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Sampling strategies for the verification of acoustic performances of buildings

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Summary

The acoustic classification of buildings has been implemented in recent years in many European countries but a methodology for the verification of acoustic requirements in new and existing buildings has been defined only in few of these countries. The proposal of the new standard ISO/DIS 19488 on the acoustic classification of dwellings describes two alternative verification procedures; one is based on calculations, visual inspections and field measurements, while the other is based only on field measurements. In this second case, at least a sufficiently representative 10% of all types of construction of separating walls and floors must be measured. Some countries have defined a specific procedure for the field measurements; in the case of Italy, there are two national standards which deal with the procedure of classification and the sampling methods.

In the paper a comparison between the sampling procedures is shown.

The examples of application of the different procedures will refer to a case study representative of typical constructions.

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1. Introduction

The classification of a dwelling or a residential building is usually based on sample measurements.

Indeed, the number of measurements that should be carried out in a building, for each acoustic descriptor, is very large, including all vertical and horizontal internal partitions, all façades and all equipment. Therefore, these measurements would be too expensive and excessively time-consuming. The main problem when dealing with sampling procedures in building acoustics is that the acoustic performance of a building component is strictly dependent on workmanship effects. For example, the acoustic performance of a floating floor, expressed as the reduction of impact noise, is strongly affected by the continuity of the elastic layer along the entire extension of the floor, but also by the type of paving (wood, ceramic, cement or other) and by the type of junction between the skirting and the paving. For this reason, it is usually very risky for an acoustician to carry out only a small number of measurements and consequently declare the conformity of the entire building.

Acoustic classification standards give some recommendations for this purpose, usually in the form of recommendations for the selection of a sample of building components for which expectations in term of acoustic performance are lower.

In this paper, the procedure given by the international standard ISO/DIS 19488 [1] and by the Italian standards UNI 11367 [2] and UNI 11444 [3] are compared and an example of application is shown.

2. Comparison between sampling methods

The sampling procedure given by ISO/DIS 19488 is quite different form that described by the Italian standard UNI 11367. Indeed, in both cases 10% of measurable elements (internal partitions, façades and equipment) need to be measured; however, in the case of ISO, this percentage refers to all types of elements, while in the case of Italian standard the percentage refers to each homogeneous group of building elements. Therefore, the number of elements that need to be measured is quite different in the two cases. In this paper, the comparison between these two approaches is described with reference to a case study.

A stricter procedure is described in the Italian standard UNI 11444. This standard describes the procedure to select the "worst case" in a sample of measurable building elements. Also in this case the selection of a minimum of 10% of the building units is required and, for the selected building units, all internal partitions, façades and equipment must be measured.

2.1. The procedure provided by ISO/DIS 19488

ISO/DIS 19488 is the draft of a standard on the acoustic classification of buildings, proposed by technical Committee 43/SC 2 of ISO, which was approved in December 2017 with 75% of the members' votes, while Austria, Hungary, Italy, Norway and Switzerland voted against it.

According to ISO/DIS 19488, the acoustic classification of dwellings must be based on a number of measurements to characterize each aspect of the acoustic class in the completed building or unit.

Two alternative verification procedures are described:

- procedure "A": verification by calculations, visual inspections and field measurements (in this case the number of measurements may be reduced);
- procedure "B": verification by field measurements only.

In the case of verification by field measurements (procedure "B"), **at least 10% of the types of construction of separating walls and floors,** to be measured in the completed building, must be selected in such a way that they are sufficiently representative of the unit. Both a large room and a small room are normally selected in each dwelling.

It is recommended to select rooms or partitions with lower expected results, such as partitions with critical flanking constructions or unfavorable locations in the building (rooms next to a mechanical room, busy road etc.). Moreover, more measurements may be selected if there are reasons to believe the performance may vary between units.

All measurement results need to meet, in principle, the limit values of the class in question. However, **compliance is also granted if the average results comply with class limits and no individual result deviates adversely by more than 2 dB**. In very small rooms ($V \leq 25$ m^3), a further 2 dB adverse deviation in the airborne and impact sound insulation are acceptable, if the single number value is determined by the performance in the frequency range 50−80 Hz.

2.2. The procedure given by UNI 11367

The procedure described by UNI 11367, applicable to buildings with repeated elements (called from now serial buildings), involves the identification of homogeneous groups for each requirement, in terms of element type and dimensions, test rooms dimensions and installation techniques.

Specific indications for the definition of the homogenous groups are listed below; a homogeneous group is defined when the identity is verified on the following aspects:

- façade sound insulation: window/door type and configuration, total façade surface, volume and dimensions of the receiving room, windows/doors surface and dimensions, etc;
- airborne sound insulation of internal partitions (walls and slabs): partition surface and dimension, volume and dimensions of the receiving room, type of partitions (materials, mass, etc), boundary conditions, etc;
- impact sound insulation: floor type plus same parameters described above;
- noise from service equipment: equipment type and features, operating conditions, system distribution of the equipment inside the building, volume and dimensions of the receiving rooms, etc.

Regarding the elements and room dimensions, a 20% tolerance is allowed.

For every homogeneous group **at least 10% of elements** (with a minimum of 3 elements) are identified to carry out measurements. In the case of residential buildings, homogeneous groups should be composed of elements belonging to different dwellings.

Within each homogeneous group, the arithmetic mean of each requirement and the corresponding sampling uncertainty is calculated.

The sampling uncertainty is related to the sampling standard deviation s_{sh} and the coverage factor k.

$$U_{sh} = s_{sh} \cdot k \,[\mathrm{dB}] \qquad (1)$$

The coverage factor k depends on the confidence level and on the number of measurements.

The “representative value” of the performance of each homogeneous group is obtained by adding (for insulations) or subtracting (for impact and equipment noise) the uncertainty to the averaged value.

Then, 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.

The application of the sampling procedure for serial buildings, with a large number of very similar properties (such as hotels or large residential areas with repeated buildings), could strongly reduce the number of measurements.

For non-serial buildings, with many building units whose elements do not repeat so often, the sampling procedure does not sufficiently limit the number of measurements. This is the case of the majority of residential buildings in Italy, with a small number of homogeneous technical elements and thus a high number of homogenous groups with a consequently high number of measurements.

2.3. The procedure provided by UNI 11444

UNI 11444 is a national standard, published in 2012, which concerns the acoustic classification of building units. It contains the guidelines for the selection of building units in non-serial buildings and refers, with simplifications, to the classification procedure given by UNI 11367.

The procedure given by UNI 11444 requires the selection of the most critical building units according to specific criteria given for each requirement.

A minimum percentage of 10% of building units (or dwellings) must be selected (with at least 2, for buildings with no more than 4 units, and 3, for buildings with up to 30 units). In each selected building unit, the requirements of all internal partitions and façades and of all the equipment must be measured according to the procedure given by UNI 11367.

The units that must be selected are those with more critical conditions (lower acoustic performances expected) with reference to the different requirements to be measured. The standard gives also indications for the selection of the more critical units.

It must be noted that the final acoustic classification of the building will be referred only to the building units that have been measured, while for the other units it is under the responsibility of the construction company to extend the results of the acoustic classification.

3. Application to a case study [4, 5]

The case study considers the acoustic classification of a building using the Italian standard UNI 11367, considering a number of measurements progressively larger starting from the elements with the expected lower values. In this paper, the results of the measurements refer to the acoustical parameters considered in UNI 11367; the conversion to the parameters used in ISO/DIS 19488 standard has not yet been prepared.

The case study is a small tower building, composed of 24 flats, distributed on six floors included the ground floor (used as entrance), with basements and technical plant and the attic used as a loft for the apartments on the fifth floor.

The building is composed as follows:

- 1st and 2nd floors with 6 flats each (total 12 flats) (figure 1);
- 3rd, 4th and 5th floors with 4 flats each (total 12 flats);
- the dwellings on the 5th floor are equipped with a loft.

The net area of the dwellings on the 1st and 2nd floors is approximately 50 m^2.

The net area of the dwellings on the 3rd and 4th floors is approximately 80 m^2.

The net area of the dwellings on the 5th floors is about 103 m^2, included the loft.

Regarding the adjacency among bedrooms and living rooms with noisy rooms (bathroom, kitchen) or technical rooms (lift, service equipment, etc.) the situation is the following:

- the lift is in contact with closets or corridors and therefore it is not expected to be critical;

- on the 1st and 2nd floors the bathrooms are in contact with two living rooms and bedrooms (four rooms);
- four apartments have both acoustic problems described above.

Finally, also the staircase is in contact with closets or corridors and therefore it is not expected to present any problems.

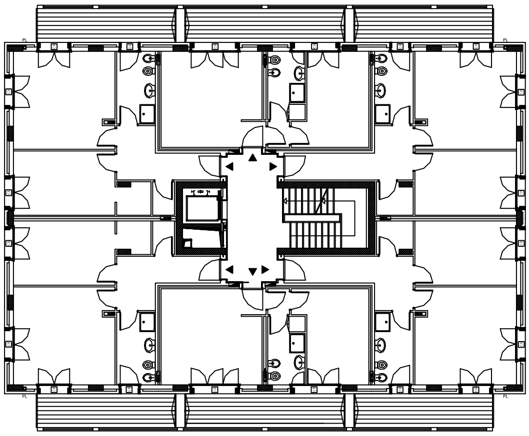

Figure 1. First floor of the building (case study) with six flats.

In the case of ISO, at least 10% of each type of separating wall and floor should be measured in the completed building. In our test case, the minimum number of measured partitions considered for the classification was approximately 20 % of the total measurable elements, but the approach was very similar with respect to the procedures considered in the ISO/DIS 19488.

In particular, for façades and floors, where there is usually a large number of elements to be measured, we selected 20 % of the global number of measurable elements. In the case of Sound Reduction Index of internal vertical partitions, considering the lower number of measurable elements, we selected 30 % of the different partitions. For the Sound Reduction Index of floors, since results of measurements are usually less dispersed, we selected 10% of the elements. Finally, for equipment noise (noise from bathrooms and lifts), considering the large dispersion of results that usually affects this kind of measurements, we selected 30% of the elements.
The number of element to be measured considering the above criterion similar to the one considered by ISO/DIS 19488 and the sampling criterion referred to UNI 11367, compared with the total number of measurable elements, is reported in table II. It can be noted that the proposed criterion determines a considerable decrease in the number of measurements with respect to the sampling procedure of UNI 11367 (from 128 to 56), especially for airborne sound insulation and impact noise level.

About 70% of the façade insulation tests, all the airborne noise insulation tests of walls, and about 70% of the impact noise level tests were carried out in the building system in question. The tests on the remaining parameters (airborne sound insulation of floors and noise from equipment) have been far fewer and for this reason have not been taken into consideration in the test case.

The first step was the identification, for each requirement, of all the measurable technical elements of the entire building system and the subsequent arrangement of the same according to the critical order. The objective was to verify that the progressive increase in the technical elements considered, chosen starting from the most critical, resulted in a progressive improvement in the determination of the results and of the acoustic class for each requirement.

The following tables (tables III, IV, V) show the results of this calculation, indicating the scale from lower to higher expected performance, the number of technical elements measured, the energy averaged index relating to each group, the respective range of results, the progressive average index and the progressive acoustic class (calculated by gradually adding the results obtained with the previous groups).

The results related to the façade sound insulation showed that the worst case was the façade with a French-door with three panes. For the rest, the increase in the number of technical elements considered in the average did not lead to a progressive improvement in performance. It must be considered that in the case study the differences between the various groups of technical elements are not evident and therefore the effect of the regulation of the correct mounting of the windows determined a stabilization of results.

With regard to the airborne sound insulation of vertical walls, an improvement in performance was observed, moving from the most critically considered a priori situations to increasingly less critical situations. This improvement also involved

a jump in class, moving from class IV to class III, approaching class II.
With regard to the impact sound level, a progressive improvement in performance was observed, moving from more critical situations to less critical situations. The improvement also concerns the acoustic class: we move from class IV to class II and, as expected, the biggest difference is in the transition from ceramic flooring to parquet flooring (improvement of about 10 dB).

The analysis of this case study shows that the progressively precautionary criterion for the selection of the samples is verified particularly for the impact sound level but also for the airborne sound insulation. The application to the façade sound insulation strongly depends on the regulation of the frames: only if all the windows of a building system are regulated in an accurate way, is it probable that the order of criticality has actually been verified.

Table I. Limit values of airborne and impact sound insulation between dwellings and against exterior noise according to UNI 11367 [2].

	Class I	Class II	Class III	Class IV
Airborne sound insulation between habitable rooms in a dwelling and rooms outside the dwelling, both in the horizontal and vertical directions	$R'_w \geq 56$	$R'_w \geq 53$	$R'_w \geq 50$	$R'_w \geq 45$
Impact sound pressure level in habitable rooms in dwellings from other dwellings, both in the horizontal and vertical directions	$L'_{nw} \leq 53$	$L'_{nw} \leq 58$	$L'_{nw} \leq 63$	$L'_{nw} \leq 68$
Façades sound insulation of habitable rooms in dwellings	$D_{2m,nT,w} \geq 43$	$D_{2m,nT,w} \geq 40$	$D_{2m,nT,w} \geq 37$	$D_{2m,nT,w} \geq 32$

Table II. Comparison between the number of measurable elements by applying the different procedures of classification.

Requirement	$D_{2m,nT}$	R' walls	R' floors	L'_n	L_{id}	TOTAL
Total number of measurable elements	76	16	68	56	60	276
Number of measured elements according to UNI 11367	21	9	36	26	36	128
Number of measured elements according to ISO/DIS 19488 (with increased percentages)	15	5	7	11	18	56

Table III. Results of the measurements for the façade sound insulation index, ordered from the lower to the higher expected performance (criterion progressively precautionary) and correspondent acoustic class (UNI 11367).

From lower to higher expected performance	Number of elements	Average $D_{2m,nT,w}$ For each group [dB]	Range $D_{2m,nT,w}$ [dB]	$D_{2m,nT,w}$ Progressive results [dB]	Progressive acoustic class (UNI 11367)
1 – Façade with a French-door with three panes	4	35.1	33.8 – 40.8	35.1	IV
2 – Façade with 2 French-doors with two panes	18	39.0	36.5 – 41.1	38.0	III
3 – Façade with a French-door with two panes without balcony	19	36.9	34.1 – 39.4	37.4	III
4 – Façade with a French-door with two panes with balcony	11	36.4	33.1 – 38.5	37.2	III

Table IV. Results of the measurements for the airborne sound reduction index of vertical partitions, ordered from the lower to the higher expected performance (criterion progressively precautionary) and correspondent acoustic class (UNI 11367).

From lower to higher expected performance	Number of elements	Average R'_w For each group [dB]	Range R'_w [dB]	R'_w Progressive results [dB]	Progressive acoustic class (UNI 11367)
1- Double masonry wall with small interspace	4	49.2	47.1 – 51.2	49.2	IV
2- Double masonry wall with larger interspace with passage of piping of the plants	6	53.8	52.5 – 54.5	51.3	III
3- Double masonry wall with larger interspace without piping	6	55.3	54.7 – 56.5	52.4	III

Table V. Results of the measurements for the impact sound level index, ordered from the lower to the higher expected performance (criterion progressively precautionary) and correspondent acoustic class (UNI 11367).

From lower to higher expected performance	Number of elements	Average $L_{n,w}$ For each group [dB]	Range $L_{n,w}$ [dB]	$L_{n,w}$ Progressive results [dB]	Progressive acoustic class (UNI 11367)
1 – ceramic flooring	4	66.1	55.2 – 68.1	66.1	IV
2 – parquet flooring with 2 French-doors on the source room	14	55.8	51.3 – 59.1	60.8	II
3 – parquet flooring with 1 French-door on the source room which is irregularly shaped	6	54.2	53.2 – 55.3	59.8	II
4 – parquet flooring with 1 French-door on the source room which is regularly shaped	10	54.5	48.7 – 59.3	58.8	II

4. Conclusions

The aim of this article was to highlight the problem of applying the sampling procedure for the acoustic classification of residential buildings. Two procedures, based on a different number of technical elements to be measured for each acoustic requirement, were considered and compared with the number of all the measurable elements. The first criterion refers to the procedure described by the Italian standard UNI 11367, while the second to the one described by ISO/DIS 19488. In this case, measured elements were selected according to an order of criticality based on progressively precautionary expected acoustic performances. By applying the criterion in a case study of a tower building composed of 24 flats, it was shown how the result of the acoustic classification could change considering a progressive increase in the number of measured elements.

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