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GRADING SYSTEM FOR DWELLINGS ACOUSTIC PERFORMANCE IMPLEMENTED IN FRENCH HOUSING QUALITY CERTIFICATION

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ABSTRACT

The QUALITEL group is the French association for housing quality, and manages the NF Habitat and NF Habitat HQE certifications. QUALITEL has developed many years ago its own grading system for dwellings acoustic performance, while the international classification technical specification (ISO/TS 19488) and the French single acoustic indicator were discussed. A classification scheme is a good idea to inform the public about building acoustics and an interesting tool for customers to compare products and more generally for the general public and non-specialists building stakeholders. The QUALITEL label grading is composed of two indicators. The first one concerns the acoustic outdoor quality of the building environment; it allows to evaluate outdoor spaces such as balconies or gardens and also reflects the importance of exterior noise in the dwellings when the windows are open. The second one concerns the building acoustic indoor quality ; it allows to evaluate the protection against outdoor noise, noise from neighbors, and service equipment. This article focuses on the second indicator about the building performance and describes how it is obtained and compares this evaluated grade to the inhabitant's satisfaction rate, obtained with surveys. Some examples on real buildings are presented and compared with ISO/TS 19488 classification.

Keywords: *acoustic performance, classification, dwellings, acoustic quality, comfort.*

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1. INTRODUCTION

In France, since the beginning of the 90s, the GIAc (Groupement de l'Ingénierie Acoustique) representing the acoustic engineering consultants companies, has worked on defining the acoustic performance of a building [1]. The method is based on the acoustic situation analysis of the building: a certain activity in a room generates noise that could be problematic in another room depending on the activities taking place there. The goal is to best adjust the acoustic performances to the different activities taking place in the building. A level of noise aggression and a tolerance level are defined for each room; correction terms are introduced depending on the type of noise sources and sensitivity level with respect to the reception room type. This method allows obtaining a balance between the different insulation levels as a function of the noise sources.
Another French work [2] investigated and proposed an acoustic classification of different types of buildings. The goal was to have similarly to energy performance of building a classification of the acoustic performance from A (very good) to F (very bad) for example that would be easily understandable by a common person. For dwellings, the medium class C of acoustic comfort was set to correspond to the level of the French acoustic regulation.
Based on the work carried out during in the European COST Action "Integrating and Harmonizing Sound Insulation Aspects in Sustainable Urban Housing Construction" [3], an international technical specification ISO/TS 19488 [4] specified a classification guideline to evaluate acoustic quality of dwellings. The acoustic quality for a dwelling is evaluated based on the acoustic performances typically included in building regulations, e.g. sound insulation towards neighboring premises and road traffic as well as sound from service equipment. Sound insulation and room acoustics internally in a dwelling are not included in the acoustic classes defined.

Following theses different investigations, The QUALITEL group as the French association for housing quality, which manages the NF Habitat and NF Habitat HQE certifications, also decided to develop its own grading system for dwellings acoustic performance. The Building Acoustics Quality (BAQ) index has been elaborated in order to reflect the satisfaction rate of dwelling inhabitants; it is adapted to fit the acoustic performance associated to French regulation and QUALITEL certification [5]. The method is based on a 6-level classification, from A+ (the highest grade) to E (the worst grade) defined on the basis of a number of points related to acoustic performances. The HQE (High Environmental Quality) entry level for QUALITEL NF Habitat certification corresponds to class B (80 points), and the French regulation for new buildings is class C (73 points).

The old residential buildings are generally positioned on C, D and E levels, where E corresponds to exceptional situations of very poor acoustic quality.

Since the A level corresponds to a high quality level that does not guarantee the absence of acoustic discomfort, an A+ level was introduced for very high quality buildings or single family detached houses.

The main objective of the BAQ index is to actually represent the occupant satisfaction rate with respect to acoustic comfort.

Therefore, the method to obtain the proposed BAQ index is different from the one proposed in the international classification technical specification ISO/TS 19488 [4] as well as the other French proposals [1-2].

Indeed, the classification type in [2 and 4] is, to some extent, based on the worst acoustic scenario, i.e., the worst acoustic performance measured or predicted, regardless of other good acoustic performances reached by the building. For instance, with this type of classification in a single family attached house, if the boiler is noisy, the complete house will be evaluated bad whereas the airborne sound insulation and impact sound insulation from the neighbors might be rather quite high. And people living in single family house (either detached or attached houses) are usually much more satisfied by the acoustic of their living spaces compared to people in multistorey apartment buildings.

On the other hand, a very low noise level from service equipment cannot compensate a bad airborne sound insulation: clearly hearing neighbors, will not be satisfactory although elevators or other service equipment are not heard.

To avoid this problem, a weighting system on the different acoustic performances has been introduced to evaluate the BAQ index, in order to give more impact to bad acoustic performances rather than to good ones.

The method and the different steps to obtain the BAQ index are presented in this paper.

It should be noted that as in ISO/TS 19488, the term ”dwellings” is referring to detached and attached dwelling houses, buildings with several flats as well as individual dwellings, and a dwelling is the living space for a household.

2. BAQ INDEX EVALUATION

2.1 Principle

The BAQ index is a class determined by a number of points between 0 to 100 obtained for the building relative to different acoustic performance levels; this number of points is similar to a satisfaction rate in %. Table 1 indicates the BAQ index as a function of the number of points.

The class, or rather the number of points is evaluated based the acoustic performance for five acoustic aspects:

- airborne sound insulation ($D_{nT,A}=D_{nT,w}+C$ in dB),
- impact sound insulation ($L'_{nT,w}$ in dB),
- façade sound insulation ($D_{nT,A,tr}=D_{nT,w}+C_{tr}$ in dB),
- service equipment noise level ($L_{ASmax,nT}$ in dB),
- reverberation time (T in s) or the equivalent sound absorption area (A in m²) of common access areas.

For sound insulation, all transmission directions are considered (vertical, horizontal, diagonal).

Table 1. BAQ index as a function of obtained number of points for a dwelling.

E	D	C	B	A	A+
≥ 0	≥ 30	≥ 60	≥ 80	≥ 90	≥ 95

For each acoustic aspect, the arithmetic average of all performed measurements (or eventually performed predictions) is computed and the corresponding class is determined, according to the performance class limits with 5 dB steps. Table 2 shows the performance class limits for dwellings for each of the five rated acoustic aspects.

Table 2. Rating of the different acoustic aspects.

Acoustic aspect	E	D	C	B	A	A+
$D_{nT,A}$ between habitable rooms in a dwelling and rooms from other dwellings	< 43 dB	≥ 43 dB	≥ 48 dB	≥ 53 dB	≥ 58 dB	≥ 63 dB
$L'_{nT,w}$ in habitable rooms in dwellings from other dwellings	> 65 dB	≤ 65 dB	≤ 60 dB	≤ 55 dB	≤ 50 dB	≤ 45 dB
$D_{nT,A,tr}$ façades and roofs of habitable rooms in dwellings against exterior noise (1)	< R–10 dB	≥ R–10 dB	≥ R–5 dB	≥ R dB	≥ R+5 dB	≥ R+10 dB
$L_{ASmax,nT}$ in habitable rooms in dwellings from outdoor and indoor service equipment	> 40 dB	≤ 40 dB	≤ 35 dB	≤ 30 dB	≤ 25 dB	–
A or **T** in common access area (2)	A<0,12S T > 2.2s	A≥0,12S T ≤ 2.2s	A≥0,25S T ≤ 1.2s	A≥0,50S T ≤ 0.8s	A≥0,75S T ≤ 0.5s	A ≥ S T ≤ 0.4s

(1) R is the façade sound insulation performance required by French regulation; it is 30 dB as a minimum but can be higher depending on the exterior noise level.
(2) S is the walkable surface of the common access area in m²

Then, a score value is associated to each class rating determined for each acoustic aspects, according to Table 3. It should be noted that Table 3 is similar to Table 1.
The overall ranking is finally evaluated by a weighted arithmetic average of the scores obtained for the five different acoustic aspects. The weights are given in Table 4. This weighting reflects the fact that most of the acoustic aspects are judged to have more impact on the occupant satisfaction than the reverberation time in access area, where people just walk through and do not live in.

Table 3. Correspondence between rating of the different acoustic aspects and points.

E	D	C	B	A	A+
0	30	60	80	90	95

Table 4. Weights for the different acoustic aspects.

Acoustic aspect	Weight
Outdoor airborne sound	2
Indoor airborne sound	2
Impact sound	2
Equipment sound	2
Room acoustics in access areas	1

2.2 Example

To clarify the procedure for BAQ index evaluation, Table 5 presents an example of a calculation based on acoustic measurements performed on a new building.
The first column shows the arithmetic average of different measurements for each considered acoustic aspect.
The calculation leads to a score of 79 points (or 79% of satisfaction with respect to acoustic comfort) and then a Class C for the BAQ index.

Table 5. Example of BAQ index evaluation.

	Averaged measured performance	Acoustic aspect rating (w/ Table 2)	Corresponding points (w/ Table 3)	Weighted points (w/ Table 4)
$\mathbf{D_{nT,A}}$ in habitable rooms from other dwellings	53	B	80	160
$\mathbf{L'_{nT,w}}$ in habitable rooms from other dwellings	45	A+	95	190
$\mathbf{D_{nT,A,tr}}$ in habitable rooms from outdoor	33	B	80	160
$\mathbf{L_{ASmax,nT}}$ in habitable rooms	31	C	60	120
A or **T** in access area	A/S = 50%	B	80	80
		Total of points		710
		BAQ points (Sum / 9)		79
		BAQ index (w/ Table 1)		C

3. BAQ INDEX VERSUS SATISFACTION RATE

An investigation was performed on 11 buildings, denoted A to K. It included of 6 old buildings (A to F) and 5 new buildings (G to K). Three of these old buildings have been refurbished (A, B and F), and acoustic performance was obtained before and after renovation (buildings after renovation are noted "refurb.").

Surveys and measurements have been carried out with a sample rate around :

- 10 to 30% of inhabitants surveyed
- 1 to 10% of dwellings tested.

It should be mentioned that the surveys were carried out on a significant number of occupants (only one occupant per dwelling surveyed) to obtain an "a priori" representative evaluation of the building as a whole; however, the dwellings concerned by the occupants survey do not necessarily match the dwellings concerned by the acoustic measurements.

It should be noted that the number of dwellings concerned with acoustic measurements is usually below the ISO/TS 19488 recommendation which is 10% minimum for verification by field measurements only. For example, the old buildings included up to 480 family apartments, which meant a minimum of 48 dwellings to test in the compliance of ISO/TS 19488. The budget that could be dedicated to the in-situ measurements was indeed not enough to achieve this recommended minimum number of investigated dwellings.

The BAQ index is calculated based on in-situ measurements, according to the method described in Section 2. Note that for simplicity in this paper, the airborne sound insulation and impact sound insultation between common access area and the dwellings have not been considered.

The survey was based on the perceptive questionnaire presented in [6-7] of more than 20 specific questions relative to

- noise and vibration from the neighbors,
- noise from neighbors using common areas (such as hallways, corridors, steps,…),
- noise from service equipment,
- noise from collective areas (such as garages, stores, restaurants, etc..),
- noise from outdoor,
- noise within rooms of the dwelling

and some more general questions (as for example the importance given to sound insulation, the sensitivity to noise, and the general satisfaction with the acoustic

situation). Some questions were adapted relatively to the renovation aspects. In the present work, the satisfaction rate is simply obtained from the ratio of occupants who answer "yes" to the question : "Are you satisfied by the acoustic quality of your dwelling ?".
Figure 1 presents the BAQ index with the corresponding occupant satisfaction rate. The BAQ index and the occupant satisfaction rate are in a relatively good agreement; a correlation coefficient of 78 % is indeed obtained.
However, a difference of around 25 still exists for the C, the refurbished F and the K buildings, which leads to one class difference between the BAQ rating and the satisfaction rate. The BAQ index of old buildings are D or E, and the new ones are D to B.
The BAQ index shows the occupant satisfaction improvements when the buildings have been renovated, except for the F building where only limited refurbishment was performed (with limited improvement of the acoustic performance), but the occupant satisfaction was slightly increased.

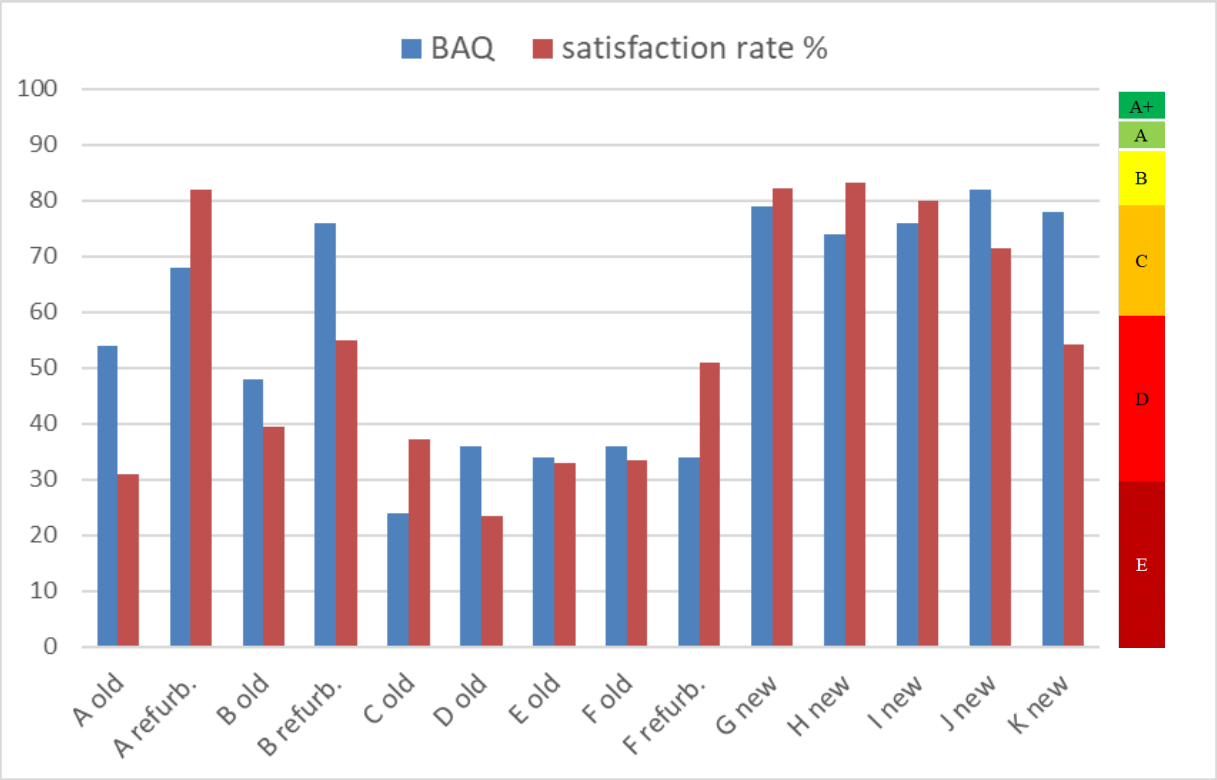

Figure 1. BAQ index for the investigated buildings.

4. ISO/TS 19488 CLASS VERSUS SATISFACTION SURVEYS

The same 11 buildings have been classified following the ISO/TS 19488 procedure. The results for each acoustic aspect are presented in Table 6. As for BAQ index (see Section 3), the airborne sound insulation and impact sound insultation between common access area and the dwellings have not been considered for simplicity. Figure 2 compares the ISO/TS 19488 class and satisfaction rate. The correspondence is approximative since ISO/TS 19488 does not associate a class to a number.
The ISO/TS 19488 gives an APD class (out of class) to most of the French old buildings investigated, and a F class to the A and the E buildings.
The new ones are between F and C. This classification distinguishes old buildings with poor acoustic quality to new ones with better performance.

The new H building is classed F which does not at all follow the occupant satisfaction rate. Indeed, Table 6 shows that the F Class has been determined by the façade sound insulation based on a high L_{den} level, whereas the French regulation for construction does not use such indicator, but other rules which lead to a lower sound insulation. By the way, service equipment noise level is classed E because of a ventilation noise of 36 and 37 dB(A) measured in two dwellings (which indeed exceeds French regulation).
Furthermore, the ISO/TS 19488 classification is not associated to rating improvements when old buildings are renovated except for the A building. However, the important occupant satisfaction increase associated to the A building renovation is not translated into an important improvement of the ISO/TS 19488 classification.

Table 6. ISO/TS 19488 class for the investigated buildings.

	Outdoor sound insulation	Indoor sound insulation	Impact sound level	Service equipment noise level	Reverberation	Global Class
A old	E	D	F	F	B	F
A refurb.	E	D	D	B	B	E
B old	F	APD	APD	D	D	APD
B refurb.	E	APD	APD	B	B	APD
C old	APD	E	APD	F	APD	APD
D old	F	APD	APD	E	D	APD
E old	E	D	D	F	D	F
F old	APD	E	APD	D	APD	APD
F refurb.	APD	E	APD	C	APD	APD
G new	C	C	B	C	B	C
H new	F	B	B	E	B	F
I new	B	B	D	D	B	D
J new	B	B	B	C	B	C
K new	C	B	B	C	B	C

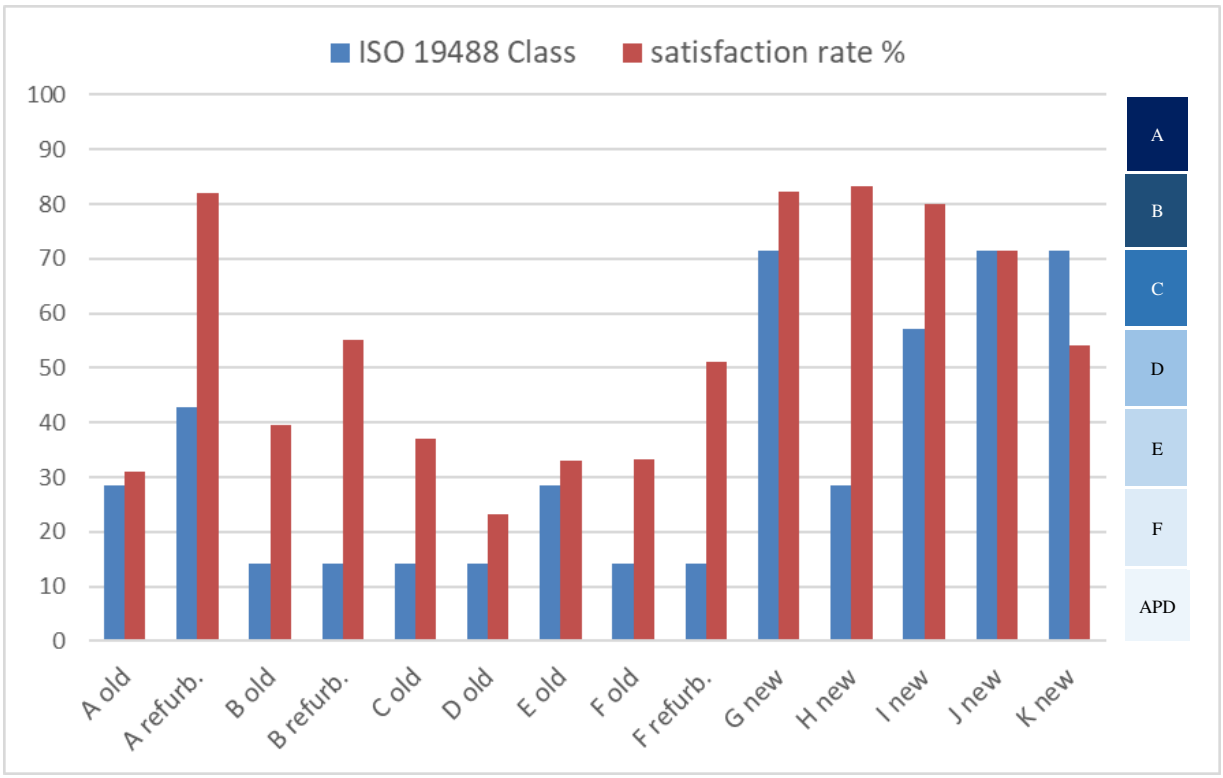

Figure 2. ISO/TS 19488 class for the investigated buildings.

5. CONCLUSION

The method to evaluate the Building Acoustics Quality (BAQ) index developed by QUALITEL has been presented.

The BAQ index was compared to occupant satisfaction relative to acoustic comfort for 11 investigated buildings, including new, old and renovated buildings.

A relatively good agreement was found between BAQ index and the declared occupant satisfaction relative to the acoustic comfort. Improvements on buildings due to renovation are shown by BAQ index and correlated by the occupant satisfaction rate.

The same buildings were also evaluated using the ISO/TS 19488 classification. The obtained class did not match well with occupant satisfaction rate. This is due to the fact that a single bad measured performance can degrade the global grade associated to the building. However, it is important to note that the ISO/TS 19488 classification was not necessarily developed to fit to satisfaction rate of the building occupants with respect to their acoustic comfort. Indeed, its purpose was rather intended to make it easier for building developers and/or authorities, willing to specify a classified level of acoustic quality for dwellings.

Furthermore, it should be emphasized that the BAQ index is not really used by building developers, because they are not interested in showing B, C or D levels for their new buildings; indeed, A or A+ BAQ index would be better for commercial reasons but remains too expensive (in terms of construction costs) as an objective, so they say. Nevertheless, its use with respect to building refurbishments is more attractive and will definitely be developed in the near future in NF Habitat Certifications of QUALITEL.

6. ACKNOWLEDGMENTS

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