Building acoustics throughout Europe Volume 2: Housing and construction

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Building acoustics throughout Europe

Volume 2: Housing and construction types country by country

13

Italy

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CHAPTER 13 Italy

13.1. Legislation and standards in building acoustics

13.1.1. The enforced legislation DPCM 5-12-97

In Italy, the acoustics enforced legislation (DPCM 5-12-97) [1] prescribes the following minimum requirements for residential buildings:

- façade sound insulation $D_{2m,nT,W} \geq 40$ dB ;
- airborne sound reduction index between dwellings $R'_W \geq 50$ dB ;
- impact sound insulation $L'_{n,W} \leq 63$ dB ;
- equivalent spl from continuous service equipments $L_{A,eq} \leq 35$ dB(A);
- maximum spl, time constant "slow", for discontinuous operation $L_{A,S,max} \leq 35$ dB(A).

In table 13.1, the complete set of limiting values for the different types of building is reported.

Table 13.1. *Legal requirements concerning sound insulation and equipment noise.*

Activities or building use	Parameter				
	$D_{2m,nT,w}$ [dB]	R'_w [dB]	$L'_{n,w}$ [dB]	L_{ASmax} [dB(A)]	L_{Aeq} [dB(A)]
Hospitals, clinics and nursing homes	≥ 45	≥ 55	≤ 58	≤ 35	≤ 25
Dwellings, hotels and inns	≥ 40	≥ 50	≤ 63	≤ 35	≤ 35
Schools	≥ 48	≥ 50	≤ 58	≤ 35	≤ 25
Offices, commercial and recreational activities	≥ 42	≥ 50	≤ 55	≤ 35	≤ 35

For schools, limiting values for reverberation time also apply. The legislation applies only to new buildings and in restoration work (only for the elements affected).

For the single numbers only the calculations with third octave bands from 100 Hz to 3150 Hz are considered; the spectrum adaptation terms are not considered.

The frequent failure to comply with the minimum sound insulation performance of buildings built since 1998 has generated a great number of civil disputes between buyers and constructors. The main explanation can be found in the strong increase of acoustic performance requirements for buildings imposed by the Italian law of 1997. Furthermore, bad practice and workmanship errors frequently lead to very different results from those expected in the design phase.

Consequently, in order to improve the procedures to fulfil the requirements, many local regulations require to provide the estimation of acoustic performance in buildings at the design stage, and, in some cases, the results of measurements made after the construction.

It is expected that in future a technical standard should be inserted in a new law that explicitly provides for the classification of the acoustic requirements of new or completely refurbished buildings. This could provide an interpretation key which is easier and more immediately understandable to the buyers, to develop a system that encourages continuous improvement of building production, and reduce disputes between buyers and manufacturers.

13.1.2. The Italian Standard UNI 11367 on Acoustic Classification of Dwellings

The Italian Standard UNI 11367 [2, 3, 4] describes the procedures to define the acoustic classification of the property units of a building, whatever its use (dwellings, offices, hotels, commercial activities, etc.).

Sound classification could be expressed for each requirement or as a single descriptor. The requirements considered are listed below:

- façade sound insulation $D_{2m,nT,w}$;
- airborne sound reduction index of internal partitions R'_{w};
- impact sound insulation $L'_{n,w}$;
- sound pressure level from service equipments divided into those with continuous and discontinuous operation (L_{ic} and L_{id}).

The determination of the sound classes is based on the average values of the performance of all field measurements carried out on the various building elements (with reference to ISO 140 series standards).

Classification can be based on the measurements of all measurable elements or of a number of elements through a sampling procedure; in the latter case the sampling uncertainty needs to be applied.

For schools and hospitals, classification scheme cannot be used; in the standard, reference values for these two types of buildings are included.

The procedure for the sound classification of a dwelling involves the identification of all the verifiable technical elements and their field measurements. For each element, the *"net value"*, which corresponds to the measured value corrected with the *measurements uncertainty*, is determined. For each requirement, the energetic mean value of the results obtained for every technical element (referred to a single dwelling) is calculated. This value defines the sound class of the related requirement, according to Table 13.2.

Table 13.2. *Sound classes for each requirement.*

Class	Parameter				
	$D_{2m,nT,w}$ [dB]	R'_w [dB]	$L'_{n,w}$ [dB]	L_{ic} [dB(A)]	L_{id} [dB(A)]
I	≥ 43	≥ 56	≤ 53	≤ 25	≤ 30
II	≥ 40	≥ 53	≤ 58	≤ 28	≤ 33
III	≥ 37	≥ 50	≤ 63	≤ 32	≤ 37
IV	≥ 32	≥ 45	≤ 68	≤ 37	≤ 42

The relevance of the standards is not only restricted to the performance descriptors and their levels, but also on the procedures to obtain the sound classification and the choice of the samples to be tested. During the preparation of the classification scheme, most of the work was devoted to the definition of the procedures for the sampling choice and for the introduction of a *sampling uncertainty* [2, 3, 4]. For serial building, with repeated elements (such as particular kind of residential buildings with serial plan of dwellings), there is the possibility to carry out measurements on a limited number of these elements (samples). The sampling procedure involves the identification of homogeneous groups for each requirement, in terms of element type and dimensions, test rooms dimensions and installation techniques. A homogeneous group is defined when the identity is verified for several aspects which could influence the measurement results. For example, for façade sound insulation: window/door type and configuration, total façade surface, volume and dimensions of the receiving room, windows/doors surface and dimensions, etc. 20% tolerance is allowed. Sample selection is based on the analysis of final construction design and on the structures and technical specifications of service equipments. In case of residential buildings, homogeneous groups should be made with elements that belong to different dwellings. For every homogeneous group at least 10% of elements (with a minimum of 3 elements) are identified to carry out measurements. Then, the sampling uncertainty U_{sh}, which is related to the sampling standard deviation s_{sh} and the coverage factor *k*, must be calculated. The coverage factor *k* depends on the confidence level and on the number of measurements; the standard fixed 3 confidence levels (70, 75 and 80 %). For each dwelling, each technical element belonging to a homogeneous group must be associated to the related representative value and the energetic mean, for each requirement, must be calculated between different homogeneous groups. After the application of the statistical procedure for each dwelling, the sound class is determined both for each requirement and as mean value. The application of the sampling procedure for serial buildings, with a large number of similar residential units (such as large residential areas with repeated buildings), this could strongly reduce the number of measurements. For non-serial buildings, with a large number of residential units whose building elements are not similar, the sampling procedure does not limit enough the number of measurements. Most part of Italian residential buildings has a small number of homogeneous technical elements and thus a high number of homogenous groups, with consequently a high number of measurements. Moreover, in this case the statistical approach, used for the sampling uncertainty calculation, is not always reliable. For this reason, a new technical standard, which refers the procedure of the acoustic classification to non-serial buildings (UNI 11444-2012), was prepared and published [5].

This standard [5] provides guidelines for the selection of those residential units with non-serial characteristics which, on the basis of current knowledge, are supposed to be most critical in terms of acoustic performances with respect to the other units of the same building. For these units, measurements of acoustic parameters can be carried out in order to determine its classification, on the basis of the procedure described by the UNI 11367: 2010 [2]. The results of the measurements carried out on the technical elements of the critical units, selected according to this specification, may constitute a useful information basis to estimate the acoustic class of the other units of the same building, although the class cannot be directly transferred. In particular, it can be assumed that, with no hidden defects, the class attributable to them would not be worse than that determined for the selected critical units.

Nowadays the technical standard UNI 11367 is still voluntary and has not been made mandatory by law. Its application, therefore, has so far been very limited. This is partly due to the need for significant amount of time and resources for the measurements, if compared with the evaluation of the simply fulfillment of administrative requirements.

13.2. Design and acoustic performance

13.2.1. Overview of housing stock

In this paragraph information on the population, building typology and quantity of housing stock is reported. Most of the data were taken from ISTAT [6] (the Italian National Institute of Statistics); useful information was found in the Italian report of the TABULA (Typology Approach for Building Stock Energy Assessment) European project [7]. Relevant for the understanding of the acoustic quality of residential buildings is the classification of the buildings considering the construction period and size. The construction period is relevant not only for the different technological solutions and the performance of the materials used, but also for the evolution of the enforced legislation. Regarding size, at a European level there are still no standard categories for classification. The most commonly used are: detached houses (single-family, not attached), semi-detached houses (multi-family homes), attached houses (terraced house, row house, linked house, town house), apartment block (block of flats, tower block), etc.

The quantities of housing stock and total population

Italy has approximately 60 million inhabitants [6]. At national level the following general information is reported [6, 7]:

- the whole Italian residential building stock consists of approximately 11.3 million of buildings;
- the total amount of dwellings in 2001 is 27.3 million (approximately 16 million flats, 5 million attached houses and 6 million single family houses);
- the average floor area of an Italian dwelling is 96 m^2.

In the following figure the number of dwellings per year is reported.

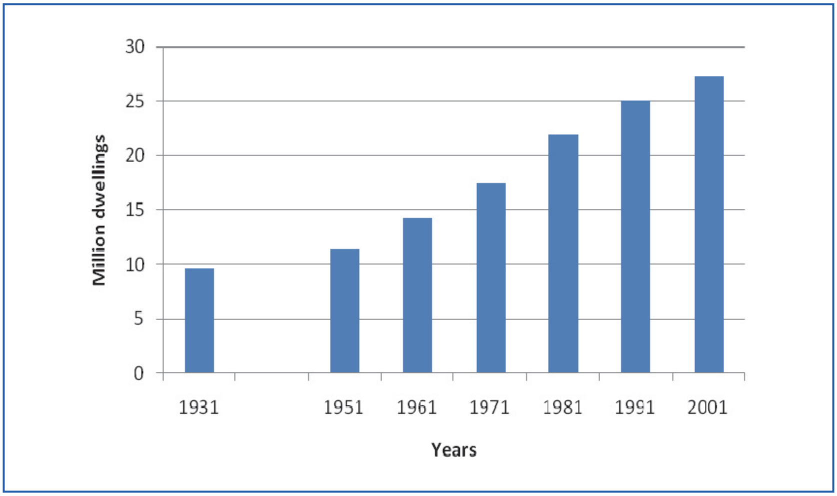


Figure 13.1. *Number of dwellings per year (up to 2001).*

Other data show that the production of new housings in Italy was about 250,000 in 2007. A decrease in the realization of new dwellings of more than 20% was estimated for the period 2007-2012.

The following pictures show some examples of building typology divided per size and per construction period: figure 13.2 apartment block; figure 13.3 attached house.

Figure 13.2. *Apartment block: a) 1950-60s; b) 1970-80s; c) 2000-10s.*

The most populated cities

The most populated cities in Italy are [8] Rome (2,64 million), Milan (1,24 million), Naples (0,96 million), Turin (0,87 million), Palermo (0,66 million) and Genoa (0,58 million).

Figure 13.3. *Attached houses: a) 1950-60s; b) 1970-80s; c) 2000-10s.*

Proportion of apartments, terraced (row) and detached houses [7]

Figures 13.4 and 13.5 [7] show the number of apartments in Italian residential buildings by construction period as a function of number of apartments per building and of contiguity to other buildings.

13.2.2. New build housing constructions

Typical heavyweight constructions

The most common building typologies are realized using heavyweight constructions, although also lightweight constructions have been more used in the last decade.

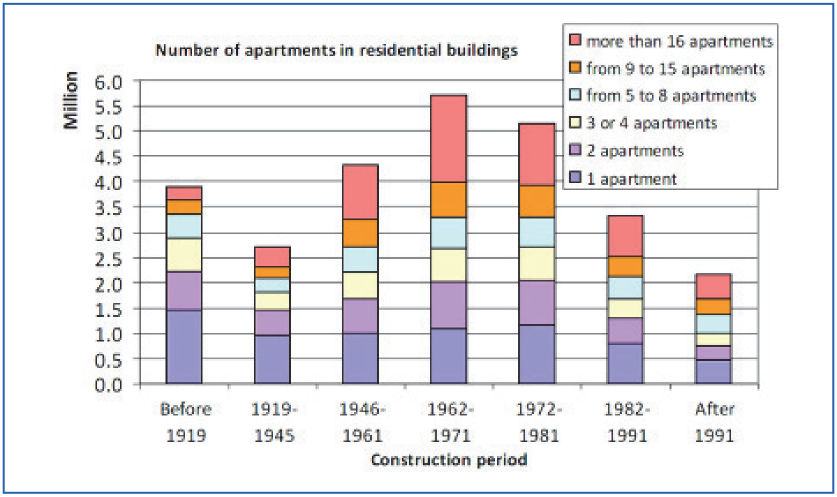


Figure 13.4. *Number of apartments in residential Italian buildings by construction period and number of apartments in the building (up to 2004) [7].*

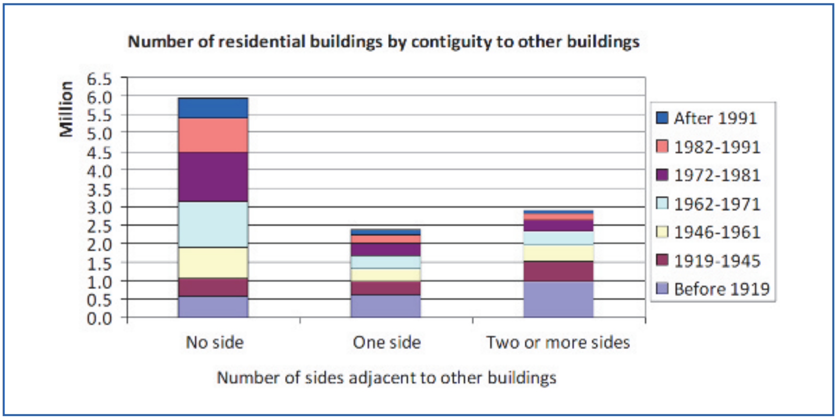


Figure 13.5. *Number of Italian residential buildings by construction period and contiguity to other buildings (up to 2004) [7].*

For the partition walls (between dwellings), the following type of solutions are used:

- double layer walls with insulating materials (69%);
- single layer walls (22%);
- single layer walls with linings (5%);
- other (4%).

For the partition floor, heavyweight floors with floating floors are generally used. The most common floors are those realised with bricks and concrete; prefabricated concrete panels or beams are also used.

Figures 13.6.a and 13.6.b show the most frequent combinations, for double walls, in Italian new buildings.

The first kind of Italian partition analyzed (figure 13.6.a) was quite largely used in buildings realized in Italy after 2000 and is still used in many cases. It consists of two layers of hollow bricks, each 80 mm thick, with an apparent density between 700 and 800 kg/m^3, plastered with 10-15 mm of mortar on both sides and on one side of the cavity. In the cavity there are two layers of mineral wood, each 40 mm thick.

The second kind of Italian partition analyzed (figure 13.6.b) is more diffused in recent years because of its better performance in comparison with the previous solution.

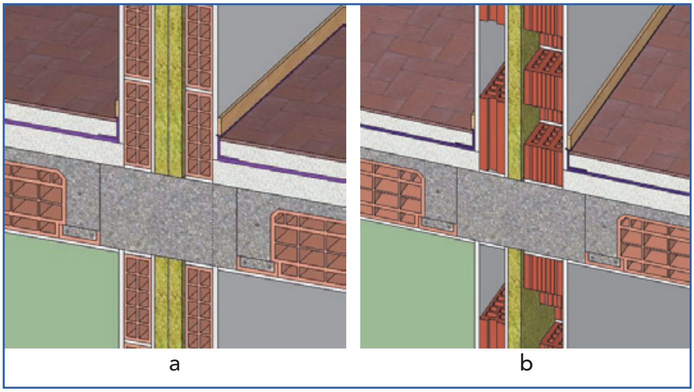


Figure 13.6. *a) Italian double wall type 1, b) Italian Double wall type 2.*

It consists of a layer of hollow bricks 80 mm thick (with an apparent density between 800 and 900 kg/m^3) and a layer of semi-full bricks 120 mm thick (with an apparent density between 800 and 1000 kg/m^3), plastered with 10-15 mm of mortar on both sides and on one side of the cavity. In the cavity there are 40-50 mm of mineral wood and 20-30 mm of air.

Concerning monolithic walls, typical Italian partitions used between dwellings, they are realized with expanded clay and concrete blocks characterized by an apparent density between 1200 and 1400 kg/m^3, plastered with 10-15 mm of mortar on both sides (figure 13.7). There are two thicknesses for this kind of partition: the first one is realized with

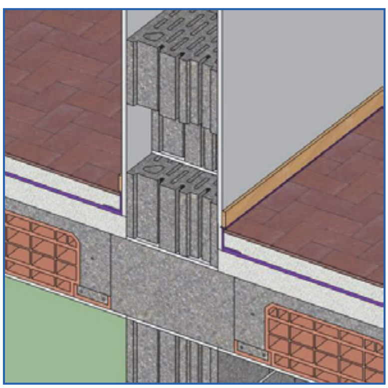


Figure 13.7. *Typical Italian monolithic wall* with expanded clay and concrete blocks.

blocks 250 mm thick, while the second with 300 mm thick blocks. Other types of monolithic walls are realized with clay blocks, frequently with big holes filled with concrete, or with additional components in order to improve the thermal insulation.

Figure 13.8 shows the comparison between averaged values of SRI for the three different type of partitions mentioned above (figures 13.6a, 13.6b and 13.7), tested in different real buildings. For the single walls (figure 13.7), data related to expanded clay and 250 mm thick concrete blocks are reported [9, 10].

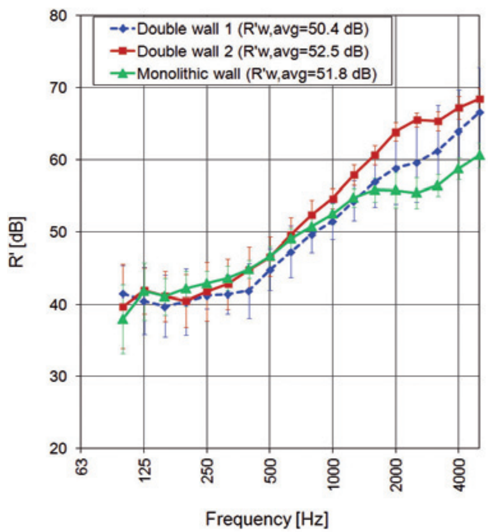


Figure 13.8. *Comparison between the average airborne sound insulation R' of the double walls and monolithic wall. The vertical bars represent the standard deviation among the measurements (10 measurements on double walls 1, 33 measurements for double wall 2, 43 measurements for monolithic walls).*

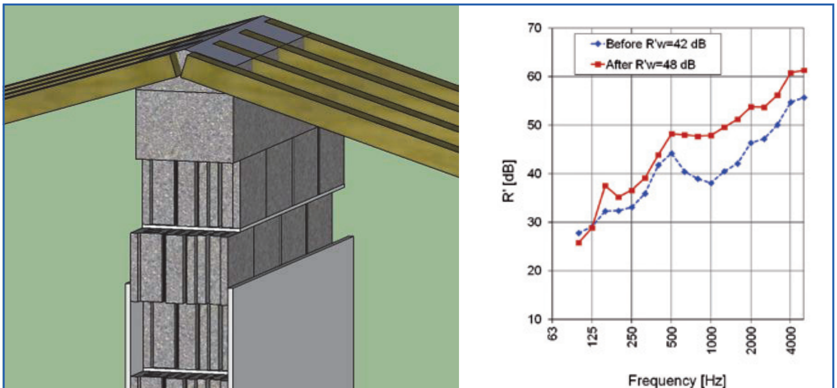
Typical errors in design [11]

In this section some examples of the most frequent design errors for airborne sound insulation, impact sound and façade sound insulation are listed.

- Attic rooms: roof (ventilated or not) not interrupted in correspondence with the junction with the partition walls (figure 13.9).

- Lack of riddle or structural beam on the floor slabs above the separating walls.
- Service zones made symmetrically (not staggered) on both sides of the wall (electrical box, ventilation pipes, etc.).
- Lack of floating floor in terraced houses, adjacent horizontally (figure 13.10).
- Stairs rigidly connected to the partition wall.
- Lack of acoustic break on the windowsill (figure 13.14).
- Shutter systems with acoustic leakage (ex.: external rolling shutter with internal boxes) (figure 13.11).

In the following figures, examples of the above mentioned errors are illustrated, including experimental results.



a b

Figure 13.9. *a) Example of a critical joint between the separating wall and the roof, b) Case study: airborne sound insulation of a wall before and after the filling of the cavities between the roof and the wall.*

Typical errors in workmanship [11]

In this section some examples of most frequent workmanship errors for airborne sound insulation, impact sound and façade sound insulation are listed.

Airborne sound insulation:

- Lack of mortar in vertical joints between blockwork.

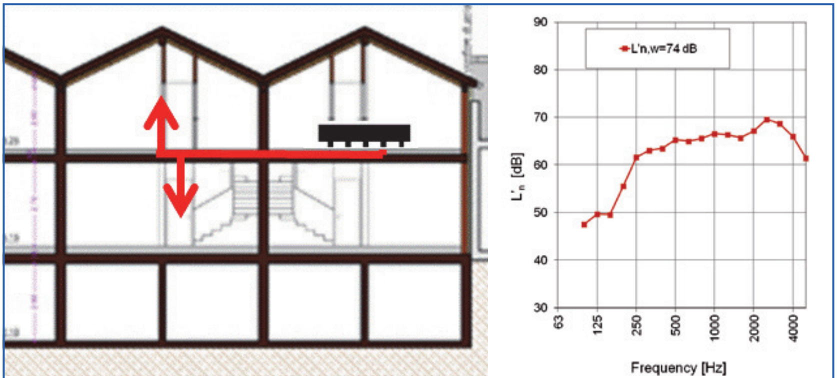


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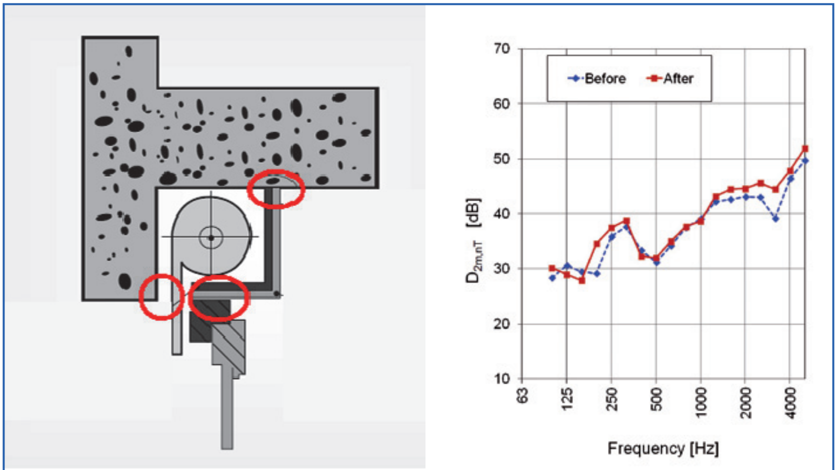
Figure 13.10. a) Example of the transmission path between two terraced houses without the floating floor, b) Case study: impact sound in horizontal direction between two terraced houses.



a b

Figure 13.11. a) Leakages between shutter box, wall and window frame, b) Case study: façade insulation before and after sealing between shutter box and wall.

- Sound absorbing material not continuous in the cavity of cavity walls.
- Pipe chases for building services not properly filled with mortar.

- Lack of plaster on one side of the cavity in the cavity wall, when prescribed in the chosen technical solution.
- Tears in the sound-absorbing material inside the cavity of walls due to service zones or pipe chases: the subsequent filling with mortar may create a bridge between the two leaves of the cavity wall.
- Non suitable resilient layer, used as isolation mechanisms at "wall-floor" junctions, under single heavy walls (risk of crushing of resilient layer).
- Interlocking blocks (blocks that do not need mortar) not properly stuck to each other.

Impact sound:

- Perimeter resilient band not continuous, especially in corners.
- Perimeter resilient band not properly adherent to the walls and the consequent presence of mortar between the band and the walls.
- Rigid contact between the ceramic tiles or the floating mortar with the French window marble doorstep (figure 13.12).
- Perimeter resilient band too short or cut before the placing of the ceramic floors (figure 13.13).
- Lack of structural separation between the floating mortar in correspondence with the door of the rooms.
- Tears in the resilient material of the floating floor.
- Ceramic tiles against the walls.
- Floor surface below the resilient material not perfectly flat or not properly cleaned (presence of brick or iron pieces).
- Skirting board in direct contact with ceramic/parquet floor (figure 13.13).
- Presence of pipes not fully embedded into the lightened mortar (under the resilient material).

Façade sound insulation:

- Bad window adjustment (regulation, set-up etc.).
- Lack of leakage sealing between shutter box and wall and/or window frame.

In the following figures, examples of the above mentioned errors are illustrated, including experimental results.

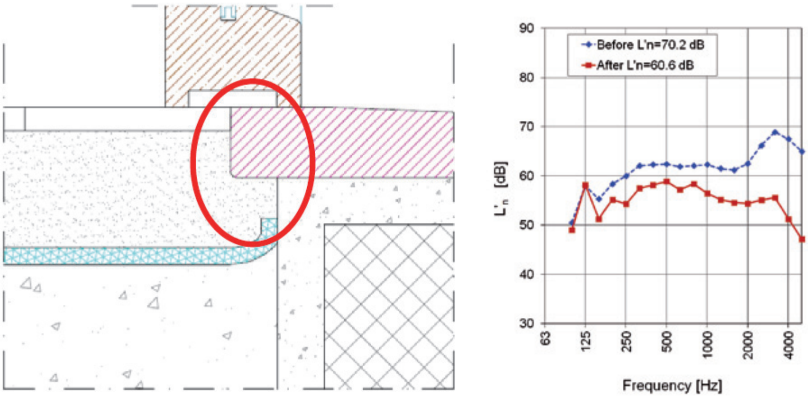


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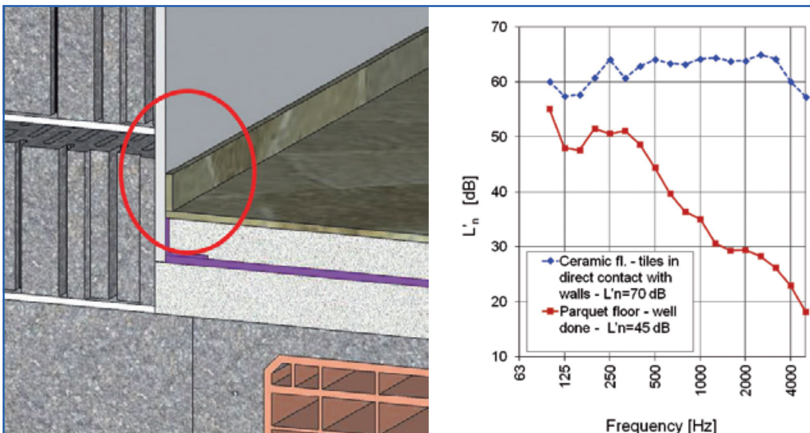
Figure 13.12. *a) Example of the rigid contact between the ceramic tiles or the floating mortar with the French window marble doorstep, b) Case study: impact sound before and after the repair.*



a b

Figure 13.13. *a) Example of tiles in direct contact with the walls and skirting board in direct contact with the floor, b) Impact sound with different paving: ceramic tiles with workmanship errors as in the picture, parquet floor well done.*

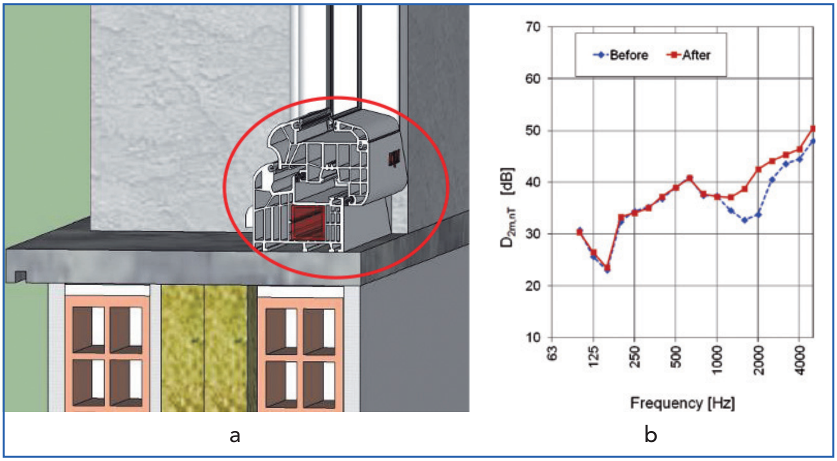


Figure 13.14. *a) Example of acoustic break on the windowsill, b) Façade insulation before and after the window adjustment.*

13.2.3. Existing housing

Typical constructions found in existing stock and their performances [4, 12]

The technological characteristics of buildings realized in Italy between 1950 and 2000 have been analyzed by means of different sources.

Approximately 90% of buildings realized in Italy since the post-war period have separating and façade walls in brick elements and floors with clay and concrete blocks (see figure 13.15).

Gypsum plasterboard walls or gypsum block walls had their maximum spread in the 70s, while the precast concrete wall panels had their diffusion in the 70s and 80s as a consequence of the diffusion of prefabrication techniques; finally, walls of lightweight concrete blocks have become more important in recent years.

In the 50s and at the beginning of the 60s there was a growing need for low-cost housing in the large city suburbs, consequently these houses were built in a short time and there were many errors caused by workmanship. The mass per unit area (m’) of the walls wasn’t sufficient to limit sound transmission.

The airborne and impact sound insulation between dwellings was improved after the publication of the first Italian law for sound insulation of buildings (the decree of December 1997 [1]) (figure 13.16 and 13.17).

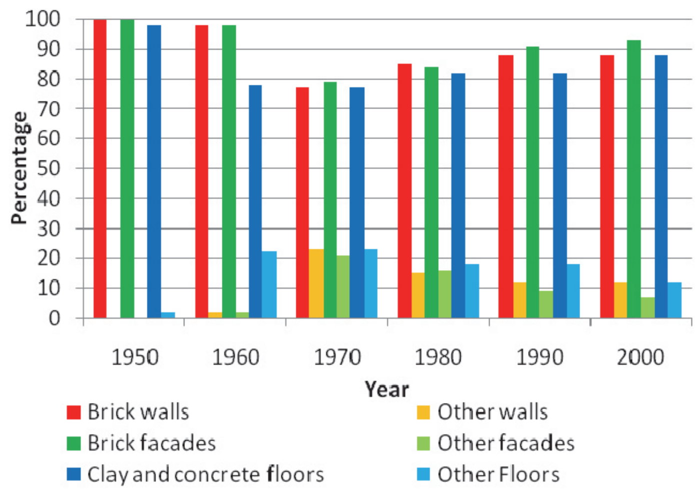


Figure 13.15. *Evolution of Italian separating walls, façades and floors technologies since the post-war period.*

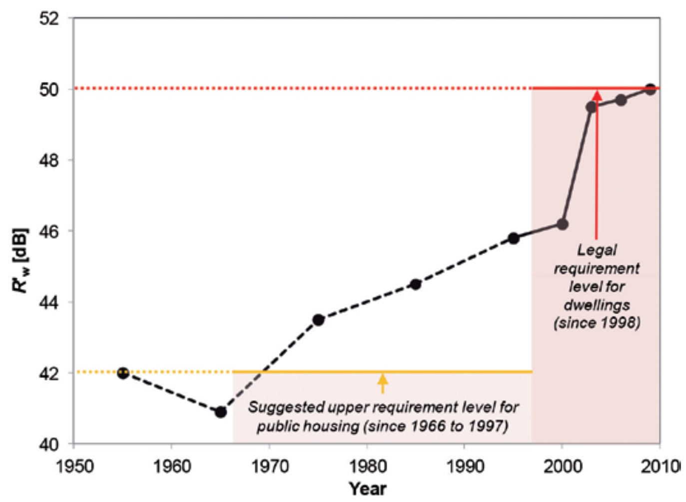


Figure 13.16. *Evolution of Airborne Sound Insulation of Italian dwellings since 1950; the solid line is a weighted average of measured data; the dotted line represents estimated data; levels of mandatory and suggested requirements in recent years are highlighted [4].*

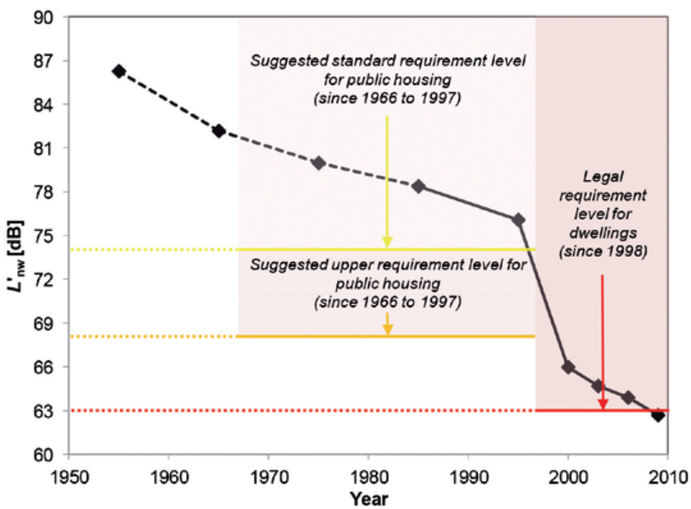


Figure 13.17. *Evolution of Impact Sound Insulation of Italian dwellings since 1950; the solid line is a weighted average of measured data; the dashed line represents estimated data; levels of mandatory and suggested requirements in recent years are highlighted [4].*

The historical analysis of the acoustic performance of façades (figure 13.18) shows that the improvement of façade sound insulation follows the effect of the technological evolution of windows.

Period of building, description of the building and acoustic performances

Italian buildings built between 1950 and 1975

In the period approximately between 1950 and 1975, building floors were mainly realized in clay and concrete, had a thickness of about 30 cm (24 cm prefabricated structure + 6 cm flooring), a surface mass of about 240 kg/m^2 and had no elastic layer (no floating floor). Their typical performance was about 47 dB for R'_w and 79 dB for L'_{nw} (values based on estimated data).

Partition walls between adjoining dwellings were about 20 cm thick and realized with a single layer of hollow bricks plastered on both sides, while inner walls were typically 10 cm thick in hollow bricks plastered on both sides.

The acoustic performance of partition walls between different dwellings may be assumed as R'_w = 43 dB.

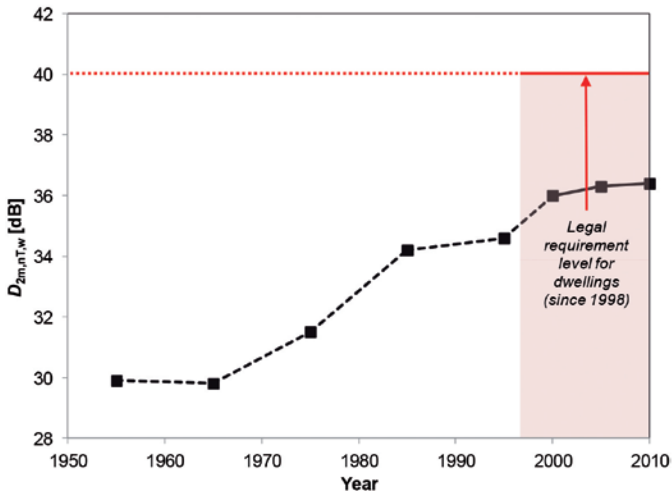


Figure 13.18. *Evolution of Façade Sound Insulation of Italian dwellings since 1950; the solid line is a weighted average of measured data; the dashed line represents estimated data; level of mandatory requirement is highlighted [4] .*

Façades were mainly realized with 26 cm thick cavity walls and windows with 3-4 mm thick single glass and wood frame. The typical acoustic performance was about R_w = 23 for windows and 52 dB for walls. In many cases there were wood roller blind boxes while the ventilation holes in kitchens weren't obligatory.

Italian buildings built between 1975 and 1998

In this period building floors were mainly realised with clay and concrete and the total thickness was about 30 cm. In some cases there was a floating floor.

The typical acoustic performance was about R'_w = 48 dB (value based on measured data) dB and L'_{nw} = 76 dB.

Partitions between adjoining dwellings realized between 1975 and 1998 were mainly 28 cm thick double walls without insulating material in the cavity, with a surface mass of about 260 kg/m^2; inner walls were made with hollow bricks plastered on both sides, 10 cm thick.

Acoustic performance of partitions between different dwellings was approximately R'_w = 47 dB (according to different measured values).

Façades of buildings of this period were composed of cavity walls with insulating material, 28 - 30 cm thick and windows with double glass panel with wood or metal frame with thermal break. Typical acoustic performance (R_w) was about 51 dB for walls and 31 dB for windows (values based on measured data).

Methods for improving sound insulation

The improvement of acoustic performance of Italian existing buildings is generally based on the following points.

Improvement of airborne sound insulation between dwellings

- Realisation of wall linings with plasterboard and elastic layer.

Improvement of impact sound insulation of floors

- Realisation of floor lining with floating floors.

Improvement of sound insulation of façades

- Window replacement using window-shutter monoblock system and stratified glazing or leakage sealing between frame and wall and/or frame and glazing.
- Improvement of acoustic performance of the internal shutter box by filling with absorbing material, by sealing leakages and adding additional heavy linings.
- Improvement of acoustic performance of the kitchen ventilation system by using silencer.

13.3. Field evaluation of acoustic performance and social survey

In the years 2009-2010, an application of Italian Classification Standard UNI-11367 regarding the acoustic classification of residential units [2, 3, 4] was made using acoustic tests carried out in several public housing buildings in the northeast of Italy. This project involved a whole neighbourhood of the city of Verona, affected by a global renewal. The purpose of the project was not only a thermal and acoustic improvement of existing buildings, but also a social renewal of the neighbourhood with the construction of new residential buildings and shops. In this stage of the project 8 residential buildings (with a total of 72 flats) were renewed and 3 new building were built (40 flats and 4 shops).

Existing and refurbished buildings were of two types: with concrete structures and with brick structures. In existing building not affected by the renewal works, only windows were changed. For refurbished buildings, a refurbishing through a "dry" construction site was used, meaning that the least amount of concrete and mortar possible has to be used. In order to complete the work in a short period of time wide use was made of prefabricated products, e.g. gypsum plasterboards coupled with soundproofing material. Within the dwellings, a ceiling radiant heating system was also installed. The selected option allows the installation of the system without resorting to the demolition of floors and screeds. Instead, for the thermal insulation of the buildings the solution chosen provides the use of a wall cladding system on the external walls. All the internal and external doors and windows were replaced. For new buildings, brick structures with external thermal insulation and radiant floating floors were chosen. In figure 13.19 the average performance of building elements is shown.

In the years 2011-2012, the COST TU0901 questionnaire [13] was distributed in existing buildings (not affected by the renewal or before the renewal), in renewed buildings and new buildings, in these two last cases after at least a year of residence. All renewed and new buildings were completely acoustical tested before tenant occupation; some of the existing buildings were not tested but they are identical to renewed buildings, tested before the beginning of works.

Questionnaires were submitted personally door to door. This form of distribution was chosen in order to have a higher percentage of response from residents. For the data analysis it is important to take into account that most tenants are retired women over 65 year old or housewives.

Extensive data were obtained from the comparison between the results of field measurements with the answers to the questionnaires. The complete analysis can be found in [14]. An interesting observation that can be derived from this analysis concerns the acoustic performance of building elements that lead to 0% of people disturbed by noise as extrapolation of data trend line.

In figure 13.20 results are given as average values of performances for people with a disturbance rate higher or equal of a certain level (subjective score higher or equal to 3, 5 and 8, where higher scores correspond to higher disturbance).

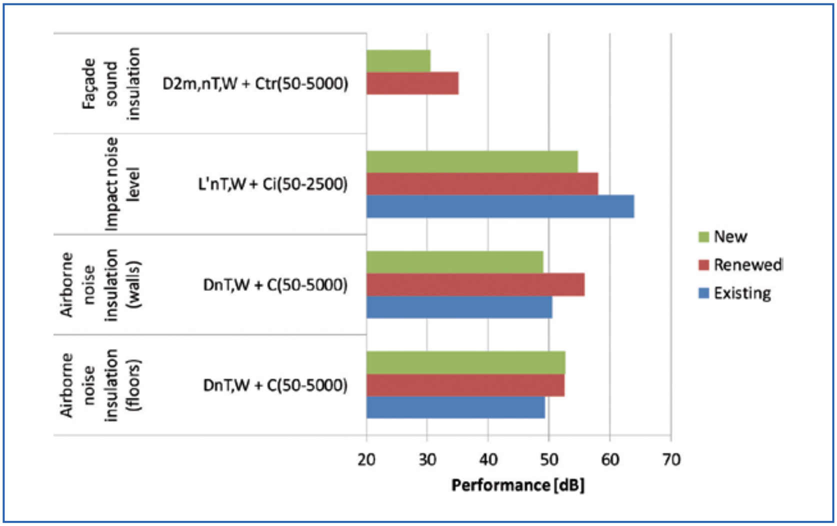


Figure 13.19. *Average performance of building elements for the dwellings involved in the survey project (field evaluation and questionnaire).*

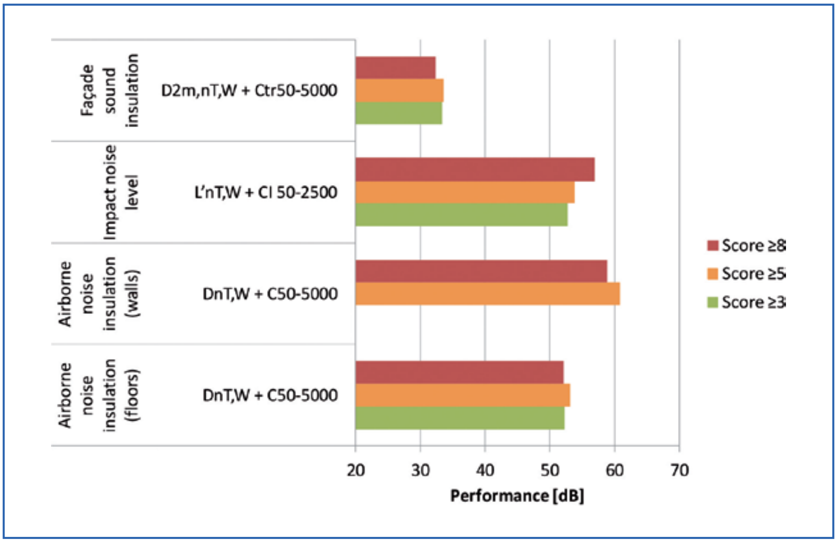


Figure 13.20. *Values of building elements acoustic performances theoretically giving a percentage of disturbed people equal to zero for a subjective score higher or equal to 3, 5 and 8 (higher scores correspond to higher disturbance) in the dwellings under test.*

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