The drying process influence on the brick walls sound reduction index: laboratory evaluations and theoretical analysis

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This paper presents the experimental results concerning the sound reduction index of different types of brick walls; the analysis was in particular carried out on double walls, single walls and single walls with external lining. Its main purpose is to find the minimum drying time of the structure necessary to obtain the sound reduction index of brick walls as close as possible to actual laboratory values. Moreover, it aims at making results of different laboratories as comparable as possible in terms of repeatability and reproducibility. All the fundamental quantities, such as sound reduction index (R), weighted sound reduction index (R_w), spectrum adaptation terms C and C_{tr}, have been analyzed, and temperature (T) and relative humidity (R.H.) in the receiving room, have been recorded. A qualitative analysis of the curves slope of the sound reduction index versus frequency has been conducted for each drying time and each type of examined wall. The measurements were carried out in the acoustics laboratory of ITC-CNR (the Construction Technologies Institute of the Italian National Research Council) in Milan, according to the procedures set out in ISO 140 part 3.

1 Introduction

Unlike other Nations, the Italian building technology principally makes use of masonry and brick walls; the acoustic behavior of these structures and its evaluation methods should be further analyzed as it has been done for other kinds of walls (light walls, plasterboard walls and others) [1].

The laboratory procedure, as set out in EN ISO 140 part 3 [2] current edition, can give different results from different laboratories, being incomplete with regard to the terms of the sample drying time.

The work described here is not intended to be exhaustive, but tries to lay the foundations for further investigations.

2 Measurements procedure

The measurements were carried out in the acoustics laboratory of ITC-CNR, which has a 10 m^2 test surface between the two rooms; the laboratory characteristics are as set out in EN ISO 140-1 [3]. The procedure was divided into the following steps:

Step 1: Conditioning of materials

The materials used for build the walls in laboratory, were conditioned with the laboratory microclimate. The bricks, the material used in the air space, and the material used for the external lining were dry.

Step 2: Installation in a neat and a workmanlike manner

The installation of bricks in "a neat and a workmanlike manner" is envisaged in order to avoid incomplete sealing of horizontal and vertical brick slots; to avoid the use of broken (not intact) bricks, and finally to avoid incomplete or missing sealing of the perimeter.

Step 3: Sound reduction index (R) measurements

Each test was carried out using the measurements methods set out in EN ISO 140 part 3 [2]. The sound reduction index measurements have been repeated until there were no more changes in the trend of R versus the frequencies of the sample. Time t = 0 is the time at the end of the sample wall construction. Not all initial tests were carried out at time t = 0, as explained in detail in the following parts.

Step 4: Surface mass determination

The surface mass of tests walls was determined by measuring and weighting a sample of the wall, at the end of the tests. In particular the surface mass of all the wall layers, including plasters, was calculated.

2.1 Samples

The analysis was carried out on double walls, single walls and single walls with external lining. The description of theses walls is showed below. For a more detailed description, see the references article [4].

a) Single walls:

a1) wall made of 12 cm perforated face bricks, plastered on one side. Surface mass: 218 kg/m^2.

a2) wall made of two rows of 12 cm perforated bricks, plastered on one side. Surface mass: 335 kg/m^2.

a3) wall made of 12 cm hollow bricks, plastered on both sides. Surface mass: 164 kg/m^2.

b) Double walls:

b1) First wall: 12 cm hollow bricks, , plastered on both sides; second wall: 8 cm hollow bricks, plastered on one side; 4 cm air gap filled with PET (polyethylene terephthalate) fibre. Surface mass: 299 kg/m^2.

b2) First wall: 12 cm hollow bricks, plastered on double sides; second wall: 8 cm hollow bricks, plastered on one side; 8 cm air gap filled with PET fibre. Surface mass: 307 kg/m^2.

b3) First wall: 12 cm perforated face bricks, plastered on one side; second wall 8 cm hollow brick, plastered on one side; 10 cm air gap partially filled with 8 cm PET fibre. Surface mass: 318 kg/m^2.

c) Single walls with external lining:

c1) Wall a2). External lining: 5 cm cork, glued to the wall, plastered with mesh finishing. Surface mass: 348 kg/m^2.

c2) Wall a2). External lining: 5+5 cm cork, glued to the wall, each cork lining plastered with mesh finishing. Surface mass: 361 kg/m^2.

c3) Wall a2). External lining: 10 cm EPS (expanded polystyrene), glued to the wall, plastered with mesh finishing. Surface mass: 341 kg/m^2.

c4) Wall a3). External lining: 10 cm elasticized EPS, glued to the wall, plastered with mesh finishing. Surface mass: 178 kg/m^2.

3 Analysis of results

The sound reduction index spectra in frequencies measured for all tests carried out at different times, for the three analyzed types of walls, are reported below.

The temperature and relative humidity into the receiving room have been recorded. For all tests: for simple walls (Table 1), for double walls (Table 2) and for simple walls with external lining (Table 3), the reported tables contain the weighted sound reduction index (R_w), the spectrum adaptation terms C and C_{tr}, temperature (T) and relative humidity (R.H.).

3.1 Single walls

The single wall sound reduction index (Figure 2) shows significant changes in time between initial and final test time, only at low and medium frequencies (100 ÷ 500 Hz); differences between analyzed samples are due to different test times and intervals; in particular sample a1) shows a greater variation, mainly because, unlike other samples, the first test was carried out at the end of the wall construction, and the second after 72 hours. The data set of each wall is not enough, but, combining the results of the three different samples, the following information can be obtained: significant changes occur only in the first hours after the wall construction, as well as for wall a2), R_w varies only by one dB between 70 and 260 hours after the end of the wall construction.

The curve trends of single walls a1) and a3), have at medium and high frequencies (from 500 Hz - up) a 6 dB/oct slope, the typical slope of the mass law [5]; wall a2), consisting of two rows of perforated bricks as shown in Figure 1, has a trend not comparable to that of a single wall: in figure 2 - a2) the curve slope (continuous line) is 3 dB/oct. In this case the curve closest to the wall experimental curve was sought and it differs clearly from the curve with a 6 dB/oct slope, dotted line, which is characteristic of a single wall. The different curve slope could be due to the particular arrangement of bricks, which creates, within the wall itself, bridge points between the two rows of bricks.

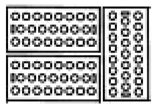

Fig.1 – Single wall a2) – bricks position

Wall	t [h]	R_w [dB]	C [dB]	C_{tr} [dB]	T [°C]	R.H. [%]
a1)	0,0	48	-1	-3	23,0	48,9%
	72,0	46	-1	-4	22,0	44,5%
a2)	71,0	52	-1	-3	28,0	57,7%
	263,0	51	0	-3	28,0	48,8%
a3)	22,0	44	-1	-3	29,0	46,8%
	46,0	44	-1	-3	30,0	45,8%

Table 1: variation of the fundamental quantities (R_w, C, C_{tr}, T and relative humidity) of single walls as a function of drying time

The curve trend of the spectrum adaptation terms C and C_{tr}, of single walls (table 1) does not show significant variations that may be related to the sound reduction index variation depending on drying time.

a1) a2) a3)

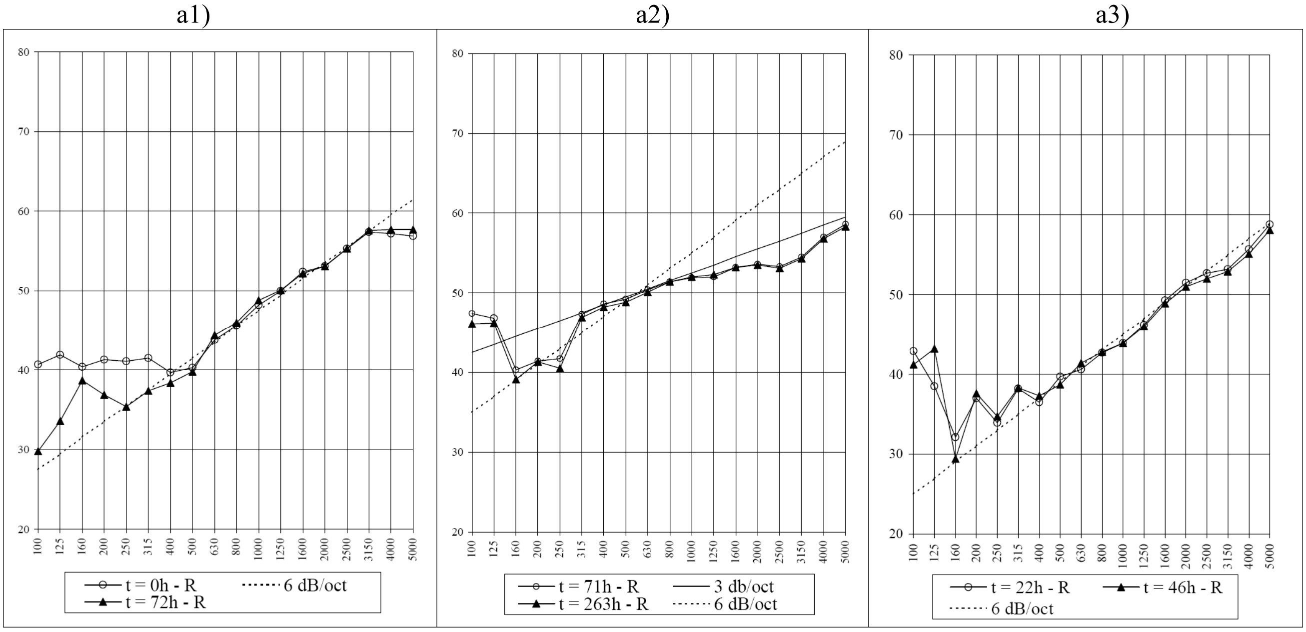

Figure 2 – Single walls sound reduction index

3.2 Double walls

The analysed double walls sound reduction index varies significantly between the first measurement (wall not yet dry) and the following measurements. The first measurements were carried out about 17 hours after the end of the walls construction, which made their results comparable. In particular, at frequencies 125 ÷ 250 Hz, there is a trend inversion between the first and following measurements, from 500 Hz onwards; however, the sound reduction index curve of the first measurement is always much higher than the curves of the following measurements. Moreover, the curve of the first measurement has a 6 dB/oct slope, while, the curve slope of all the other measurements is 9 dB/oct. Various slopes were considered for all the analyzed curves, until finding the slope that best fitted the curve plot, paying particular attention to the curve slope variation with time. This slope change indicates not only a sound reduction index decrease, according to the mass decrease due to drying, but also a variation of the flexibility of the material in the air gap which has a different behavior when it is not perfectly dry. At first, the curve slope variation may mean a variation of the modes of vibration of both the single walls making up the double wall, and of the double wall itself; in addition, there is the drying effect of the insulation material into the air gap. This behaviour underlines the great variation of the double wall sound reduction index especially in the 24 hours following the end of the wall construction. Regarding the weighted sound reduction index, the value obtained in the first test, is far higher than the value obtained in the following tests: for wall b1) there is a 7 dB variation between the first and the last test, for wall b2) there is a 5 dB variation and, finally, for wall b3) there is a 5 dB variation.

The spectrum adaptation terms C and C_{tr} of double walls are shown in Table 2. The R inversion at low frequencies between the first test and the following tests can not be related to a corresponding change in the C_{tr} value which not only does not show significant changes, but remains constant for walls b1) and b3).

Wall	t [h]	R_w [dB]	C [dB]	C_{tr} [dB]	T [°C]	R.H. [%]
b1)	17,0	60	-1	-3	19,3	46,0%
	63,5	54	-1	-3	19,1	49,7%
	88,0	54	0	-3	19,3	50,2%
	159,5	53	0	-3	19,8	53,3%
	183,5	53	-1	-3	20,0	52,4%
b2)	17,0	58	0	-2	20,0	51,9%
	39,5	54	0	-3	21,0	47,7%
	64,5	53	0	-2	20,0	50,7%
	159,0	53	0	-2	23,0	44,5%
b3)	18,0	59	0	-3	22,0	41,2%
	43,0	55	-1	-3	23,0	54,0%
	66,5	54	-1	-3	22,0	54,2%
	72,0	54	-1	-3	23,0	53,0%
	90,0	54	-1	-3	21,0	48,8%

Table 2: variation of the fundamental quantities (R_w, C, C_{tr}, T and relative humidity) of double walls as a function of drying time

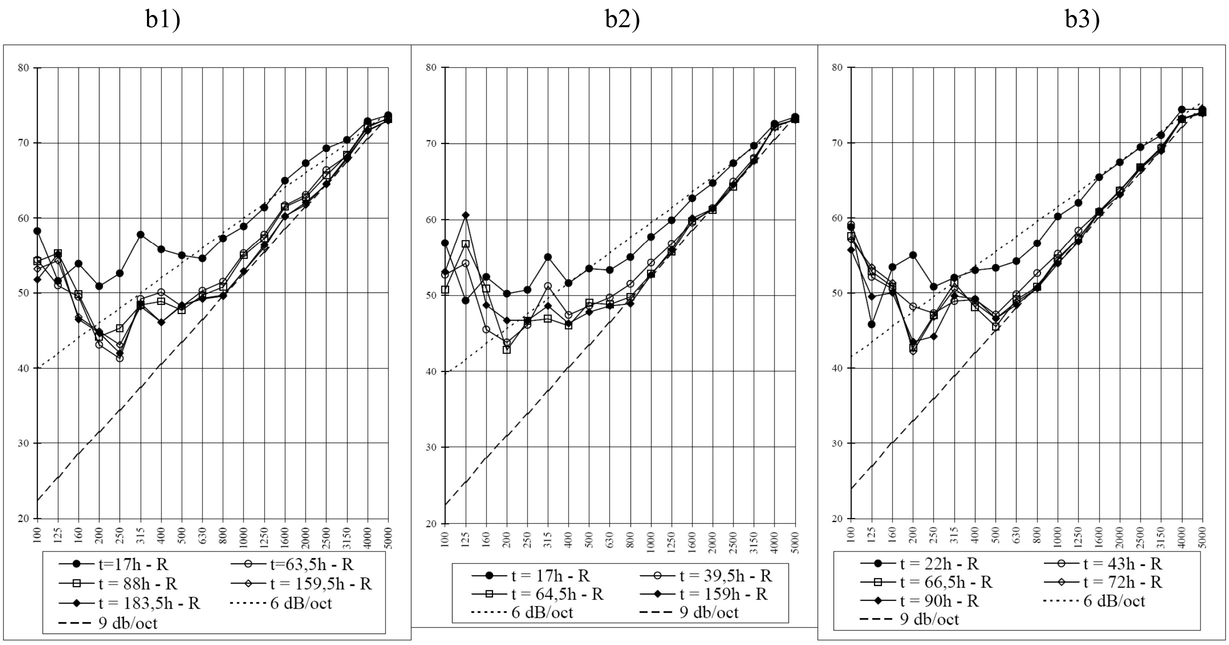

Figure 3 – Double walls sound reduction index

3.3 Single walls with external lining

For single walls with external lining there is a significant change of R in the first hours after completion of the installation of the external lining on already dried walls; this suggests that it is mainly due to the drying of the plaster with mesh finishing. For just-completed wall c1) compared to the measurements made later (see Figure 4), it is possible to remark a lower value of R at low frequencies (125 Hz) and higher values at medium frequencies range (500 - 1000 Hz). Wall c3) sound reduction index has a particular trend and the change occurs at all frequencies; the weighted sound reduction index decreases in the first 24 hours after the end of the wall construction, tends to rise again after 48 hours and finally settles at a level still lower than the initial one.

Even for the single walls with external lining, the spectrum adaptation terms, reported in Table 3, show no significant changes: they remain constant or have a maximum variation of ± 1 dB.

Wall	t [h]	R_w [dB]	C [dB]	C_{tr} [dB]	T [°C]	R.H. [%]
c1)	0,0	51	-1	-3	27	28,8%
	24,0	50	0	-3	28	31,5%
	96,0	50	0	-3	28	53,1%
c2)	19,0	51	0	-3	28	27,7%
	42,0	51	-1	-3	28	32,0%
	66,5	51	-1	-3	27	37,4%
c3)	0,0	52	0	-4	28	57,9%
	24,0	50	0	-3	27	48,2%
	48,0	50	0	-3	28	46,0%
	72,0	51	-1	-4	28	41,3%
	96,0	51	-1	-4	27	43,4%
c4)	18,0	48	-2	-6	29	49,5%
	42,0	48	-3	-7	30	43,0%

Table 3: variation of the fundamental quantities (R_w, C, C_{tr}, T and relative humidity) of single walls with external lining as a function of drying time

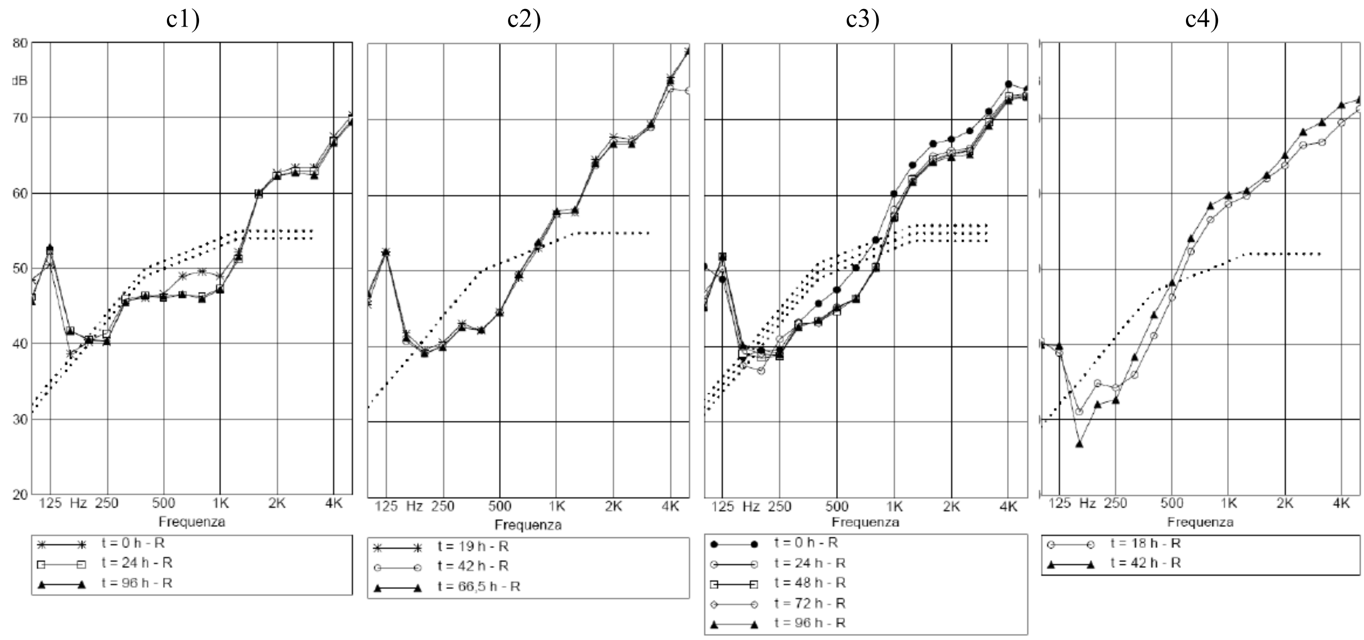

Figure 4 – Single walls with external lining sound reduction index

4 Conclusions

The following considerations only apply to the tested wall types and, in particular, to the type of brick plaster and mortar used for the construction of the samples. The aim is to indicate a "helpful" or "minimum" drying time, after which it shall be guaranteed that there are no significant changes (± 1 dB) in the sound reduction index of the wall under consideration. For single walls, the data obtained from this work could lead to assume a minimum drying time of no less than 24 hours after the wall construction. For double walls, in the first instance, the minimum drying time results to be more than that of single walls: at least 4 days (96 hours). This is due to the higher amount of plaster used in the double walls in both vertical and horizontal joints of the wall and in the inner plastered face of the wall; in addition, also the drying time of the material in the air gap, which absorbs humidity from the masonry, has to be taken into account.

Finally, in the case of single walls with external lining, the drying time (from the end of the application of plaster with mesh finishing) is even less (about 20 hours) and essentially depends on the amount of plaster used and not on the material used for the external lining; changes in terms of R_w are minimum (1 dB).

The control of the spectrum adaptation terms C and C_{tr} is not enough in itself to give indications about the shape variation of R curves: the inversion trend at low frequencies between the first test and following tests does not have a correspondence in C_{tr} values variation.

A further indication of the variation of the acoustic performance of walls as a function of drying time, particularly for double walls, comes from the observation of the change of the curve slope of sound reduction index at medium-high frequencies, starting from 500 Hz: measurements taken with a not yet dry wall, within the first 24 hours after the end of the wall construction, have 6 dB/oct slope (which follows the mass law [5]), while the sound reduction index curves at time t> 40 h already show a curve slope change at 9 dB/oct.

References

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