COMPARISON BETWEEN SOUND REDUCTION INDEX MEASUREMENT TECHNIQUES

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ABSTRACT
The Sound Reduction Index of a partition can be measured according to the method described by ISO 140-3. This measurement technique does not make it possible to discern between direct transmission through the partition and transmission through the lateral structures of the rooms.
The paper reports the preliminary results of a research project aimed at comparing three different methods of SRI measurement: the traditional method, the sound intensity method and a method based on the measurement of the vibration velocity of the partition.
The comparison makes it possible to explain the drop in the performance of a specific double partition at certain frequencies.

INTRODUCTION

The Sound Reduction Index of a partition can be calculated from the normalized difference of the average Sound Pressure Levels in the source and in the receiving room, according to the method described by ISO 140-3 [1].
This way, it is impossible to separate the structural transmission through the test specimen from the airborne transmission through particular paths (like leakages, air ducts, etc.) or from the structural transmission through lateral paths (lateral walls and floors). Normally, this is not a problem in laboratory tests, because of the structural separation between the two adjoining rooms and the absence of airborne paths of transmission.
In many real situations (field measurements), it is very important to define all the paths of transmission to improve the sound insulation between the rooms. This is possible by using measurement techniques that make it possible to analyze the different transmission paths.
In the paper, three measurement techniques are used to calculate the Sound Reduction Index of a particular partition.
The measurement procedures were verified with reference to a common partition wall where there was no airborne transmission between the adjoining rooms.

THE MEASUREMENT METHODS

Sound Reduction Index measurements were performed by mean of the following three methods:

- the traditional method defined by ISO 140 – 3 [1];
- the intensity method defined by ISO/DIS 15186-1 [2]
- the method of the vibration velocity of the partition, not standardized.

According to ISO 140-3 (traditional method), the average sound pressure levels must be measured both in the source and in receiving room. The SPL in the receiving room must be greater at all the frequencies of analysis than the background level by at least 10 dB. Moreover, the reverberation time has to be measured in the receiving room to normalize the sound pressure level difference between the two rooms.
With the sound intensity technique the sound power incident on the test specimen is determined by the sound pressure in the source room and the sound power transmitted is determined by direct measurement of the sound intensity through the test specimen. The latter measurement is independent of the flanking transmission from any path not enclosed in the measurement surface. Intensity measurements take into account both the structural and the airborne transmission through the partition wall and any other components of the partition (like leakages and air ducts). In laboratory conditions, intensity measurements should give results near those obtained with the traditional method.
The ISO/DIS 15186-1 gives this equation for the determination of the intensity sound reduction index:

$$R_I = L_{ps} - L_{I_n} - 6 + 10\log\left(\frac{S}{S_m}\right) \tag{1}$$

where L_p is the average sound pressure level in the source room, L_{In} is the average normal sound intensity level over the measurement surface in the receiving room, S is the area of the test specimen and S_m is the total area of the measurement surface completely enveloping the test specimen.
In order to make the results more comparable with the conventional two-room method, a correction (room or Waterhouse correction) shall be used. This correction takes into account the higher energy density close to the test specimen boundary in the source room. In the standard ISO/DIS 15186-1 the correction is called "adaptation term K_c" and the modified intensity sound reduction index become:

$$R_{I,m} = R_I + K_c$$

Intensity measurements need a particular acoustic field in the receiving room and for this reason they are often less practical than traditional measurements.
An estimate of the quality of the measurement environment could be obtained by the surface pressure intensity indicator F_{pI}:

$$F_{pI} = L_p - L_{In}$$

The third measurement method gives results that depend only on the structural transmission through the partition wall and not on any airborne path or lateral path. In this case, it is necessary to measure the average velocity of vibration of the partition wall and the sound pressure level in the source room. The sound pressure level must be measured by taking into account the reflecting effects of the partition itself.
Moreover, it is necessary to estimate the radiation factor of the partition wall. Some formulas for the evaluation of the radiation factor, both above and below the critical frequency, are given in EN 12354-1 [3]
In particular, the radiation factor for free waves, when the critical frequency f_c is at least double the natural frequency (this is typically the case for masonry walls), is given by:

$$\sigma = \frac{1}{\sqrt{1 - \frac{f_c}{f}}}, \ (\sigma \le 2) \tag{2}$$

The sound reduction index of the partition can be calculated according to the following formula:

$$R = 10\lg\left(\frac{\Pi_i}{\Pi_{rad}}\right) = 10\lg\left(\frac{\langle p_s^2 \rangle}{4\boldsymbol{r}_0^2 c_0^2 \langle v^2 \rangle \boldsymbol{s}}\right) \tag{3}$$

where σ is the radiation factor, $\rho_0 c_0$ is the specific impedance of air ($kg/m^2 \cdot s$), $<v^2>$ is the spatial average of the squared vibration velocity of the partition $(m/s)^2$ and $<p_s^2>$ is the spatial average of the squared sound pressure in the source room $(Pa)^2$.

VALIDATION OF THE MEASUREMENT METHODS

The three measurement methods were tested by evaluating the Sound Reduction Index of a simple brick wall, plastered with mortar on both sides. No airborne transmission path was present between the two adjoining rooms.
Vibration measurements were performed also in the lateral structures of the receiving room to evaluate the amount of structural lateral transmission, in accordance to annex E of ISO 140-3.
For the measurement of SRI with the intensity method, a grid of 4 x 5 points was defined in the receiving side of the partition wall. The vibration velocity of the partition was measured in ten points randomly distributed in the receiving side of the partition wall. Their position respects the recommendations given in ISO/CD 10848 – 1 [4].
A Brüel & Kjær type 4371 accelerometer, with a weight of 11 grams and a not-damped resonance frequency of 48 kHz, and a B&K type 2635 charge amplifier were used for the velocity measurements.
The accelerometer was fixed to the wall surface by means of a thin layer of bees-wax, being this mounting technique recommended both for the roughness of the wall plaster and for the minor variation introduced in the resonance frequency of the mounted accelerometer. In fact, it is known that the mounting condition of the accelerometer can lower the resonance frequency of the measurement system, creating problems at higher frequencies of analysis.
Intensity measurements were performed by means of a intensity probe B&K type 3584.
All measurements were performed by means of the sound analyzer B&K 2260.
Figure 1 shows the comparison between the results obtained with the three techniques.

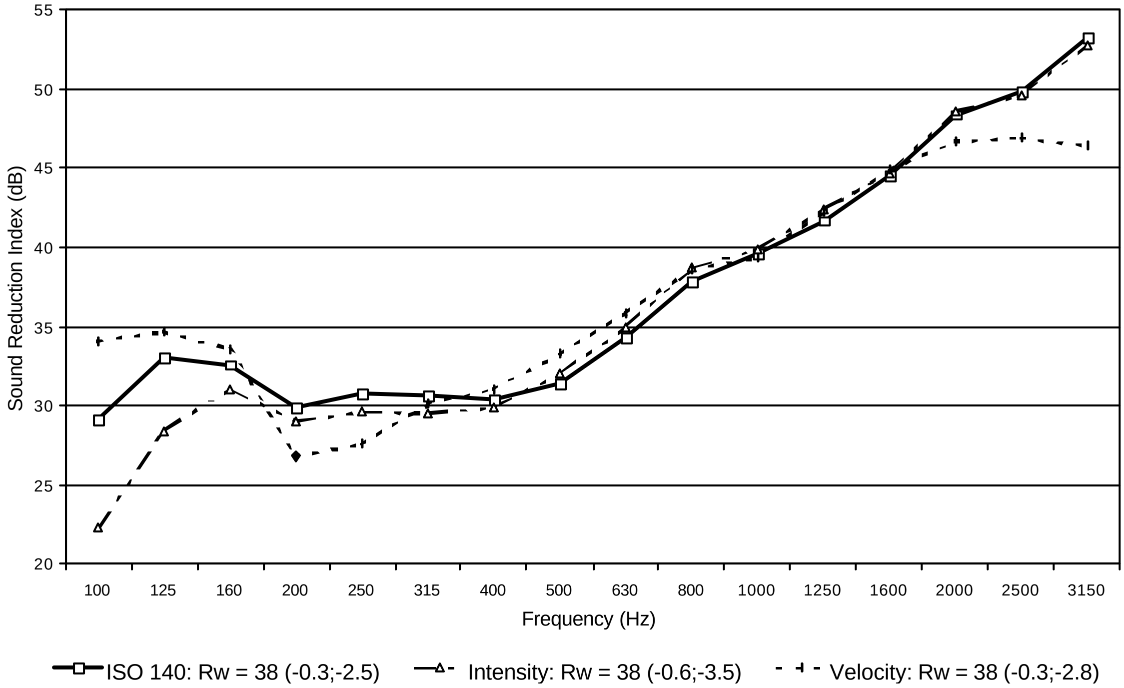

Figure 1: results of SRI measurements in the test wall, with the three techniques.

The results in terms of Rating of Sound Reduction Index, R_w, are identical for the three techniques, with some differences in spectrum adaptation terms.
The frequency analysis of the Sound Reduction Index points out a scattering of results in the low frequencies region, with lower values obtained with the intensity technique and greater values for the velocity techniques.
It is necessary to point out the difficulty in estimating the radiation factor of the wall around the critical frequency region that should be about 200 Hz. The values of the radiation factor of the tested wall, calculated according to annex A of EN 12354 – 1, are shown in table 1.

frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1 k	1.25 k	1.6 k	2 k	2.5 k	3.15 k
radiation factor	0.15	0.24	0.61	2.00	2.00	1.65	1.41	1.29	1.21	1.15	1.12	1.09	1.07	1.05	1.04	1.03

At the frequencies of 200 and 250 Hz, the limiting value of 2 has been given to the radiation factor, being the value calculated with equation (2) greater than this limiting value.
At high frequencies, the results obtained with the velocity techniques are lower than the other ones, probably because of the difficulties in creating a perfect junction between the accelerometer and the wall.

CASE STUDY: DOUBLE PARTITION WALL WITH AIRBORNE TRANSMISSION

The wall studied was realized with a double layer of 6 cm hollow bricks, plastered on the external sides, and with a 2 cm thick self-adhesive resilient layer in the internal cavity (figure 2).
The design of the double wall partition was optimized to have a high Sound Reduction Index values together with limited thickness and mass. For this reason, a resilient material with a low value of dynamic stiffness was chosen. In particular, a double layer of polyethylene with closed cells characterised by a dynamic stiffness of 20 MN/m^3 was inserted in the cavity of the double wall in order to have a low value of the mass – spring – mass resonance frequency..
In the connections between the partition and its flanking structures (lateral walls and floors), a thin strip of neoprene was inserted, in order to reduce the flanking transmission by realizing an elastic junction.
The Sound Reduction Index of the double wall was tested in the acoustic laboratory of the University of Padova.
After the realization of the double wall in the laboratory, the following two problems arose.

- A leakage opened along the junction line between the partition and the ceiling of the laboratory; this was probably due to the shrinking of the mortar between the bricks and to the fall of the resilient layer;
- the connection between the two layers of bricks was varied because of a little inflection of the layers and of the reduced adherence between them (assured by the self- adhesive strip of neoprene).

Because of these two problems, the Sound Reduction Index of the double wall was much lower than expected.

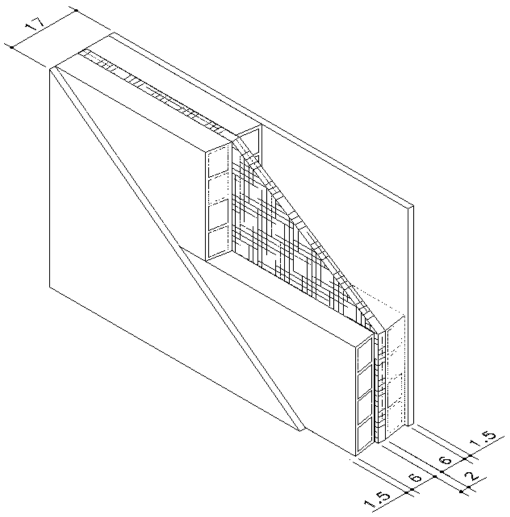

Figure 2: axonometric view of the double partition of the case study.

In particular, it was observed that a great amount of sound could pass through the leakage opened along the junction between the partition and the ceiling of the laboratory.
For this reason, after a preliminary test of the wall, the leakage was sealed with silicone and, as a consequence of this, the Sound Reduction Index of the partition greatly increased at high frequencies.
To better characterize the real performance of the double wall in the presence of structural and airborne transmission paths , measurements were carried out by means of both the traditional technique (based on ISO 140 – 3) and the vibration velocity technique, described in the previous paragraph.
In particular, results obtained by means of the vibration velocity technique are determined only by the structural transmission through the partition wall and not by the airborne transmission through the leakage nor by the structural flanking transmission through the lateral structures of the laboratory, though in any case this second form of transmission should be negligible. In fact, the laboratory of the University of Padova, being realized in accordance to ISO 140 – 1, is characterized by suppressed flanking transmission.

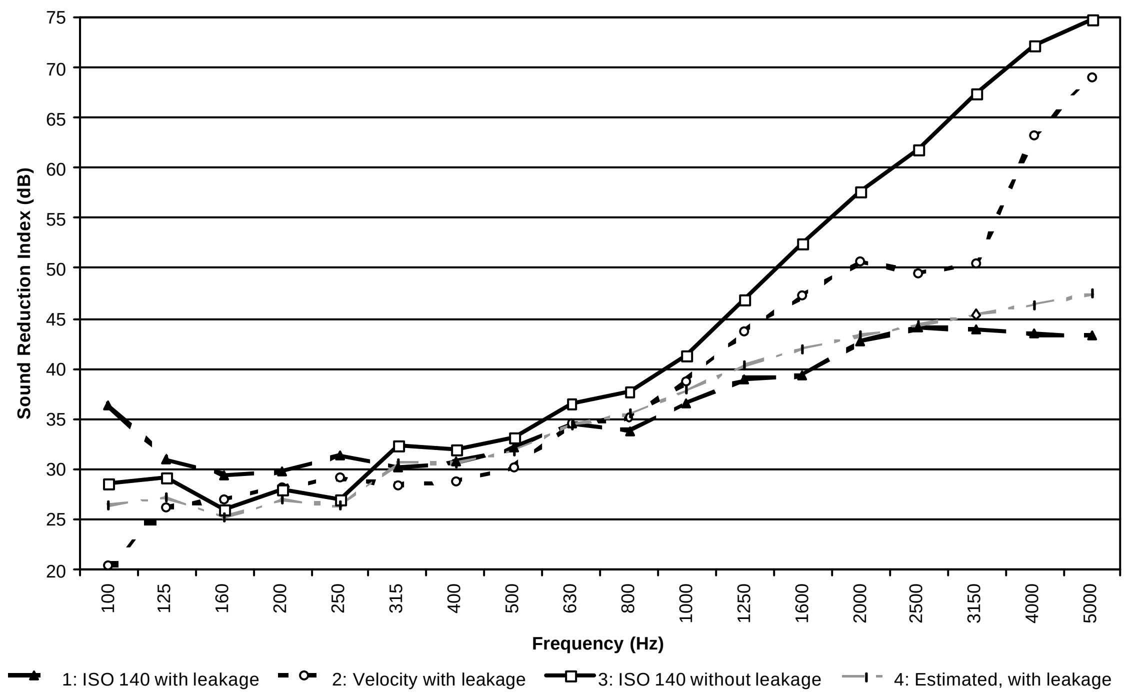

Figure 3:Sound Reduction Index of the partition with (1, 2) and without the leakage (3), measured with different techniques, and estimated (4).

Figure 3 shows the results obtained for the partition with the leakage in the upper edge with the traditional technique (1) and with the vibration velocity technique (2) and for the partition after the sealing of the leakage with silicone with the traditional technique (3).
The great influence of the leakage in the drop of insulation at high frequencies is clear.
Measurements carried out with the vibration velocity technique are not influenced by the transmission through the leakage, but are affected by two problems.
At lower frequencies, in correspondence of the critical frequency of the double wall (at about 80 - 100 Hz) there is a difficulty in the estimation of the radiation factor. In fact, at the coincidence, the radiation factor should assume very high values, but this effect can be attenuated by the damping of the structure.
At higher frequencies, there is probably a problem in the velocity measurement because of the difficulties in creating a perfect connection between the accelerometer and the wall plaster.
It is interesting to note that the results obtained before the sealing of the leakage (curve 1 in figures 3) can be well approximated by averaging the transmission of the partition without leakage (3) with the transmission of a leakage.
The Sound Reduction Index of the leakage, whose dimensions were about 4 mm wide x 3600 mm long, has been assumed to increase linearly with the frequency, with an increase of 3 dB per octave.
Curve 4 in figure 3 shows the result of the estimation of the Sound Reduction Index of the partition with a leakage characterized by the dimensions mentioned above.
It can be noted that the presence of a 4 mm wide leakage can produce a drop in the performance of the partition up to 25 dB at higher frequencies.
The comparison referring to the rating of Sound Reduction Index indicates a good agreement between estimated (R_w = 37.5 dB) and measured values (R_w = 37.3 dB).

CONCLUSIONS

The results of the comparison between the three measurement techniques of the Sound Reduction Index indicate a good agreement between the values obtained.
Though there are some difficulties in the measurements based on the intensity and on the vibration velocity, the case study analyzed shows the utility of these techniques in the

identification of particular problems of sound transmission.

In the case study presented, the opening of the leakage was mainly due to the crushing of the resilient layer put between the partition and the floor.

The neoprene resilient layer, whose purpose was the reduction of the flanking transmission between the partition and the floor, has therefore produced a negative result with reference to the acoustic performance of the wall. Therefore, it is important to evaluate all the structural and the acoustic consequences when using resilient layers in the junctions between partitions and lateral structures.

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[2] ISO/DIS 15186-1, Acoustics - Measurements of sound insulation in buildings and of buildings elements using sound intensity – Part1: Laboratory conditions

[3] EN 12354 – 1: Building acoustics - Estimation of acoustic performance of buildings from the performance of products, part 1: Airborne sound insulation between rooms;

[4] ISO/CD 10848 - 1, Acoustics - Laboratory measurement of the flanking transmission of airborne and impact noise between adjoining rooms, - part 1: frame document.