Proceedings of the XXXVIII IAHS World Congress

Visions for the Future of Housing
Mega Cities

April 16-19, 2012 Istanbul Technical University

edited by

Oktay Ural
Muhammed Şahin
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International Association for Housing Science

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Pioneer through the ages

IAHS HOUSING ISTANBUL 2012

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Congress Secretary

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Parametric Analysis of the Acoustic Performances of Timber Buildings

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Abstract

In the last 20 years, a growing attention has been put towards the design of eco sustainable buildings from many points of view, especially the use of materials with a low LCA impact and the construction of buildings with high energy performances. There has been a proper renaissance of timber buildings and new studies about their thermal and structural behavior have been done, reaching a very high design and construction level. Anyway, very often an important aspect of human comfort has been neglected, that is the acoustic performance of the buildings and their elements. Very few studies have been done concerning this features and scientific literature is not well developed yet, being the acoustic theory still well bind to the behavior of massive elements.

In this paper, a study concerning the acoustic performances of timber buildings is presented. The research has been done by means of in situ acoustic surveys of walls, floors and inner partition in wooden buildings as built. Buildings with frame and X-lam system have been taken into consideration. The surveys have been done following the recommendation of standard UNI EN ISO 140-4-5 and UNI EN ISO 10140-3 and the results have been analyzed following standard UNI EN ISO 717-1-2 .

The acoustic indexes resulting from the survey (R'w = airborne apparent sound insulation of wall, L'nw normalized impact sound level, D2m,n,Tw airborne sound insulation of façade) have been compared with the limits given by Italian legislation and the main criticality has been pointed out. A comparison between the frequency spectrum analysis of the surveyed buildings and the ones coming from a database of 300 traditional buildings (brick block masonry and concrete slab) has been performed in order to point out the main criticality of timber structures concerning noise control.

1 Introduction

In the last years a great interest towards the respect of passive and active acoustic requirements in buildings has grown because of the awareness of the impact of noise on human health. This issue has been introduced, even if slowly and sometimes with some limitations, in the energy and environmental certification process. In particular, in Italy a new standard has been recently issued, UNI 11367 [1], concerning the acoustic assessment and verification of buildings and building elements on site. Moreover, the new system for energy and environmental certification of timber buildings recently introduced in the Autonomous Province of Trento (Italy), called ARCA [2], specifically provide for the calculation of noise index in order to get credits in the certification rating of the building.

The realization of field noise measurements is a very important step in the building process because both the quality of the design and of the final realization and installation are assessed.

This paper deals with a research carried on by the Laboratory of Building Design of the University of Trento (Italy), which consists in making field noise testing on six buildings with timber structure: one with frame wall system, three with X-Lam system, two with framed structure system plus frame cladding walls.

The buildings, besides different constructive typologies, have also different destination of use:

- one multi-storey building with 11 apartments and one with 6 apartments;
- one two-storey building for two families;
- one hotel;
- one terrace houses complex;
- one multi-family building with 3 apartments.

The surveys have been done following the recommendation of standard UNI EN ISO 140-4-5 [3-4] and UNI EN ISO 10140-3 [5] and the results have been analyzed following standard UNI EN ISO 717-1-2 [6-7].

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2 Method

2.1 Measurement procedure

In all noise measurements that have been performed, the following parameters have been considered: background noise, reverberation time T, airborne apparent sound insulation R'w of walls and floors, normalized impact sound level L'nw of floors, airborne sound insulation D2m,nT,w of facades normalized on the reverberation time.

A standardized procedure has been followed concerning in: inspections of the building, verification of the geometrical dimensions (inside and outside), definition and preparation of the test, microphone calibration, determination of reverberation time in receiving rooms, determination of background noise in receiving rooms, determination of average sound level in receiving rooms, determination of average sound level in source rooms, elaboration of phonometric data and calculation of acoustic indexes provided by standards (T, R'w, L'nw, D2m,nT,w).

All field noise measurements have been done following the recommendation of standards UNI EN ISO 140-4-5 and UNI EN ISO 10140-3. At the end, data coming from field surveys have been compared with the limits provided by existing regulations.

2.2 Instruments

Instruments of class 1 have been used according to standard I.E.C. n.651/77 "Sound Level Meters", I.E.C. n.225/82 "Octave, Hall-octave and Third-octave Bande Filters Intended for the Analysis of Sounds and Vibrations" and European standards EN 60651:1994 and EN 60804:1994.

In particular, the following instruments have been used: a sound level meter Sinus – SoundBook MKII (sn 7017), a microphone PCB – 377B02 (sn 118112), a calibrator Larson Davies – CAL200 (sn 5616). Before each measurement campaign, the sound level meter has been calibrated by means of the sound level calibrator. Moreover, the following sound sources have been used: omnidirectional sound source LookLine – D303 (sn D3090101), tapping machine LookLine – EM50 (sn T100300), directional sound source LookLine – FL02 (sn F2090103).

Data elaboration has been made using software SAMBA (SAMURAI Building Acoustic).

3 In field noise measurements

Due to the huge number of data acquired during the surveys on the six buildings, in this paper only one survey is presented. The procedure described in paragraph 2.1 has been followed.

The case study presented is a building placed in Caorle (Province of Venice, Italy). It is a two-storey building for two families (fig. 1). The structure is a frame system with frame cladding walls. The survey has been done in November 22nd 2010 in both the apartments, first and second level. See fig. 2 and fig. 3 where the test arrangement is shown. In particular:

red hatch: inner wall that has been tested (R'w = airborne apparent sound insulation);

grey hatch: floor on which the L'nw normalized impact sound level has been calculated;

blue squared hatch: outer façade for the calculation of D2m,n,Tw airborne sound insulation.

The survey has been made on the building finished, i.e. floors, windows, doors, finishing and so on were present and properly installed. The building was not used yet, so the rooms were empty (no furniture inside).

In the following tables (Table 1-4), the results of the survey are presented.

Table 1: R'w - airborne apparent sound insulation of inner wall – first floor.

Measured value [dB]	Limit value Italian regulation [dB]	Uncertainty [dB]	Limit value UNI 11367 [dB]	Class of the element UNI 11367
64	50	±1	63	I

Table 2: R'w - airborne apparent sound insulation of inner wall – second floor.

Measured value [dB]	Limit value Italian regulation [dB]	Uncertainty [dB]	Limit value UNI 11367 [dB]	Class of the element UNI 11367
63	50	±1	62	I

Figure 1: External façade of the building during the survey.

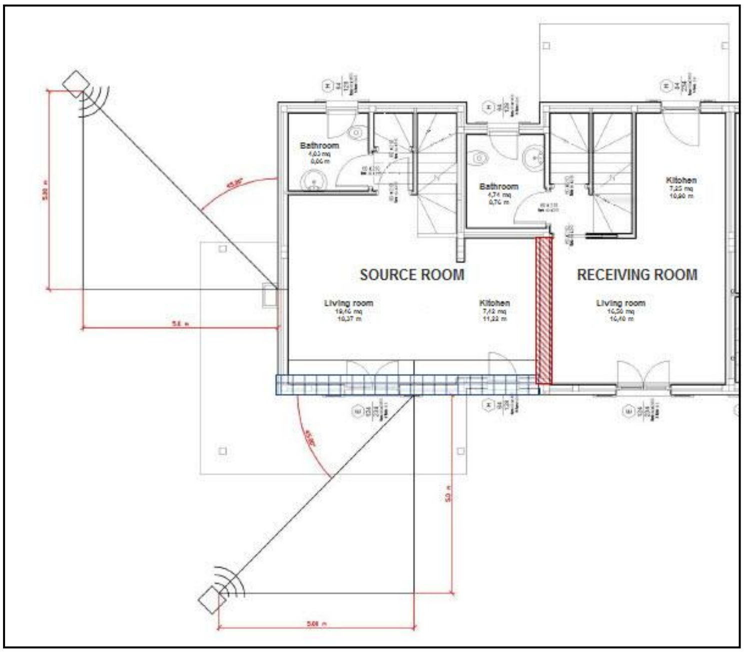

Figure 2: First floor: red = inner wall under test, blue = external façade under test.

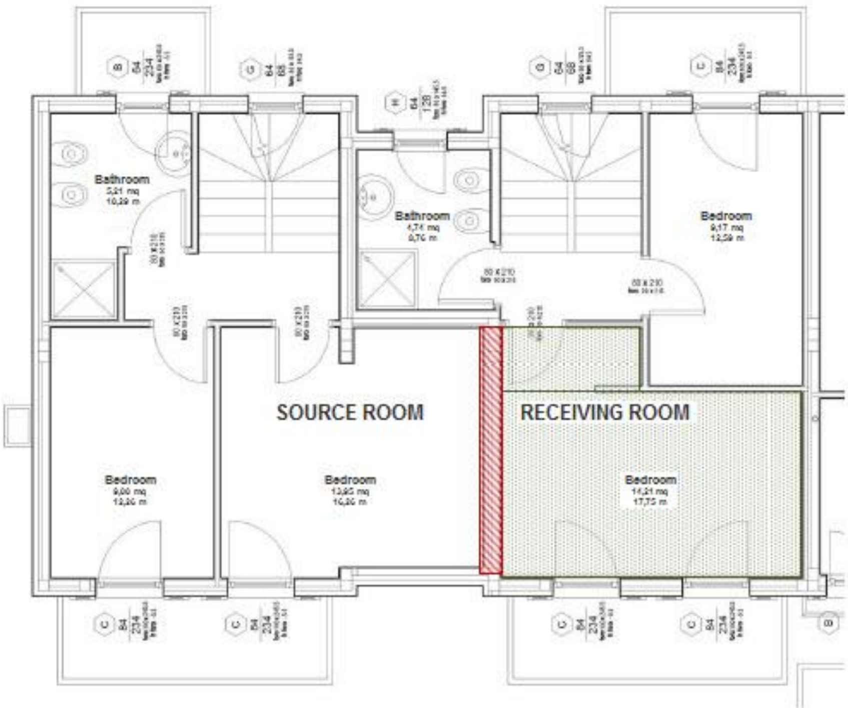

Figure 3: Second floor: red = inner wall under test, grey = floor under test.

Table 3: L'nw normalized impact sound level.

Measured value [dB]	Limit value Italian regulation [dB]	Uncertainty [dB]	Limit value UNI 11367 [dB]	Class of the element UNI 11367
70	63	±1	71	Not classifiable

Table 4: $D_{2m,n,Tw}$ airborne sound insulation of façade.

	Measured value [dB]	Limit value Italian regulation [dB]	Uncertainty [dB]	Limit value UNI 11367 [dB]	Class of the element UNI 11367
with no windows	>49	40	±1	>48	I
with windows	35	40	±1	34	IV
Overall	38	40	±1	37	III
with shutters closed	40	40	±1	39	III

It is easy to notice that only the results of the measurement of R'w for the two inner walls and of D2m,nT,w for the façade without windows fulfill the regulation requirements.

4 Data analysis

The survey briefly presented in chapter 3 has been repeated for the other 5 buildings. The result is summed in the following table (Table 5).

Table 5: data coming from the surveys on the six timber buildings.

	Number of tests performed	% positive	Minimum value [dB]	Maximum value [dB]	Average value [dB]
R'_w walls	8	100	50	64	57
R'_w floors	5	100	53	59	56
L'_{nw}	7	71.4	58	70	64
$D_{2m,nT,w}$	5	80	39	44	42

It is clear that floors and façades are the critical elements (lower percentage of standards value fulfillment).

In a second step, data coming from the acoustic surveys in field made on the building elements of frame and X-lam system constructions have been compared with the ones coming from a database of 300 traditional buildings (brick block masonry and concrete slab) with the same typology of the surveyed ones. The following conclusions can be drawn.

4.1 R'_w of inner partitions between residential units

Comparing the values of airborne apparent sound insulation of walls R'w, timber buildings reach very high values of noise reduction, even over 60 dB. As shown in fig. 4, where the frequency spectrum of two walls representative of the one analyzed is printed, timber walls have lower sound insulation power at low frequencies (at 100 Hz R'w value is around 30 dB) growing up to 80 dB at high frequencies following a quasi-linear trend. Instead, brick masonry behaves better at low frequencies with R'w values always over 50 dB, but just after 250 Hz the timber element gives better performances.

So, the global R'w of timber walls strongly depends on the performance at high frequencies that compensate for the bad behavior at low frequencies.

Moreover, a deeper analysis of timber walls frequency spectrum reveals that it is linked to the acoustic behavior of light plasterboard partitions. In fact, at low frequencies there is the so called mass-spring-mass effect that reduces the sound insulation power while at medium frequencies the linear trend is due to the inner insulating material. On the contrary, at high frequencies there is not the coincidence factor, typical of plaster boards, that usually causes a sharp decrease of insulation power around 3150 Hz.

Note that in all the graphs the brick line has been shifted so to compare lines of different elements having the same R'w value, even is virtual.

4.2 R'_w of horizontal partitions (floors) between residential units

Even in this case, looking at the R'w index, timber structures have higher performances compared to traditional ones. Anyway, a deeper analysis considering the whole spectrum reveals that timber slabs have problems at low frequencies due to the low mass value of the elements.

4.3 L'_{nw} of floors between residential units

Acoustic performance of timber slabs are comparable with the traditional ones made of clay/cement mix. Even in this case, the critical point is at low frequencies where the reduced mass value of timber slabs lay to a lower normalized impact sound level L'w. The trend line of the clay/cement mix slab well follows the reference theoretical line given by standard UNI 717-2, at least till 2000 Hz. At low frequencies, the noise is higher due to the presence of the floating floor and to the typical resonant frequency of the vibrating system made by the elastic layer and the concrete slab. As usual, timber floors experience some problems at low frequency where the impact sound level is quite high, while it decreases quite rapidly when frequency increases. For this reason, sometimes the limits given by existing regulation may not be fulfilled (as in the example described in chapter 3).

4.4 $D_{2m,n,Tw}$ of façades

For what concerns the building façades, no frequency analysis has been done because values of noise reduction strongly depend on the proper installation of windows and on the presence of ventilation holes. In particular, for what concerns windows, the use of numerical control machines and the realization of precast timber elements allow the realization of openings with very high precision, so considerably diminishing the possibility to have little cracks between the window frame and the wall (traditionally of 15-20 mm, filled in with polyurethane foam and finished with a doorcase). Moreover, in timber buildings usually the subframe is directly fitted in the timber structure during the precast process.

5 Conclusions

Field noise measurement following existing standards have been done on six timber buildings made with three different systems: frame wall, X-Lam and framed structure with frame cladding walls. A frequency analysis has been performed and the main acoustic indexes have been calculated (namely R'w = airborne apparent sound insulation of wall, L'nw normalized impact sound level, D2m,n,Tw airborne sound insulation of façade). The results have been compared with the ones coming from a database consisting of 300 field surveys on traditional buildings (brick block masonry and concrete slabs) of same typology of the timber ones. It can be noticed that inner walls made in timber generally have better acoustic performance than masonry ones, while timber floors are strongly limited by their low mass that is positive by a structural point of view (they are borne structures) but negative for noise reduction. Façades performance strongly depends on windows and ventilation holes rather than on constructive material. Anyway, the use of numerical control machines and the realization of precast elements in timber construction allows the realization of elements with very high precision, avoiding possible cracks or uncertainty during the installation process. Of course, generally speaking, especially in timber constructions, particular attention must be paid on the proper realization of joints between elements, in order to limit possible passive paths of sound transmission.

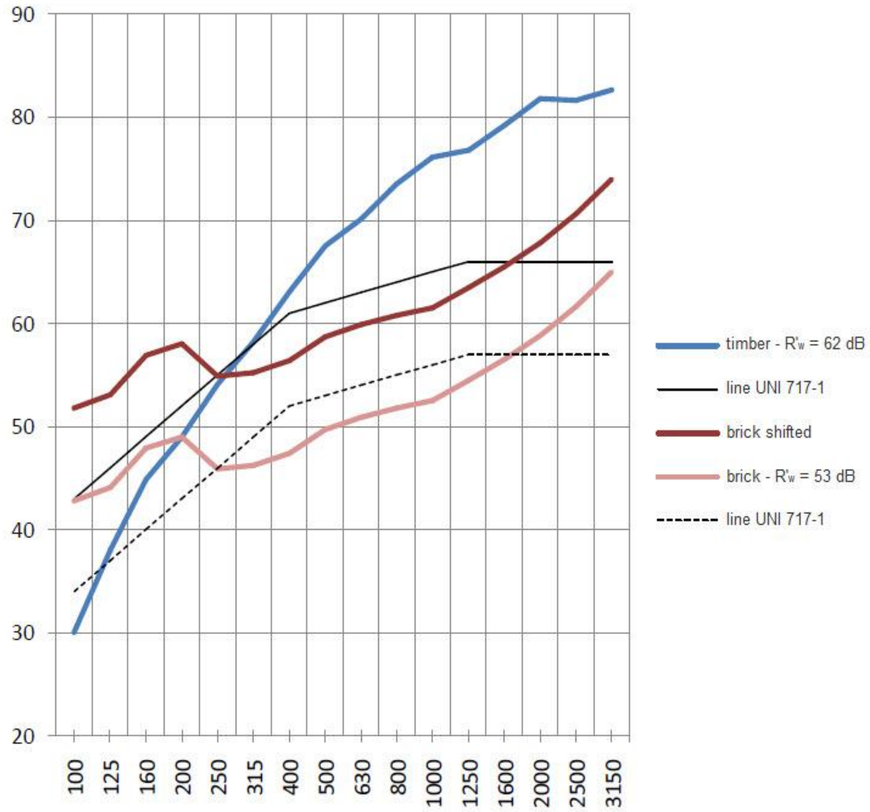

Figure 4: frequency spectrum of timber walls vs brick masonry.

6 References

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[4] UNI EN ISO 140-5:2000, Acoustics - Measurement of sound insulation in buildings and building elements - Measurement of airborne sound insulation in field of façades and façade elements

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[6] UNI EN ISO 717-1:2007, Acoustics - Evaluation of sound insulation in buildings and building elements - Part 1: airborne sound insulation

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