# IN-SITU SOUND INSULATION MEASUREMENT WHEN A ROOM IS VERY ABSORPTIVE

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## INTRODUCTION

When a noise source is placed in a room the resulting acoustic energy will be contained in two fields, reverberant and direct. The relative magnitude depends primarily on the amount of absorption, room dimensions, and distance from the source. Transmission loss test methods (ASTM E90, E336, ISO 140) assume that the energy density of the reverberant field will dominate. Consequently, laboratory test chambers are large and have little absorption to ensure that the reverberant field dominates, and the sampling positions are located away from sources. Unfortunately, for in-situ measurements there may be significant absorption in the rooms that may cause a marked deviation from these idealized conditions. This paper investigates the sensitivity of the ASTM E336 to absorption in either the source or receiving room and its effect on the number of microphones needed to sample the resulting field.

## MEASUREMENT METHOD AND METRIC

The metric used by most European objective based building codes is the weighted apparent sound reduction index ($R'_w$ ISO 140-4), a single number rating derived from sound pressure level difference measurements made without suppressing flanking and normalized to the area of the separating partition and the receiving room reverberation time (RT). A similar result is obtained when ASTM E336 is applied without suppressing flanking paths. In this summary paper the resulting measure is referred to as the "apparent transmission loss", (ATL) and is computed using,

$$ATL = 10Log\left[\frac{1}{N}\sum_{i=1}^{N}10^{\frac{P_{source,i}}{10}}\right] - 10Log\left[\frac{1}{N}\sum_{i=1}^{N}10^{\frac{P_{receive,i}}{10}}\right] + 10Log\left[\frac{S}{0.161V\cdot N}\sum_{i=1}^{N}RT_{60}\right] \quad (1)$$

where $P$ is the resulting sound pressure level (SPL) at the $i^{th}$ sampling position, $N$ is the number of positions in the room, $S$ is the area of the separating element, while $V$ and $RT_{60}$ are volume and the reverberation time of the receiving room, respectively.

Measurements were made using the four-room Flanking Transmission Facility at the NRC/IRC in which realistic sound transmission paths in multifamily dwellings, including flanking, between rooms can be evaluated under controlled conditions. Each room (volume 35-50 m$^3$) had three incoherent sources below 1.2 kHz and one above this. Nine microphone positions satisfying the ASTM E336 location requirements sampled the SPL.

The ATL was measured in both directions between the three possible room pairs: horizontally separated by a partition wall, vertically separated by a floor, and diagonally where there was no common element (in this special case the normalization area was set to 10m$^2$). These measurements were made for three absorption conditions, Minimum, Partial, and Maximum. Sheets of 50-mm thick open cell foam were placed on room surfaces not involved in a transmission path. This allowed for coverage on three room surfaces, each orthogonal to the others.

Figure 1 shows that the Partial condition has a receiving room RT that is typically within one standard deviation of the mean value measured in 300 Canadian multifamily dwellings[1]. The maximum condition represents an extreme case.

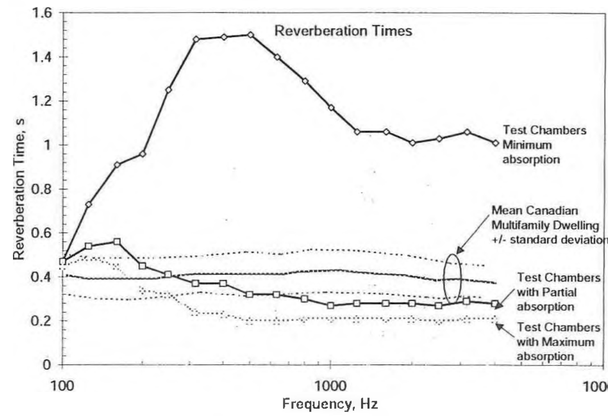


*Figure 1: RT for the three absorption conditions examined in this study and the mean for 300 Canadian multifamily dwellings.*

## MEASURED RESULTS

When all nine microphone positions are used to sample the source and receiving room the mean change in measured ATL (averaged for the three possible room pairs) relative to the case when there is Minimum absorption is typically less than 2.5 dB as shown in Figure 2.

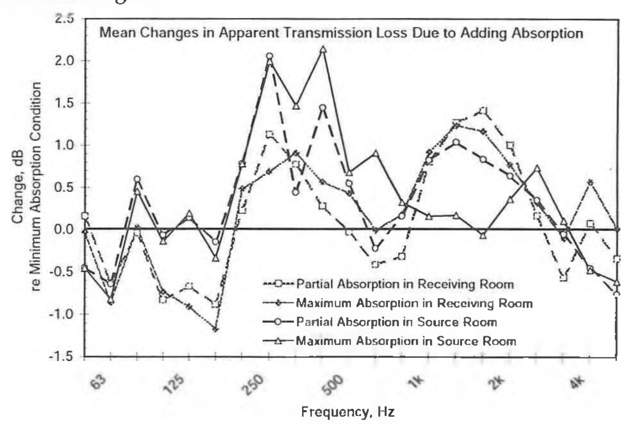


*Figure 2: Change in measured ATL due to adding absorption to either the receiving room or source room.*

Below about 200 Hz adding the absorption to either the source or receiving rooms had minimal effect which is consistent with the change in the RT which was not as large as in the mid and high frequencies. A significant change occurred in the frequency range, 250-500 Hz, especially when absorption was added to the source room. A physical explanation for this is not known. However, there was also a significant change in this range when absorption was added to the receiving room so it is speculated that this is related to room dimensions which tended to be similar in two of the three orthogonal directions. Above 500 Hz the change due to adding absorption was typically less than 1.5 dB. If ASTM E413 were applied the resulting change in the single number rating would be typically 1 with a maximum change of 1.

ASTM and ISO test methods use the concept of energy balance to express the power transmitted into the receiving room in terms of the resulting SPL (which is assumed to be reverberant) and the room absorption. If the receiving room does not satisfy the necessary conditions then the resulting receiving room SPL will not vary as -10Log(A) where A is the receiving room absorption in $m^2$. Figure 3, shows that although the correct trends are observed there is a greater change in the absorption correction term than the receiving room SPL. This may indicate the presence of a strong direct field the magnitude of which does not depend on the room absorption.

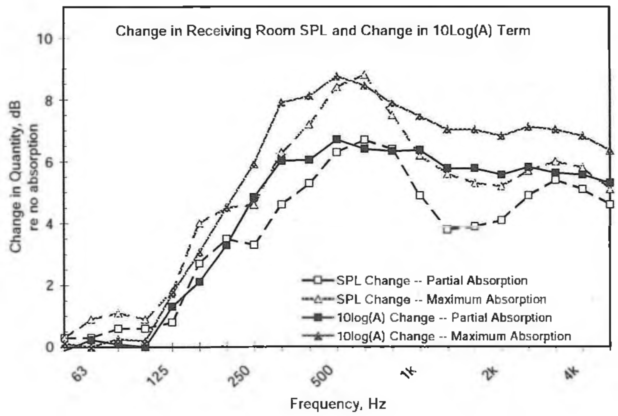


*Figure 3: Change in receive SPL and absorption correction term.*

## SENSITIVITY TO ROOM SAMPLING

To investigate the sensitivity of the measurements to the number of sampling positions, mean values for each quantity were computed using a sub set of 2 through 8 positions of the original nine. The mean values for each possible set of positions were then compared to the mean value for the full set of nine and a standard deviation (STD) computed which was then band averaged, using,

$$STD = \sqrt{\frac{1}{5N-1}\sum_{j=1}^{5}\sum_{i=1}^{N}\left(\overline{X}_{mean\ all\ nine,\ j} - X_{subset\ value,\ i,\ j}\right)^2} \qquad (2)$$

where $i$ is the index to the sampling position and $j$ is the index to the five frequency bands from 125 to 400 Hz, and $N$ is the total number of sampling positions. The Schroeder frequency with Minimum absorption is approximately 400 Hz.

In general, Figure 4 shows that the uncertainty (expressed as STD) increases with increasing absorption and/or with reducing the number of sampling positions. The STD of the absorption correction term is an order of magnitude lower than that for the receive or source SPL. It shoud be noted that the measurements below 1.2 kHz were made using three incoherent sources and reducing the number will increase uncertainty in SPL estimates.

## DISCUSSION AND CONCLUSIONS

Since the overall accuracy of the ATL will be determined by the sum of all the uncertainties, the uncertainty of the room correction term, 10Log(A), was insignificant relative to those for the SPL. The change in estimates of the mean SPL proved to be sensitive to the number of sampling positions when the room had significant absorption. Increasing the amount of absorption increased the uncertainty. Thus, the results indicate that measurements in rooms having absorption typical of furnished multifamily dwellings are possible if the room volumes are adequately sampled.

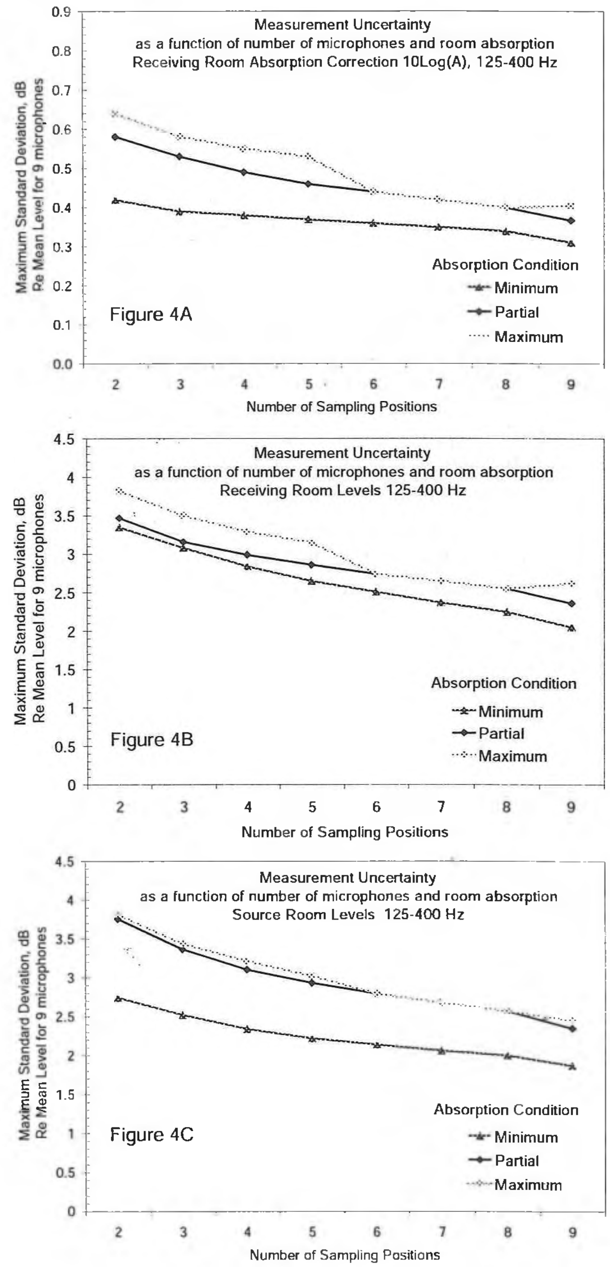


*Figure 4: Uncertainty in measures as a function of absorption conditions and number of sampling positions.*

## REFERENCES


1.) J.S. Bradley, "Acoustical measurements in some Canadian homes," Canadian Acoustics, Vol. 14, No. 4, 1986, pp. 19-21, 24-25.