Influence of flanking transmission in typical Italian constructions

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Actually acoustic performance of building components are analyzed with reference to standardized conditions, in laboratories with suppressed flanking transmission. Laboratory results still often show values of the performances quite different from those measured in real buildings, as a consequence of flanking transmission and/or of different conditions of realization in situ.
Moreover, in spite of all efforts aimed to standardize laboratory test conditions, it's quite easy to find different certified performances of same building components obtained in otherwise laboratory. In some cases, these differences may be very relevant.
Besides, the Italian decree on acoustic requirement of buildings prescribes limiting values to be measured in situ.
For these reasons, many producers of building materials and components more frequently present in their depliants both laboratory values and in situ values of acoustic performances of their products.
The paper shows the preliminary results of an research aimed to verify acoustic performances of partition walls and floors in a laboratory which respect conditions of ISO 140-1, but with the presence of relevant flanking transmission, similar to stock buildings.
The relevance of the flanking transmission has also analyzed by means of a lining applied to the ceiling of the receiving room of the laboratory.

1 Introduction

The research presented in this paper is aimed to verify the typical difference between laboratory and in situ measurements of Sound Reduction Index (SRI), with particular reference to the Italian stock building.

The apparent SRI (R') may be estimated by means of the calculation model defined by the European standard 12354, part 1 [1]. This model cannot take count of many details of the constructions, such as the presence of pillars in the junction between partition wall and flanking structures, or the direction of the beams of the floors.

A particular laboratory for the measurement of apparent sound reduction index has been realised in collaboration with a textile factory with the aim of investigate the relevance of flanking transmission and typical defects of the constructions.

2 Description of the laboratory

The experimental laboratory has been realised inside an existing factory of textile products near Florence.

The two reverberant rooms of the laboratory are characterized by volume of 40,5 m^3 (room A) and 43,7 m^3 (room B) in the basic configuration, with a partition wall 0,15 meter thick (Fig.1). With thicker test walls, the difference between the volumes of the rooms increases.

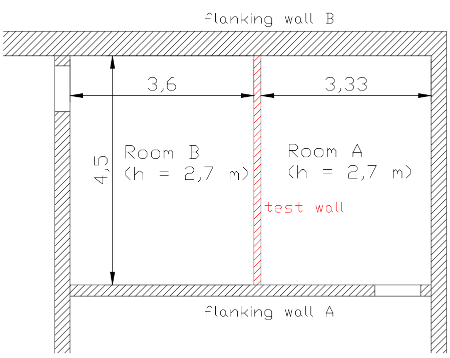

Fig.1 The experimental laboratory in its basic configuration.

Flanking walls and floors of the laboratory are rigidly connected to the partition wall (under test) and made of hollow bricks and blocks, without pillar or beams in the junctions. The characteristics of these flanking structures have been defined considering typical buildings realised in Italy, with relevant flanking transmission.

In particular, the flanking wall A (Fig.1) has been realized with the hollow bricks of Fig.2, plastered with mortar 1 cm thick on both sides. The surface mass of this wall is approximately 170 kg/m^2.

Fig.2 The brick of the flanking wall A (on the left) and the whole wall during the realization (on the right).

The ceiling of the laboratory has been realised with tile – lintel floor laid parallel to the partition wall (Fig.3). The surface mass of ceiling is approximately 240 kg/m^2.

Fig.3 The blocks of the ceiling (on the left) and the whole tile-lintel floor during the realization (on the right).

Both the flanking wall B (Fig.1) and the floor of the laboratory have been realised with heavy structures in such a way to produce a little structure flanking transmission between the source and the receiving rooms.

The doors of the source and of the receiving rooms have been realised in walls not adjoining each other (Fig.1) to reduce the airborne sound transmission between the rooms.

3 The measurement method

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

- the traditional method defined by ISO 140 – 3 [2];
- the method based on the vibration velocity of the structures [3].

According to ISO 140-3, 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. The results of these measurements are expressed as Apparent SRI (R').

With the method based on the measurement of the vibration velocity of the structures, it is possible to determine both the SRI of the partition (for direct transmission only, R_d) and the Flanking SRI through the four structural flanking paths (R_{ij}, two paths through the flanking walls ant two paths through the flanking floors). With this method, which gives results that depend only on the structural transmission through the partition and the lateral walls and not on any airborne path, it is necessary to measure the average velocity of vibration of the partition wall and the Sound Pressure Level in the source room. 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 [1]

In particular, in the case of free bending waves, the radiation factor is a function of the frequency and of the critical frequency and the dimensions of the radiating structure. According to Vér [4], for frequencies greater than 1,3 times the critical frequency f_c, the radiation factor σ is due only frequency f and f_c, and converges to unity at high frequencies (Eq.(1)).

$$\sigma = \frac{1}{\sqrt{1-\frac{f_c}{f}}} \qquad (1)$$

Below the critical frequency, the radiation factor is due also of the critical wavelength of the surface area and the perimeter of the plate [1].

According to Eq.(1), the determination of radiation factor at frequencies near the critical frequency can be difficult, because it tends to assume very high values. For this reason in ref. [1] a limiting value of 2 is assigned.

The critical frequency f_c, may be evaluated with Eq.(2).

$$f_c = \frac{c^2}{1.8 c_L t} \ \text{(Hz)} \qquad (2)$$

where:

c is the speed of sound in air (m/s);
c_L is the speed of longitudinal waves in the plate (m/s);
t is the thickness of the plate (m).

The determination of these properties for brick walls is quite complex.

In the case of masonry blocks, in ref. [5], the value of 23,200 is given to the product of critical frequency, f_c, and surface mass , m'.

The Sound Reduction Index of the partition (R_d), for direct structural transmission, can be calculated according to Eq.(3).

$$R_d = 10\lg\left(\frac{\Pi_i}{\Pi_{rad}}\right) = 10\lg\left(\frac{\langle p_s^2\rangle}{4\rho_0^2 c_0^2 \langle v_d^2\rangle \sigma}\right) \qquad (3)$$

where:

σ is the radiation factor;
$\rho_0 c_0$ is the specific impedance of air (kg/m^2·s);
$\langle v_d^2\rangle$ is the spatial average of the squared vibration velocity of the partition (m/s)^2;
$\langle p_s^2\rangle$ is the spatial average of the squared sound pressure in the source room (Pa)^2.

With reference to Fig.(4) (left), the SRI R_d takes count of the structural direct transmission (Dd) through the partition and of flanking transmission path F-d.

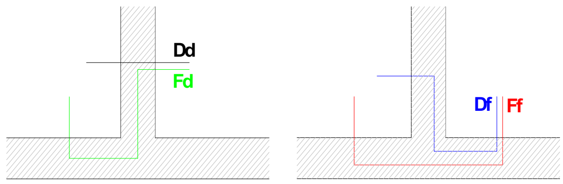

Fig.4 The structural direct and flanking transmission paths.

The SRI of the partition (R_f), for flanking structural transmission (paths Df and Ff of Fig.(4), on the right), can be calculated according to Eq.(4).

$$R_f = 10\lg\left(\frac{\langle p_s^2\rangle}{4\rho_0^2 c_0^2 \langle v_f^2\rangle \sigma}\right) \qquad (4)$$

where:

$\langle v_f^2\rangle$ is the spatial average of the squared vibration velocity of the flanking structure (m/s)^2.

The Apparent SRI R' can be finally evaluated by adding the direct path to all flanking paths with Eq.(5).

$$R' = -10\lg\left\{10^{-\frac{R_d}{10}} + \sum^{4} 10^{-\frac{R_f}{10}}\right\} \qquad (5)$$

4 Instrumentation used

Measurements of acceleration levels were carried out by an accelerometer (Brüel & Kjær type 4371), with a charge amplifier (Brüel & Kjær type 2635) and spectrum analyser (01 dB Symphonie) with processing software (01 dB Bati).

The accelerometer was fixed to the partition and to flanking structures (walls and ceiling) by bees wax.

The number of measurement positions was between 10 and 20 for each wall or ceiling.

5 Results

Three walls were tested in the experimental laboratory.

All paths of structural flanking transmission were determined by measuring the vibration velocity of the partition and of all flanking structures of receiving room; the flanking transmission through lateral wall B of Fig.(1) and through floor resulted negligible. This is due to the great surface mass of these flanking structures.

For this reason and to simplify the graphs, in Fig.6, Fig.8 and Fig.10 only the results for direct transmission and for flanking paths through lateral wall A (fig.1) and ceiling are shown.

All results are base on Eq.(3), for direct transmission, and Eq.(4), for flanking transmission.

The radiation factor was assumed equal to the unity at all frequencies because of the difficulty to estimate the critical frequency of flanking structures.

5.1 Wall A

Wall A was realized with hollow bricks 12 cm thick (Fig.5, on the left) plastered with mortar 1 cm thick on both sides and covered with absorbing material 3 cm thick (recycled textile fibre) and with two layers of plasterboard 1,25 cm thick each one (Fig.5, on the right).

The supporting structure of the plasterboard was not fixed to the basic partition but only on lateral walls and floors.

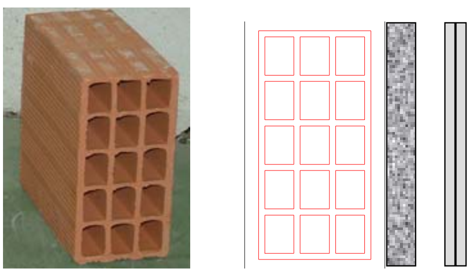

Fig.5 The hollow brick for the masonry of wall A (left) and the whole wall (right).

Results for SRI measurements based on the velocity vibration of partition and of flanking wall A and ceiling are shown in Fig.6.

According to ISO 717-1, ratings of SRI were:

$R_{w,d}$ = 49 dB;
$R_{w,f,wall}$ = 56 dB;
$R_{w,f,floor}$ = 51 dB.

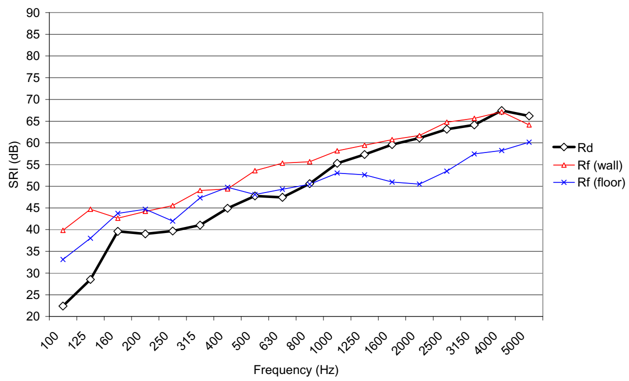

Fig.6 Comparison between direct and flanking paths for wall A.

5.2 Wall B

Wall B (Fig.7, on the right) was realized with the same hollow bricks of the wall A, but with two layers of absorbing material 3 cm thick on one side (recycled textile fibre), one layer of plasterboard 1,25 cm thick and another wall realized with hollow bricks 8 cm thick plaster on the external side (Fig.7, on the left).

Fig.7 The hollow brick for the second masonry of wall B (left) and the whole wall (right).

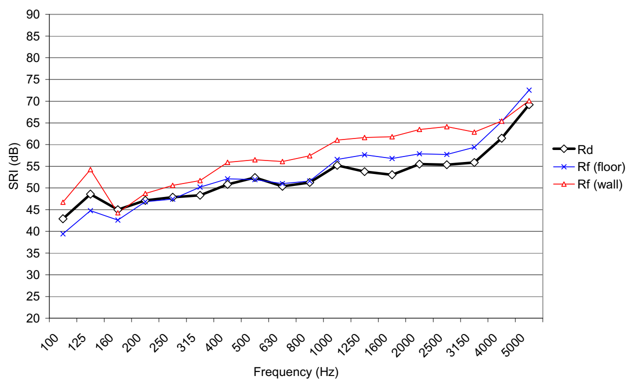

Fig.8 Comparison between direct and flanking paths for wall B.

Results are shown in Fig.8 and the ratings of SRI were:

$R_{w,d}$ = 53 dB;
$R_{w,f,wall}$ = 59 dB;
$R_{w,f,floor}$ = 55 dB.

5.3 Wall C

Wall C (Fig.9) was realized with the same hollow bricks as wall A, but with one layer of absorbing material 3 cm thick (recycled textile fibre) and two layers of plasterboard 1,25 cm thick on both sides.

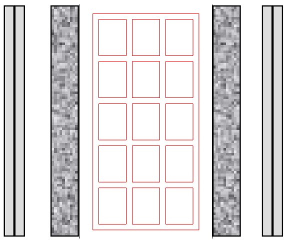

Fig.9 The wall C.

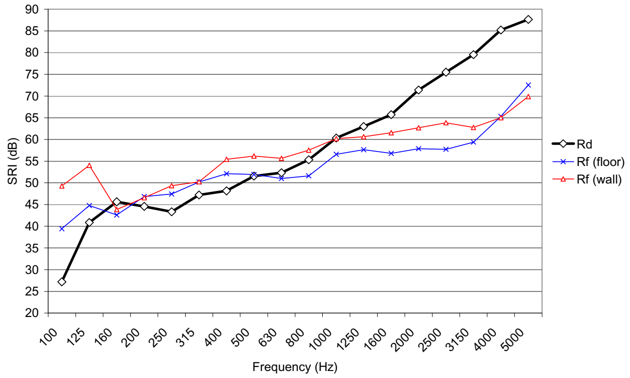

Fig.10 Comparison between direct and flanking paths for wall C.

Results are shown in Fig.10 and the ratings of SRI were:

$R_{w,d}$ = 54 dB;
$R_{w,f,wall}$ = 59 dB;
$R_{w,f,floor}$ = 55 dB.

6 Comparison between the methods

Fig.11 to Fig.13 show the comparisons between results of apparent SRI measured according to ISO 140-3 [2], and obtained with Eq.(5) by adding the results of direct and flanking transmission ($R'_{velocity}$).

In Eq.(5) all flanking transmission paths (two paths through the flanking walls and two through the flanking floors) are considered.

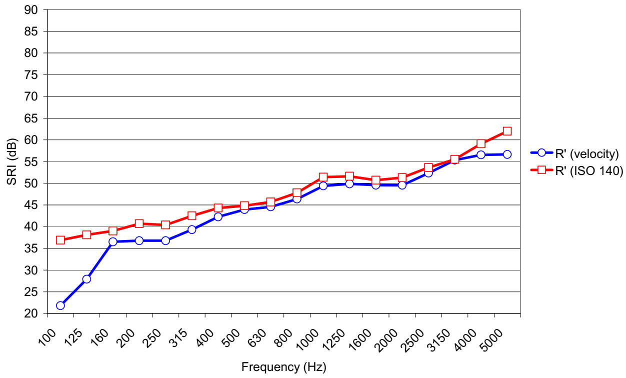

Fig.11 Comparison between results of apparent SRI for measurements based on ISO 140 and on the vibration velocity for wall A.

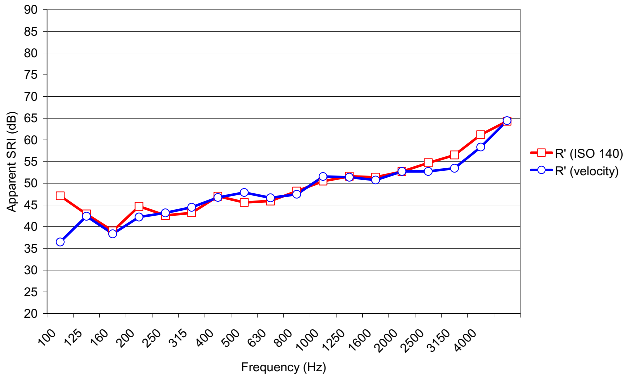

Fig.12 Comparison between results of apparent SRI for measurements based on ISO 140 and on the vibration velocity for wall B.

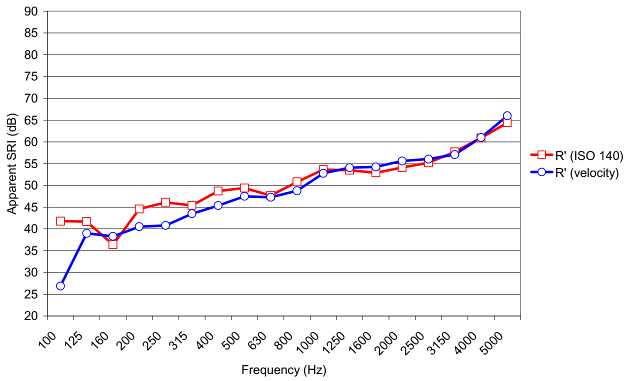

Fig.13 Comparison between results of apparent SRI for measurements based on ISO 140 and on the vibration velocity for wall C.

Results show relevant differences at frequencies below 160, probably due to difficulties in estimating the radiation factor at frequencies below the coincidence.

According to ISO 717-1, ratings of direct and flanking SRI and of Apparent SRI are reported in Table 1.

Type	Wall A	Wall B	Wall C
$R_{w,d}$	49	53	54
$R_{w,f,wall}$	56	59	59
$R_{w,f,floor}$	51	55	55
$R'_{w\ (vibration)}$	46	50	50
$R'_{w\ (ISO\ 140)}$	49	50	52

Table 1 Comparison among results.

Further measurements, not reported in this paper, have shown that by adding a suspended ceiling in the receiving room, and increasing of about 2 dB in apparent SRI (R') can be achieved. This fact confirms that the greater path of flanking transmission, in the cases examined, is due to the junction with the ceiling. In several cases, where there is a beam in this junction, this path of flanking transmission can be less relevant.

7 Conclusion

The study has pointed out that with typical Italian construction it is really hard to have high values of Apparent SRI because of the great relevance of structural flanking transmission. An upper limit of 50 – 52 dB of R'_w is usually due to these flanking paths.

Only using linings on some flanking structures (normally the ceiling and the lighter flanking walls) it should be possible to have values of Apparent SRI (R') greater than 52 – 53 dB, as required in some cases by Italian and other countries regulations.

Results of two method of measuring the Apparent SRI show a fairly good accordance.

The differences in rating of Apparent SRI for wall A and C are due to the differences between the models at lower frequencies, in particular at the frequency of 100 Hz. This is due to the difficulty in estimating the real value of the radiation factor for the partition and the flanking structures at frequencies below the coincidence.

Acknowledgments

Authors wish to thank "Manifattura Maiano" that has realized the laboratory and founded the research.

References

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