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EVALUATION OF FLANKING AIRBORNE SOUND TRANSMISSION INVOLVING INTENSITY AND VIBRATION MEASUREMENT TECHNIQUES FOR *IN SITU* CONDITION

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Abstract

Building structures can provide different flanking transmissions *in situ* condition compared to those in laboratory. Two different measurement techniques were used and compared for this paper. Both techniques measured the airborne sound insulation in buildings (between rooms) and evaluated the contribution of the partition wall and respective flanking walls. The Intensity measurement technique was used according to EN-15186-2. The Vibration measurement technique was used following some specifications of the EN-10848, this method is also evaluated as a procedure to be used instead of the Intensity technique. This paper reports the first results obtained by both techniques used *in situ* and estimates the overall flanking contribution for different types of junction in common Spanish buildings.

INTRODUCTION

In building acoustics the flanking sound transmission is a very important issue to evaluate the sound reduction index of walls and floors in our home. In this work we evaluate the airborne sound insulation of a wall between two rooms. In laboratory

conditions it is possible to produce the settings to obtain the flanking contribution of a specific joint, but in real circumstances we need to quantify these contributions without the laboratory environment and settings. In real situations we have sound radiating from all paths and it is important to have a procedure that can be easily implemented to quantify these flanking paths.

The aim of this work is to evaluate and compare the *in situ* apparent airborne sound insulation between two rooms obtained with three measurement procedures:

- ❖ Pressure method according with standard EN 10140-4 [3] ;
- ❖ Intensity method according with standard EN 15186-2 [4];
- ❖ Vibrations velocity method not standardized.

With the Intensity method it is possible to evaluate the apparent sound reduction index and compare it with the Pressure method, with the advantage of knowing the flanking contribution of each element of the receiving room, performing measurement with Intensity technique requires professional experience to achieve good results and needs particular attention on the arrangement of the receiving room, for instance, putting some sound absorbing material to reduce the influence of the reverberant field. It is also a method that spends much time and becomes tedious when it is necessary to measure all flanking surfaces. With the Vibration velocity technique the measurement procedure is faster with less cost and once implemented it does not need a highly skilled experience to set instruments and perform measurements and in theory it is possible to compute the contribution of each flanking element. However it requires a mathematical calculation of the radiation efficiency to compute the results. Several authors propose mathematical models, i.e. Novak [1], and more recently Davy [2]. The one used in this work was proposed by Rindell [5].

MEASUREMENT PLACE

The measurements took place in a structure built in the seventies and was used till a few years ago as a superior school.

Room characteristics

The source room dimensions are 6,80x 9,70x3,01 [m] and a volume of 181 [m³] in Figure 1 is shown a partial view of this room with the main separating wall. The receiving room dimensions are 4,18x3,71x3,02 [m] corresponding a volume of 43,8 [m³]. All lateral walls are built of bricks and finalized with a concrete (mortar or plaster) layer on each side, the total thickness is 115 [mm] with approximately 90 [Kg/m³]. The critical frequency is approximately 175 [Hz]. The ceiling is composed by beams, compression layer and finalized with a paving-tile on the superior part, with an overall thickness of about 370 [mm] and density of approximately 400 [Kg/m²] corresponding to a critical frequency less than 100 [Hz].

Type of junctions

The connections between the source room and the receiving room are made by simple rigid T junctions in vertical and horizontal connections. Although there is one particular vertical connection made probably with a double layer wall with 300 [mm] of thickness plus 115 [mm] of our single wall and is not extended to all length, but with low influence in the final performance compared to a single layer wall.



Figure 1- Partial view of source room

Measurement conditions

The main transmission path or direct path is the separating element between the two rooms, the wall dimensions are 4,18x3,02 [m] corresponding to an area of 12,62 [m²] and a thickness of 115 [mm].

IN SITU MEASUREMENTS

Pressure measurements

The equipment used in this work was for the pressure measures, the dual-channel real time frequency analyzer B&K type 2144 with an octahedral sound source, a sound level calibrator B&K type 4231 and a microphone B&K type 4190. The data was post-processed by the software B&K “Building acoustic program” WT9343 Ver.1.71 (1992).

Measurements were made using procedures of the standard EN ISO 10140-4 [3]. The sound pressure measured in the source room was used for the Intensity and Vibrations calculations.

Intensity measurements

For the intensity measures, the same equipment was used as for the pressure method and additionally the sound intensity p-p probe B&K type 3520 modified to a more recent model, with sound intensity microphone pairs B&K type 4181. For the calibration procedure the sound intensity calibrator B&K type 3541 was used.

All the measurements were made in 1/3 octave bands, between 100 and 3.150 [Hz]. Measurement conditions must be satisfactory and in accordance with the requirements of the standards EN ISO 15186-2 [4] and EN ISO 9614-2 [6].

Measurement scans were of 1 minute each (maximum) and the surfaces were divided in 9 or 12 sub-areas, depending on the surface dimension, in the Figure 2 is shown a partial view of the separating element from the receiving room point of view with the sub-areas division (12 sub-areas).



Figure 2 – Partial view of receiving room

The calculation of the sound reduction index R'_I for the separating element was done using the equation present in the standard EN ISO 15186-2 [4].

The apparent sound reduction index R'_I with the contribution of all the flanking walls is obtained by the equation (1) also present in the EN ISO 15186-2 [4] annex C. The Waterhouse correction factor K_c was also computed in the final results.

$$R'_I = \left[L_{p1} - 6 + 10 \log \left(\frac{S}{S_0} \right) \right] - 10 \log \left[\sum_j S_{M_j} 10^{\frac{\bar{L}_j}{10}} \right] + K_c \quad [dB] \quad (1)$$

Vibration measurements

The equipment used for vibration measurements was composed by real-time analyzer B&K type 2144; two charge accelerometers of B&K. model type 4384. The accelerometers were connected with bee wax to the wall. An accelerometer calibrator

from B&K. model type 4294 was also used. The accelerometers were calibrated before each measurement and using a reference acceleration of 10^{-6} [m/s²]. The measurement procedure for this vibration method used some of the criteria suggested in the standard prEN ISO/DIS 10848-1 [8].

There are a total of 12 measurement positions, randomly distributed over the entire surfaces, in Figure 2 some accelerometers positions for the separating element are shown. The measurement time for each position was of 60 [s] and all the measures were taken in steady-state conditions. All data was acquired in acceleration values with the real-time analyzer and then post-processed to vibration velocities calculated with a reference velocity of 5×10^{-8} [m/s] with Microsoft ExcelTM sheet.

To compute the power level radiated by the surface the equation (2) developed by Cremer in [7] was used.

$$L_{w_v} = L_v + 10 \log(S) + 10 \log(\sigma) \quad [dB] \quad (2)$$

Where S is the area of the surface and σ is the radiation efficiency. The radiation efficiency can be estimated for random incidence with the equation (3) given by Rindell in [5]:

$$\sigma = \frac{1}{2} [0,20 + \log(k \cdot e)] \quad (3)$$

Where k is the wave number and e is a characteristic dimension of the surface and is determined from $e=4S/U$, where S is the area and U is the perimeter. This equation is independent from the critical frequency of the element.

As an example, the following table shows the radiation efficiency calculated using equation (3) for the separating element.

Table 1 – Radiation efficiency for the separating element in one third octave frequency bands

Freq	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150
σ	0,5	0,5	0,6	0,6	0,7	0,7	0,8	0,8	0,9	0,9	1,0	1,0	1,1	1,1	1,2	1,2

The apparent sound reduction index R'_v for vibrations measures and for the separating element is calculated with the equation (4).

$$R'_v = \left[L_{p1} - 6 + 10 \log \left(\frac{S}{S_0} \right) \right] - L_{w_v} \quad [dB] \quad (4)$$

Where L_{p1} is the sound level in the source room, S is the separating element area and S_0 is the reference area of 1 [m²].

The apparent sound reduction index R'_v , where all the flanking surfaces are added is obtained using equation (5), similar to the one used by the Intensity method, in this case without the Waterhouse correction factor K_c .

$$R'_V = \left[L_{p1} - 6 + 10 \log \left(\frac{S}{S_0} \right) \right] - 10 \log \left[\sum_j S_{M_j} 10^{\frac{\bar{L}_{v_j}}{10}} \right] \quad [dB] \quad (5)$$

RESULTS AND CONCLUSIONS

The results obtained by the three previously detailed methods are now shown and compared. The apparent sound reduction index calculated by both methods, Intensity and Vibration velocity, for the separating element, is shown in Figure 3.

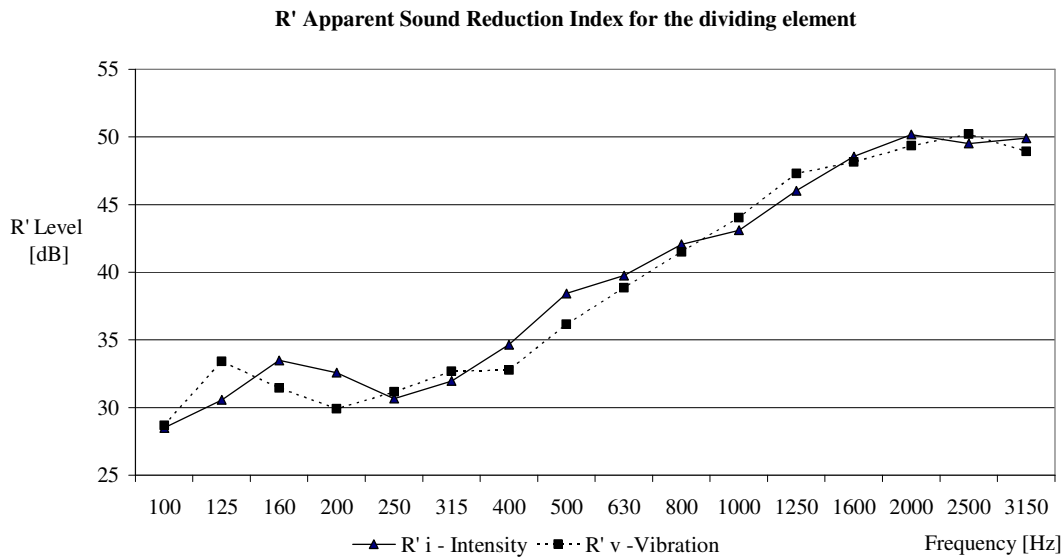


Figure 3 – Separating element sound reduction index

Figure 4 shows the apparent sound reduction index calculated by the three methods described in this experiment, and including the contribution of all flanking elements. The slope representing the Pressure method apparent sound reduction index R' , obtained according the standard EN ISO 10140-4, was performed without shielding any flanking surfaces.

As it can be seen, the curves follow each other rather well. The R'_I curve (Intensity method) shows at low frequencies a small divergence. This can be partially due to the fact that the sound probe spacer that we have used is not very suitable for low frequencies.

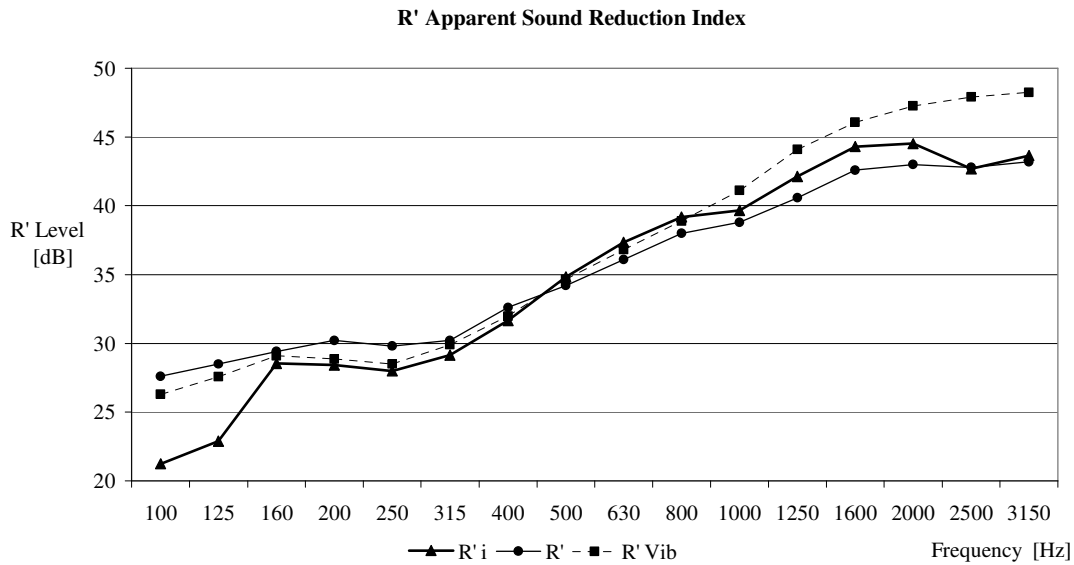


Figure 4 – Apparent sound reduction index for the three methods

Besides, the sound direction obtained with the sound probe at low frequencies is very instable. To obtain better results at low frequencies it is recommended to use a bigger receiving room, to create a better sound diffuse field at low frequencies, but as we were measuring in situ this could not be done.

The Pressure method presented lowest values of R' between the 1000 and 2000 [Hz], but with small difference, what is not expected (in all the frequency range) because it is believed that the Intensity method measures better the contribution of the flanking elements than the Pressure method and therefore the sound reduction index for Pressure method should produce higher values, although the results for Intensity method were computed including the Waterhouse “correction factor”, but at middle and higher frequencies this has not much influence, even thought, the curve is more similar to the Vibration velocity curve without this correction factor. The Vibration velocity curve follows the Intensity curve rather well down to 1000 [Hz], but above this frequency it shows higher values, corresponding to a better sound reduction. This is possibly not correct and the justification is that the accelerometers are measuring values near the background noise levels and the values obtained by the accelerometers for the ceiling and floor are very near the noise levels above the 800 [Hz].

In terms of elements flanking contribution for the sound reduction index the Intensity and the Vibration velocity methods produce similar results showing that the main flanking contribution element is the lateral wall with door and the second is the other lateral wall. Both methods confirm that the ceiling has a low flanking contribution, followed by the floor element. To finalize it must be said that the Intensity method requires twice as much the time spend to complete all the measures than the Vibration Velocity method.

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