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Acoustical proprieties of light brick walls and its effects on flanking transmission

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Light brick walls 8-10 cm thick are typical structures frequently used in Italian building constructions as a internal partitions between dwellings and as internal layer of double façade walls. Due to low surface mass and rigid connection to other horizontal and vertical structures, light brick walls are often responsible of high flanking transmission.

The simplest acoustic modelling of this structure for the evaluation of sound transmission in buildings, is the approach proposed by the EN 12354 standards, where the brick wall can be considered as a homogeneous structure and required main acoustic parameters are the sound reduction index and the vibration reduction index K_{ij} .

The aim of this paper is to analyse results of physical and acoustical properties (like sound reduction index, structural reverberation time, longitudinal wave velocity) of a typical 8 cm thick brick wall measured in laboratory testing facility.

1 Introduction

Hollow brick walls are widely used in Italian buildings as a simple partition between rooms or as internal layer of an external multi-layer wall. In the first case the structure is plastered on both sides, while in the latter is one-side plastered. Acoustic parameters for both configurations are expected widely different due to important effect of the cement plaster layer on both surface mass and internal damping of the wall. The effect of this kind of structure as a lateral wall connected to an heavy partition has also been tested in laboratory test facility, in order to evaluated the effect of T junction flanking transmission. Experimental data have then been compared with calculation method of the EN 12354-1 [1] standard.

2 Test specimen

The light hollow brick wall was built in a laboratory test facility. Block dimensions are 8x25x25 cm; inside these bricks there are 10 holes of 4.5x2.7x25 cm dimensions.

The first configuration of the wall (named wall “A”) has been built connecting horizontally and vertically bricks with cement mortar and finished on only one side with cement plastering (1700 kg/m³) of 1.5 cm thick.

The wall surface mass, measured on a 1 m² specimen is 72 kg/m².



Figure 1: Hollow brick



Figure 2: wall “A” test configuration.

Afterwards the wall (named B) has been plastered on the other side, giving a wall surface mass of 97 kg/m².

3 Experimental results

The laboratory apparent sound reduction index, R_w , have been calculated according to EN ISO 140-3 [2] e EN 717-1 [3], giving the value of $R_w=33$ dB for the test wall “A” and $R_w=37$ dB for the test wall “B”.

Frequency results of the sound reduction index for both configuration is showed in figure 3.

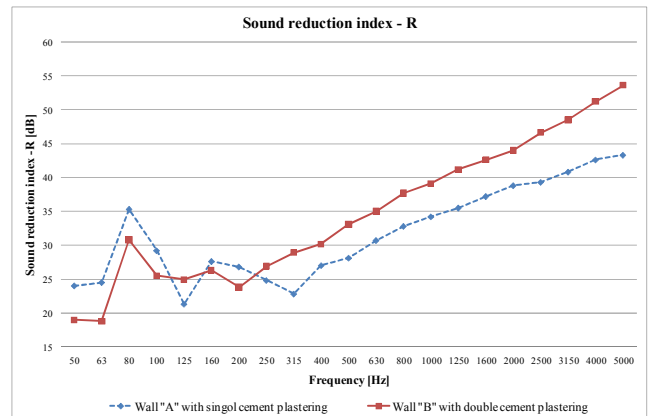


Figure 3: Sound reduction index R of both test walls

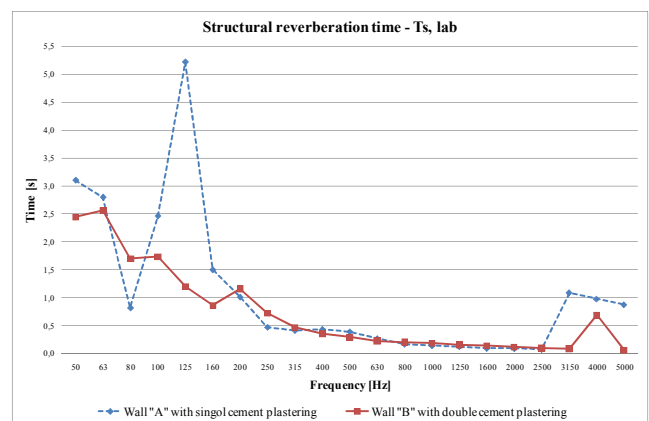


Figure 4: Structural reverberation time $T_{s,lab}$ of both test walls.

The mean structural reverberation time (obtained from 12 accelerometer position for 3 impact hammer positions) measured by the impulsive technique in accordance with Schroeder method [4] is shown in figure 4.

The structural reverberation time at high frequencies (2500 – 3150 Hz) of wall “A” and “B” presents peaks due to resonance modes of the holes brick cavity. In fact using the formula determining natural mode for 3-D systems:

$$f_n = \frac{c}{2} \sqrt{\left(\frac{n_x}{l_x}\right)^2 + \left(\frac{n_y}{l_y}\right)^2 + \left(\frac{n_z}{l_z}\right)^2} \quad (1)$$

and inserting as input data the real dimensions of holes bricks, we obtain the first resonance frequency at $f_n=3382$ Hz.

Total loss factor are: $\eta_{tot} = 0.013$ for test wall “A” and $\eta_{tot} = 0.012$ for test wall “B”.

Longitudinal wave speed are very different: $c_L = 3124$ m/s for test wall “A” e $c_L = 2100$ m/s for test wall “B”.

4 Flanking transmission effects

A following test was performed in order to evaluated the structural flanking transmission of the light brick wall strong coupled with an heavy partition characterized by a double brick wall (8x25x50 cm), with a rock-wool panel (80 kg/m³) inside the 5 cm cavity. The total surface mass of the partition is 290 kg/m².

The sound reduction index of the measured partition in the same laboratory, with flanking transmission suppressed, is $R_w = 52$ (-1, -4) dB, according to EN ISO 140-3 e EN 717-1.

Thereafter a single brick wall (8 cm) plastered on one side was built perpendicularly to the partition, forming an “T” junction, in order to determine the vibration reduction index K_{ij} , according to standard ISO 10848:2006 [5]. Both acoustical and vibration measurements were performed in order to compare different methods.

The test analysed configuration was a “T” junction between the partition “i” and the 8 cm lateral wall “j” that was built from the source and the receiving room (figure 5). This is a typical situation that occurs in Italian buildings where the external façade is realised with a double leaf brick wall where the internal side is the light element rigidly connected to internal partitions of the building. In this way the light continuous wall (element “j”) causes an high flanking sound transmission.

Table 1 shows the results of the measured sound transmission index R_w of the single partition without flanking transmission, and the measured apparent sound transmission index R'_w of the partition with the flanking transmission (“T” junction). Flanking transmission effects was considerable, and the reduction of the sound transmission index was of 8 dB. This results depends also on particular configuration of the lateral walls that are heavy connected only on the floor and on the partition, while the other two sides are disconnected from the laboratory test specimen.

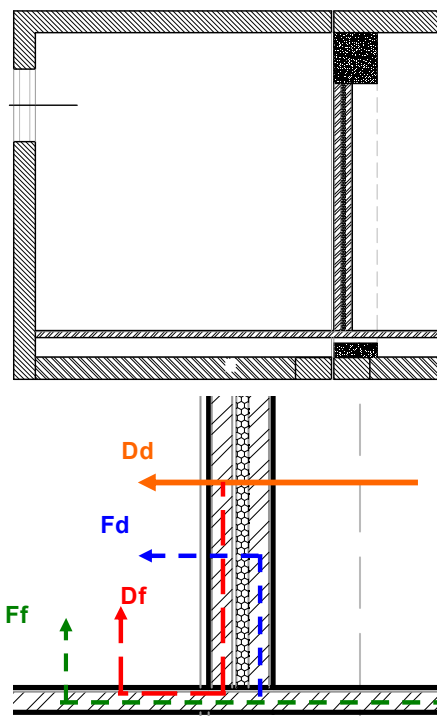


Figure 5 – “T” junction (second test configuration) and sound transmission paths “ij” between two rooms

Testing wall	Junction	R_w (R'_w)
Partition (8+5+8)		52
Partition (8+5+8) + 2 lateral wall (8)	“T”	(44)

Table 1 – (Apparent) Weighted Sound reduction index R_w (R'_w)

4.1 Vibration reduction index K_{ij} and calculation of apparent sound reduction

The estimation of apparent sound reduction according to CEN model specified in EN 12354-1 gives the single number rating involved in the sound transmission between two rooms, with the following expression:

$$R' = -10 \lg \left(10^{-\frac{R_{Dd}}{10}} + \sum_{F=1}^n 10^{-\frac{R_{Ff}}{10}} + \sum_{f=1}^n 10^{-\frac{R_{Df}}{10}} + \sum_{F=1}^n 10^{-\frac{R_{Fd}}{10}} \right) \quad (2)$$

where:

$R_{Dd,w}$ is the weighted sound reduction index for direct transmission, in decibels ;

$R_{Ff,w}$ is the weighted flanking sound reduction index for the transmission path Ff, in decibels ;

$R_{Df,w}$ is the weighted flanking sound reduction index for the transmission path Df, in decibels ;

$R_{Fd,w}$ is the weighted flanking sound reduction index for the transmission path Fd, in decibels ;

n is the number of flanking elements in a room; normally $n=4$, but it can be smaller or larger depending on the design and construction of the considered situation.

From apparent sound reduction (for every frequency band) is possible to determine the sound reduction index R'_w of the test wall according to EN ISO 717-1 method.

We can obtain the terms of the expression (2) by the following formulas:

$$R_{Dd} = R_{s,situ} + \Delta R_{D,situ} + \Delta R_{D,situ} \quad (3)$$

$$R_{ij} = \frac{R_{i,situ} + R_{j,situ}}{2} + \Delta R_i + \Delta R_j + K_{ij} + 10 \log \frac{S}{l_0 \cdot l_{ij}} \quad (4)$$

where

$R_{i,situ}$ ed $R_{j,situ}$ are sound reduction index of element i and j in the actual field situation;

ΔR_i e ΔR_j are sound reduction index improvement by additional layers for element i and j ;

K_{ij} is vibration reduction index for each transmission path ij over a junction;

S is area of separating element;

l_{ij} is common coupling length between element i and element j;

l_0 is reference length (= 1 m).

In this case the ΔR terms are null, while lateral transmissions path considered are only Df, Fd and Ff.

The relations for vibration reduction index for each transmission path ij over a junction has been calculated as function of the surface masses (m' e m'^{\perp}) making the junction with the following expression cited in EN 12354-1:

$$M = \log \frac{m' \perp}{m'} \quad (5)$$

and with relationships included in annex E in the same standard. In this case the two expressions used for "T" junction are:

$$K_{ij} = 5,7 + 5,7 * M \quad (6)$$

and for Df and Fd paths and

$$K_{ij} = 5,7 + 14,1 * M + 5,7 * M^2 \quad (7)$$

for Ff path.

The value of the index of reduction of the vibration K_{ij} for a determined configuration of joint among two structures perpendicularly connected, can be nevertheless evaluated experimentally according to the methodology reported in the ISO 10848 standard on the base of the following expression:

$$K_{ij} = \overline{D}_{v,ij} + 10 \log \frac{l_{ij}}{\sqrt{a_i \cdot a_j}} \quad (8)$$

where $\overline{D}_{v,ij} = \frac{D_{v,ij} + D_{v,ji}}{2} \quad (9)$

$D_{v,ij}$ and $D_{v,ji}$ are the differences of the average levels of vibration velocity in the two structures, respectively in the direction ij and in that ji [dB].

l_{ij} is the length of the junction under test: 3.00 [m];

a_i and a_j are, respectively, the lengths of equivalent absorption of the elements i and j [m].

The terms a_i and a_j are calculated with the following expression:

$$a_{i,j} = \frac{2.2 \cdot \pi^2 \cdot S_{i,j}}{c_0 \cdot T_{si,j}} \sqrt{\frac{f_{ref}}{f}} \quad (10)$$

S_i is the area of the element i, 10.2 [m²];

S_j is the area of the element j, 11.5 [m²];

T_s is the structural reverberation times [s];

c_0 is the speed of the sound in the air, 340 [m/s];

f is the current frequency [Hz];

f_{ref} is the frequency of reference, 1000 [Hz].

The average vibration velocity levels and the structural reverberation times have been evaluated by using impulsive sources (steel hammer 500 g). [6] [7]

4.2 Results

Experimental results related to the weighted sound reduction index are compared with those obtained by the analytical model of the EN 12354-1 standard (detailed method in frequency).

As input data in the formulas (3) and (4) the weighted sound reduction index measured in the laboratory of the partition and the lateral walls have been used. The surface masses have been evaluated by a direct measure on a small test wall (1 m²).

The K_{ij} values have been evaluated by means of experimental measurements determined through the (8) and of calculation according to the ratio between the masses and to the type of joint according to the expressions (6) and (7).

Testing wall	K_{ij}	$T_{s,situ}/T_{s,lab}$	R'_w
Partition (8+5+8) + 2 wall (8)	measured		44
Partition (8+5+8) + 2 wall (8)	EN 12354	No	47
Partition (8+5+8) + 2 wall (8)	EN 12354	Yes	45
Partition (8+5+8) + 2 wall (8)	laboratory	No	47
Partition (8+5+8) + 2 wall (8)	laboratory	Yes	44

Table 2 – (Apparent) Weighted Sound reduction index R'_w

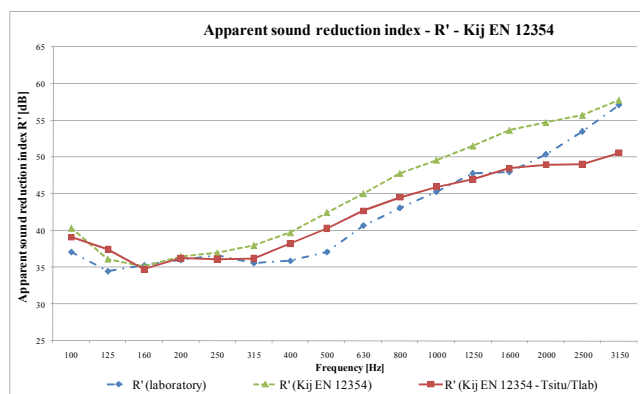


Figure 6: Comparison of apparent sound reduction

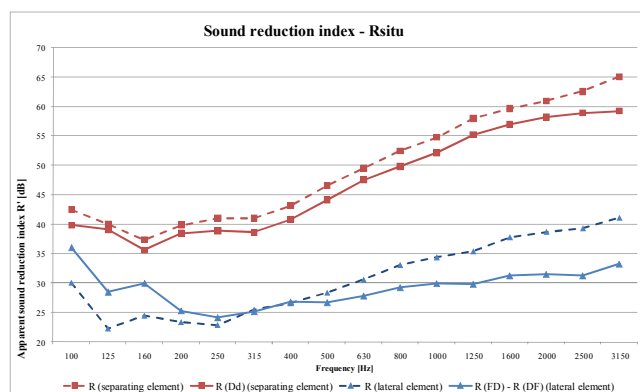


Figure 7: Comparison of apparent sound reduction in the actual field situation

5 Conclusion

Typical light brick wall analyzed in this paper present some interesting results especially for acoustical performance data necessary for calculation models for the evaluation of the sound insulation in real buildings.

The sound reduction index, present a great dependency with the cement plaster (+4 dB with the second size plastered). Structural reverberation time and longitudinal wave speed are also dependent on second plaster in a significant way.

Comparison between calculated and measured apparent sound reduction index shows the great importance of the correction term $T_{\text{situ}}/T_{\text{lab}}$, and therefore the necessity to always measure in laboratory the structural reverberation time of the partition.

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