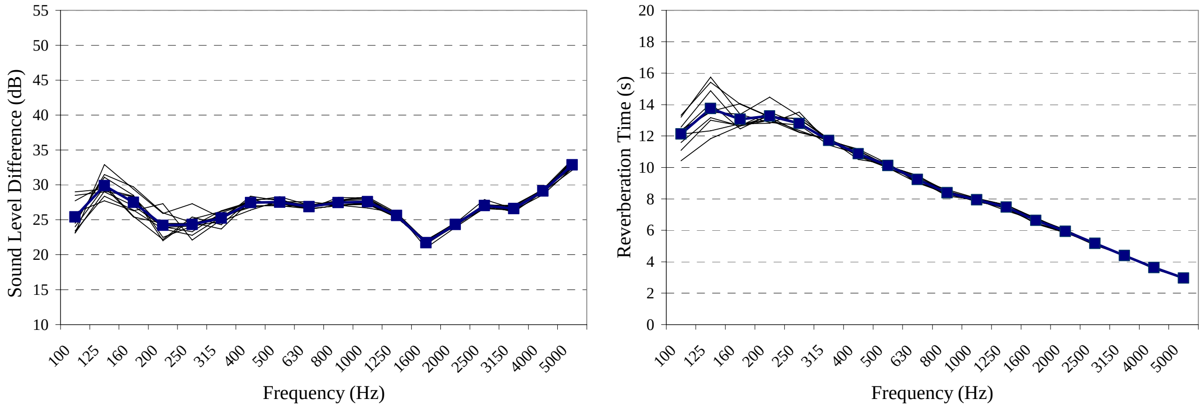

Figure 6. Sound Level Difference in decibel versus Frequency in hertz (a)
and Reverberation Time in seconds versus Frequency in hertz (b) for Door 1.2 after changes.

Random uncertainty was observed in the standard deviations at low frequencies. Maximum standard deviations got to 3.4 dB for the sound level difference of Door 1.1 and 2.3 dB for Door 1.2 in both cases at 100 Hz. For the reverberation time, the highest standard deviation for Door 1.1 and 1.2 got to 1.4 s and 1.29 s, respectively, both at 125 Hz.

Figure 7 and 8 represent results of the sound level difference and reverberation time for Door 2 with one open door, 2.1 and both doors closed, 2.2.

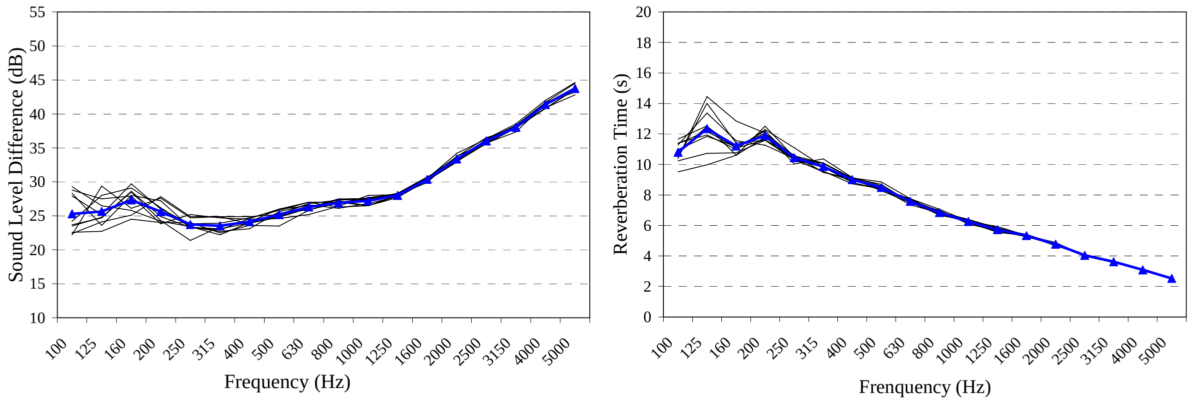

Figure 7. Sound Level Difference in decibel versus Frequency in hertz (a)
and Reverberation Time in seconds versus Frequency in hertz (b) for Door 2.1 with one open door.

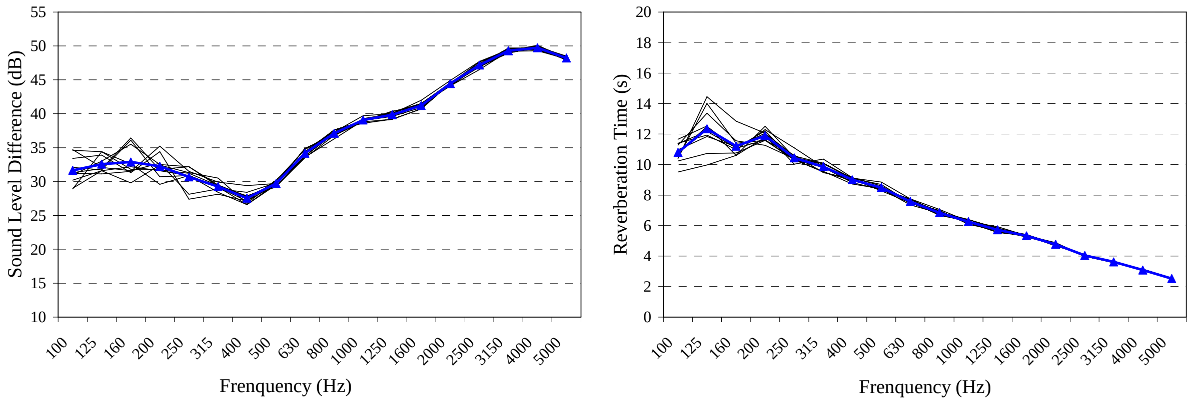

Figure 8. Sound Level Difference in decibel versus Frequency in hertz (a)
and Reverberation Time in seconds versus Frequency in hertz (b) for Door 2.2 with both doors closed.

The maximum standard deviation for the sound level difference for Door 2.1 and 2.2 was 2.9 dB at 100 Hz and 2.3 dB at 160 Hz, respectively. For the reverberation time, the greater standard deviation was 1.37 s at 125 Hz.

The sound level difference and reverberation time of Door 3 are presented in Fig. 9.

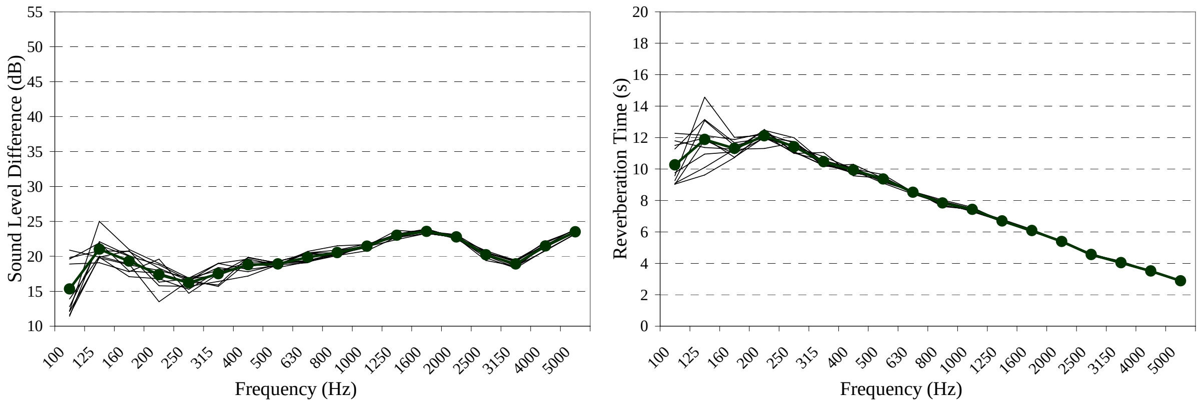

Figure 9. Sound Level Difference in decibel versus Frequency in hertz (a)
and Reverberation Time in seconds versus Frequency in hertz (b) for Door 3.

The maximum standard deviation for the sound level difference was the greatest among tested doors and resulted in 3.94 dB at 100 Hz. For the reverberation time, deviation got to 1.48 s at 125 Hz.

4. CONCLUSIONS

4.1. Considerations regarding the Brazilian project standard

Even with modifications in 2007, the standard project referenced here still hasn't made clear how to evaluate building elements like doors and windows by the laboratory method. The issue is not the methodology but the suggested criteria for determining the good performance of these building elements. The only reference to the sound insulation door values are on table 24 (ABNT, 2006) "…to verify the global performance including doors, and in the absence of R_w values for walls with doors, adopt values included in Table 23 relative to field measurements.", in other words, one must search for the criteria of weighted standardized level difference, $D_{nT,w}$, to evaluate the insulation of doors.

Openly $D_{nT,w}$ and R_w criteria should not be directly compared given that both their field and laboratory acoustic magnitude and measurement conditions are different. Therefore, the standard project committee should suggest a specific form to evaluate the sound insulation of doors and windows so that a clear and coherent policy is available for analyzing laboratory results.

Nevertheless, when comparing the present doors results with values suggested by the standard, only Door 2 achieved the minimum values of R_w on the item referring to "living room walls and kitchens between a residential unit and corridors, hallways and stairways for a stories standard".

Both field and laboratory criteria determining high values bring some interesting issues such as: why is it necessary to have such high values? When will the environmental noise stop to increase in urban areas and what is the construction society doing to reach these criteria? In a certain way, the civil construction is being demanded by the ABNT commission to give better acoustic insulation to buildings. A contradiction is made when the construction society gradually searches for economic lighter materials, while denser materials are necessary for reducing the sound transmission and obtain better acoustic insulation. Clearly, other methods of sound insulation rather than the mass law exist, like the mass-spring-mass effect, among others. In low frequencies cases, the mass law is not sufficient to guarantee acoustic insulation given the structural sound transmission.

Another point to observe is the increasing noise pollution in developing countries given by bad car maintenance (Kihlman, 2005) or cultural aspects such as the "culture of extremes" (Hobsbawn, 1995). Indirectly, who is paying for the environment noise problem is the civil construction given that "silence" in big cities is only obtained in resting areas, or else, homes. The issue gets more complicated when less privileged classes also search for sound comfort. Few are the enlightened ones that recognize that a good acoustical performance is not limited to expensive acoustic products and that this can be obtained with common materials.

To determine high values of acoustic insulation is only a form to obtain some acoustic comfort to the society, but it is not the ultimate solution. It would be of great human benefit to have a global acoustic reeducation so that sound levels decrease in favor of a healthier sound environment and all people could enjoy "silence".

4.2. Final considerations and future research

Results presented in this work pointed that the method applied for laboratory measurements of sound reduction index (ISO, 1995) still needs to obtain more repeatability in low frequencies. Better characterization of controlled laboratory conditions should be researched so to obtain more constancy and credibility results at low frequencies.

The presented graphics demonstrated the lack of repeatability among the low frequency values. Despite the laboratory conditions being controlled and rigorous, this inconstancy can be explained by some stationary frequency inside rooms or even outside noise interference. Researches on the number of sound source positions during low frequency measurements are being done (Mello et al., 2006) and should be considered for measurement procedure improvements in this aspect.

On another hand, the results of medium and high frequencies had good convergence of the 10 measured points to the average result. This gave great reliance to results in these frequencies. Around 13 to 18 frequency bands had repeatability, same as 70% of results are credible.

Regarding the manufactured doors, new measurements will be done in other laboratory facilities so to validate results, new models should be tested in order to obtain higher weighted sound reduction index values, and special attention should be given to get more repeatability at low frequencies.

According to Melo (2005), to obtain repeatable results at low frequencies more source positions are necessary regardless their physical position in the source room. It is still a great challenge for Brazil to have inter-laboratory tests for sound insulation. The scarce number of Brazilian laboratories is far from the suggested eight laboratories by ISO 140-2 (1991). All these considerations and new aspects to come are relevant for future measurements.

5. ACKNOWLEDGEMENTS

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