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"The Acoustic Classification System in Norway. Overview and some conclusions after more than 20 years experience."

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ABSTRACT

The building code in Norway is referring since 1997 to a standard for acoustical requirements in buildings, NS 8175 "Acoustics conditions in buildings – Sound classification of various types of buildings". The standard uses a system of four classes for the requirements, A to D, where Class C in mandatory to fulfil when the building code applies. NS 8175 is used systematically in building projects and has been reviewed several times since the first issue, incorporating for instance comments from hearing processes and changes in the law regarding universal design. After all these years of systematic use, it might be time to summarize the experience. The author presents his view on the achieved acoustical quality in buildings, the positive and constraining aspects of using an extensive standard, the relevance of classes and possible improvements to the standard.

Keywords: Building acoustics, sound classification, standard
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1. INTRODUCTION

The Norwegian building code "*Regulations on technical requirements for construction works"* was changed in 1997 and the standard NS 8175 "*Acoustics conditions in buildings – Sound classification of various types of buildings*" was introduced. The building code establishes that acoustical and vibrations conditions must be satisfying in buildings. Sound conditions are assumed to be satisfying when limit values for class C in NS 8175 are fulfilled.

NS 8175 gives limit values for acoustical conditions such as sound insulation, impact noise, room acoustics, noise from technical equipment, in a variety of building types (dwellings, schools, offices, hospitals and more).

The author, based on his experience as a consultant in acoustics, presents his view on the achieved acoustical quality in buildings, the positive and constraining aspects of using an extensive standard, the relevance of classes and possible improvements to the standard.

2. DESCRIPTION OF NS 8175

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NS 8175 must be used for new buildings but also when renovating or changing function of existing buildings. In fact, every work that necessitates a construction permit is subjected to NS 8175.

NS 8175 gives limit values for acoustical conditions in dwellings, schools, kindergarten, hotels, hospitals, offices, restaurants, transportation buildings (train stations, airports etc.), commercial centres, culture buildings (museums, library, swimming halls), laboratories and workshops / industrial halls.

Limit values are given for sound insulation, impact noise level, room acoustics (reverberation time and/or average sound absorption coefficient), noise level from technical equipment (both indoor and outdoor) and indoor noise level for external noise sources (typically transport noise).

Limit values are divided in four sound classes defines as follow:

- Class A: Corresponds to very good acoustic conditions in which exposed people will only exceptionally be able to notice sound and noise.
- Class B: Corresponds to good sound conditions, but exposed people may be disturbed by sound and noise to a certain extent.
- Class C: Corresponds to satisfactory sound conditions for a large proportion of exposed people. Class C are minimum requirements according to the building code.
- Class D: Corresponds to sound conditions in which a great share of exposed people can be expected to be disturbed by sound. Limit values for class D can be used for renovation projects when technical unfeasibility or prohibitive costs limit achievable acoustical conditions.

Limit values are presented in table form throughout the standard. Limit values for sound insulation in dwellings are presented in Table 1 below as an example.

Table 1 – Limit values for field sound insulation in dwellings according to NS 8175

Type of room	Class A $R'_w+C_{50-5000}$ [dB]	Class B $R'_w+C_{50-5000}$ [dB]	Class C R'_w [dB]	Class D R'_w [dB]
Between dwellings	63	58	55	50
Between dwellings and commercial areas, garage	68	63	60	55

The limit values in NS 8175 are based on inquiries about annoyance for users, scientific literature, relevant standards and feed-back given by users during hearing process. The class C limit values aim at no more than 20% of the users will be annoyed or very annoyed (cumulative) when annoyance curves are available.

It worth noting that all the limit values in NS 8175 are for field conditions, including for instance flanking transmission.

As every standard, NS 8175 is written by specialists of the field and is submitted to revision every five years with a hearing process where other specialists are involved. That insures that limit values are scientifically sounded and that new researches and comments from practitioners are likely to be implemented within a relative short time. This a certainly an advantage compared to having limit values directly in legal texts which are written by lawyers and have a far more complex and slow revision process.

3. EXPERIENCE USING NS 875

3.1. Design phase

NS 8175 is used in the design phase for dimensioning and as reference when checking acoustics conditions following complaints.

With very few exceptions, buildings are designed according to class C requirements. Exceptions are typically luxurious dwellings with class B sound insulation and impact noise, but these are very rare. Apparently, when the supplementary costs are compared to the advantages of having better acoustical conditions (more satisfied users, supplementary point in BREEAM for instance), the balance leans almost always on the same side.

Although very comprehensive, NS 8175 doesn't provide limit values for every type of room or use. Some examples of room without requirements for sound insulation: group rooms or classrooms with a communicating door in schools, quiet rooms in offices, and WC in general. Limit values must then be specified by the designing acoustician in order to fulfil the building codes's main intention of having satisfying sound conditions.

Limit values that are not readily written is NS 8175 are however quite often challenged by the constructor or the building owner as a mean to reduce construction costs. That puts the designing acoustician into an uncomfortable situation: to accept marginal or even insufficient solutions from his client while still taking responsibility for the acoustical conditions in the eye of the law. This is also against the intention of the building code that acknowledges class C limit values in NS 8175 as a base and not as exclusive and restrictive means to achieve good acoustical conditions.

Certain adjustments to class C limit values must also be done when proved to not be achievable like sound insulation between classrooms with folding walls.

The strict limits to reverberation time in room like auditoriums can create unwanted conflict with the wish of using the room without sound reinforcement. It also can be complicated to meet the limit value for reverberation time in classrooms and open offices as much area for absorption is needed on walls while glass tends to be used profusely in facades and partitions.

3.2. Field experience

Although recommended in the standard, it's not common to perform control measurements to verify the compliance of the buildings with the regulation. The experience cases below are then mostly based on measurements performed by the author following complaints from the users.

According to the author's experience, impact noise is by far the mean reason for complaints in dwellings. This is confirmed by a recent study [1] that showed that as much as 39% of the inhabitants of dwelling buildings are moderately to very annoyed by impact noise. The study also showed that the annoyance is correlated with low frequencies as the annoyance is important even though the mean impact noise measured from 100 to 3500 Hz in the controlled dwellings is 4 dB below the limit value in NS 8175 ($L'_{n,w}$ 49 dB vs 53 dB). As consequence, the spectrum adaptation term $C_{I50\text{-}2500}$ will be added to the class C limit values for both impact noise and sound insulation in the coming version of NS 8175. With these new limit values, it is expected that the annoyance (cumulative very annoyed and annoyed) will be reduced to 20% and 10% for impact noise and sound insulation respectively.

Acousticians are requested to perform measurements of traffic noise in dwellings, but in a far lesser degree then impact noise and sound insulation. This is in contrast with a large-scale study [2] conducted by the Norwegian *Directorate for quality of buildings* DIBK. According to the received questionnaires from more than 700 residents in dwelling blocs, annoyance from traffic noise is as important as annoyance from impact noise. The study concludes meanwhile that there is no reason to change the limit values in NS 8175 as they are in accordance with recommendations from WHO which are thoroughly documented.

Commercial areas in the first floor of dwelling buildings do not normally pose problems unless they are training centres. The low frequencies from the music and sometimes vibrations from dancing people or weights being dropped almost systematically cause annoyance to residents living above. NS 8175 has a note saying that this dual use should be avoided and if not, that limit values for technical equipments should be applied. Although restrictive, these limit values do not seem to be sufficient as many residents still complain even though NS 8175's requirements are fulfilled.

In kindergartens and schools, many complaints concern reverberation. They are however often the results of class C requirements not being meet. It is not clear from the author's experience whether these nonconformities are the result of insufficient design or changes made to the design in the construction phase without an acoustician being involved.

NS 8175 sets severe limit values for ventilation noise, but, because of the requirements for good energy efficiency, ventilation systems are designed with low air speed which gives in turn low noise levels.

Noise from activities are the most common complaint in open plan offices. This, even though NS 8175's severe limit values for reverberation time are met. Lack of sufficient sound insulation is also a common complaint, but it is most of the time the result of design or execution errors, typically flanking transmission through glass curtain facade profiles or through the ceiling tiles.

Hospitals are seldom subjected to complaints about sound conditions although, according to the author's experience, doors in patient rooms very often stay open day and night.

Restaurants are often suffering from lack of sound absorption and are therefore noisy places which are especially unsuited for people with hearing impairment. One reason for this in many cases is that the decoration works in existing restaurants usually aren't submitted to the building code and then to NS 8175.

3.3. Considerations about requirements

Limit values for room acoustics in NS 8175 appear to be based on the principle of signal to noise ratio to reach intelligibility. The shorter the reverberation time is and the lower the noise level is, the better the intelligibility should be. However, a short reverberation time often creates impairing effect on intelligibility as distinct sound reflections appear when sound absorption isn't evenly distributed. This is mostly the case in classrooms with extensive use of glass in the facade and the partition to the corridor.

NS 8175 states also a minimum requirement to intelligibility in open classrooms of STI $\geq$ 0,70. This is implying that the teacher addresses the students as in traditional classrooms while this kind of open classrooms are mostly used to parallel work in smaller groups.

A short reverberation time and low ventilation noise appear also to be detrimental for acoustical conditions in open plan offices as recent study [3] shows. According to this study, annoyance in open plan offices is mostly related to disturbances caused by too good intelligibility and too low distraction distance rather than too low special decay. Limit values in NS 8175 are in this view going the wrong way with shorter reverberation time and lower noise level for each class.

Nowadays, schools and offices are designed with flexibility of use being a core feature. Folding walls and rooms for group work or informal conversations are very common. This flexibility of uses is not yet implemented in NS 8175 as theses uses are not mentioned. Furthermore, certain requirements to sound insulation are not technically achievable like when classrooms are connected with a door or a folding wall.

As limit values are stricter for each class, one reaches soon a technical or economical limit to what is practical to achieve. An example to that is the limit value for ventilation noise in classrooms as low as $L_{p,A,T} \leq 22$ dB and 25 dB for class A and B respectively. Another example is reverberation time for class B limited to 0,3 seconds in kindergartens. Yet an example is class A limit values for sound insulation and impact noise in dwellings which require almost a box in box construction.

Questions can also be raised about how adapted to the use some limit values are. As mentioned above, very short reverberation time and very low ventilation noise do not necessarily provide better acoustical conditions. Another example is limit values to impact noise and sound insulation in hospital. The author personal experience is that doors in patient rooms are often kept open and that there's not much impact noise as the staff and the patients are wearing shoes for comfort with soft soles. The use of somewhat soft floor covering is furthermore in contradiction with the specification of ease of rolling in hospitals and are not accepted by the users' representants.

The answer from the marked to the feasibility and necessity of class A and B is clear: with very few exceptions, buildings are designed and build according to class C limit values. For that reason, one could conclude that class C limit values are satisfying for a sufficient number of users. In the other hand, complaints from users indicate that some issues like impact noise in dwellings and annoyance in open plan offices aren't properly addressed by NS 8175.

4. PROPOSALS

It should be stated more clearer in the Building code that the limit values in NS 8175 are not the only limit values to be considered but rather a base to be extended and adapted to each project by a professional acoustician in order to achieve satisfying acoustical conditions for a great majority of users.

Control measurements on a sample of rooms should be made mandatory in the Building code as this measure would insure better follow up in the construction phase. Wrong execution and unfortunate changes to design would be reduced, insuring better quality of the buildings.

To use classification of acoustical conditions in buildings makes sense to rank existing dwellings. It is certainly a good mean to inform potential buyers of the quality of the dwelling and if, for instance, renovation works would be required to reach a good standard. It can also give the Authority and oversight of the quality of the dwellings in a city or at a larger scale.

It is however less obvious that sound classes are relevant when the regulation aims at 80% or more of the users being satisfied as:

- Complaints are limited to specific acoustical conditions and in certain types of building. These specific problems could be addressed by more suited class C limit values.
- A technical or economical limit is often reached when using limits values that are stricter than class C.
- Limit values for class A and B do not necessarily provide better acoustical conditions, especially in the case of room acoustics.

For these reasons, the systematic use of sound classes for every type of building and acoustical condition does not make much sense. Therefore, the author proposes to have only mandatory requirements in NS 8175 with guidelines and recommended limit values in annex when one wishes to achieve superior acoustical conditions.

Low frequencies from impact noise in dwellings are definitely a problem. The author support therefore the proposal in the current hearing version of NS 8175 to include the spectrum adaptation term $C_{I50\text{-}2500}$ in the class C limit value.

The limit values for open plan offices should be focused on intelligibility, or the lack of it, rather than noise level.

Limit values for noise levels from training centres and the like should be expressed as relative to the background noise measured in the dwelling rather than as absolute values since disturbance is resulting from the perceived difference with the background noise.

5. CONCLUSIONS

The systematic use of NS 8175 has resulted in good acoustical conditions in buildings in Norway in general, though to a less satisfying degree in dwellings.

Although NS 8175 includes four different sound classes, almost only the mandatory class C is used.

Complaints seem to be both the result of not totally appropriate limit values for certain acoustical conditions and the lack of systematic follow up and control measurements in the construction phase.

Some proposals are made to improve the resulting acoustical conditions in the buildings. In the view of the author, the use of several sound classes lack relevance in the Norwegian context.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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