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# Some European policies regarding acoustical comfort in educational buildings

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**Human learning depends strongly on verbal learning. Research has shown that the quality of the acoustical environment is a significant element that influences verbal learning. Noise and room acoustical peculiarities are the main descriptors of acoustical comfort pertaining to learning spaces. The adverse effects of inappropriate acoustical environments on the learning-teaching activities in educational buildings have been summarized by an abundance of research and other published data. Recommendations for both interior noise levels and equipment noise in school classrooms have been documented in a variety of national and international noise policies, guidelines, standards, and regulations. However the importance given to the subject, the content and the context of the requirements depends basically on the general noise policies of the countries involved. This article presents and compares, to a reasonable extent, the acoustical requirements for educational buildings of some European countries. National guidelines, recommendations, regulations and standards are the basic documents referred to in this study.** ***© 2002 Institute of Noise Control Engineering.***

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## 1. INTRODUCTION

In Europe it is estimated that 10% of the population, i.e 25 million people, are living in a noisy environment in which sound pressure levels exceed 65 dB and among them are 8 million, including 2 million children, who are exposed to high noise levels, exceeding 70 dB in A-weighted equivalent sound level [$L_{Aeq}$. (8-20h)].[1]

For children, noise exposure during learning is a risk factor for their mental development and for normal learning of language and reading. Children are not annoyed in the same way as adults; and it is only at the end of adolescence that several concrete effects become apparent as reduced achievement. This reduction is due to the cumulative effects of:

- masking of speech and a decrease in the intelligibility of the content of lessons,
- diminished attention and mental fatigue,
- a delay in learning to read,
- some restlessness, aggressiveness, or lack of interest, when there was low speech signal, and fewer significations during talks,
- vocal fatigue among teachers, indicated by a shift in higher voice frequencies, and absences due to voice loss.

As a result of these potential effects of noise in educational buildings, most European countries have published standards or guidelines that:

- propose noise levels not to be exceeded inside buildings used for education, varying with the type of town areas, and the outdoor noise,
- suggest technical design or performance in airborne sound insulation for exterior and interior walls, to control emission from fans, heating and other equipment, and to limit the structure-borne transmission of impact and shock noises.

To control noise in learning environments is a must, however acoustical comfort in these spaces depends not only on noise control but also on room acoustics. That is why considerations pertaining to room acoustical criteria have begun to be incorporated into several types of requirements recently. In fact, the type and the strength of the national requirements for educational buildings differ from country to country. In some countries requirements are more compelling and are given as part of a standard or a building code, whereas in others they are presented as recommendations or guidelines. This article presents and compares requirements regarding ambient and equipment noise levels, sound insulation, and room acoustics as they are being applied to the acoustics of educational buildings in some European countries. National guidelines, recommendations, regulations and standards are the basic documents referred to in this context. Most of definitions are from standards or guidelines dealing with general building acoustics.

The documents examined are from Belgium, France, Germany, Italy, Portugal, Sweden, Turkey and the United Kingdom.

In Belgium the requirements on sound insulation are given in the standard NBN S01 400 (1977), the technical requirements on official school buildings are specified in "Type Bestek 110" (1979) and the background levels are those of the standard NBN S01401 (1987).

In France, the Ministerial Order to limit the noise levels in educational buildings refers to the Law 92-1444 on the control of noise and the Decree 94-20 on the Building Code for buildings other than housing.

Schools in Germany are governed by the states and the standards must be implemented in all 16 states. In Germany the standard DIN 18031 (1963): "Hygiene in school buildings; recommendations," provided among other things requirements on room acoustics in classrooms, which was however

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withdrawn in 1983. The standard DIN 18041 (1968): "Acoustical quality in small to medium size rooms" is currently under revision. The German standard DIN 4109 (1989): "Sound insulation in buildings; requirements and verifications," is devoted among other things to schools and similar educational buildings. The standard governing planning aspects for gymnasiums, sport halls etc., is DIN 18032 (1989): "Sport halls; halls for gymnastics, games and various other purposes; principles for planning and construction," which is at this time also under revision.

In Italy, the Ministry of Public Works promulgated a specific law (1975) on room acoustic requirements in schools. Then in 1997 a new law on acoustic passive requirements in all buildings was promulgated, including limit levels for schools. For HVAC systems a standard UNI8199 has been published; all these policies refer to the ISO standards 140-1/12.

In Sweden, general recommendations on noise indoors and high sound levels are given by the Swedish National Board of Health and Welfare in the guidelines SOSFS 1996:7 (M). The Swedish Board of Housing, Building and Planning has published building regulations with requirements for hospital, day care centres, rooms for teaching and after school centres, in the BBR 99,§ 17. They were completed in 2001 by the Swedish Standard SS 02 52 68, "Acoustics—sound classification of spaces in buildings—institutional premises, rooms for education, day centres and after school centres, rooms for office work, and hotels."

In Turkey, acceptable indoor noise levels for some of the educational spaces are given in the Noise Control Regulation (1986). The British Standard 8233 (1977) applies for "Sound insulation and noise reduction for buildings". In 1997 the UK Department for Education and Employment edited "Guidelines for environmental design in schools" in the Building Bulletin n° 8.

In most countries the general standards or guidelines are undergoing various revisions, both for general building acoustics and for educational buildings acoustics.

## 2. THE RECOMMENDATIONS FOR INTERIOR NOISE LEVELS AND EQUIPMENT NOISE

### A. Interior noise levels

Speech interference is the foundation for noise policies for classrooms because it significantly impacts the learning process. Finitzo-Hieber[2] estimated that the recognition scores, in percent correct, vary from 95% when the signal-to-noise ratio is 12 dB in the classroom, to 46% when the ratio is 0. This accounts for the regulatory concern about the ambient noise levels inside the classrooms.

All European recommendations give a noise level as a limit not to be exceeded. The threshold value varies according to the type and the use of the rooms (Table 1). Indoor levels are related to outdoor levels via "transfer functions" and it may be thought that indoor noise levels should be independent of exterior noise. Exterior wall insulation would be modulated accordingly. However, Belgium has adopted threshold noise levels for ambient indoor levels, according to the outdoor noise levels.

Noise measurements surveys recently carried out provide data describing current noise exposure levels; they show that the noise levels in classrooms vary between 35 dB and 49 dB in A-weighted equivalent sound level in Canada.[3] In Italy the median levels are contained in the range 40.8 dB - 46 dB in A-weighted equivalent sound level.[4]

### B. Equipment noise

Mechanical equipment installed in educational buildings, especially in northern Europe, generate airborne and structure borne noise. HVAC (Heating, Ventilation, Air Conditioning) equipment is the most common source. Noise from lifts and boiler rooms cause non-continuous noise, which is also disturbing at high levels. Rumble is caused by insufficient vibration insulation (wall mounted unit). Roar and hiss can be due to a lack of duct liner and excessive air velocity (grille too small). A second source of steady state noise is computers and other educational devices, located in classrooms.

In Italy, continuous noise generated by HVAC equipment is defined by the standard UNI 8199. The noise limits in A-weighted sound pressure level are 30 dB in classrooms and 45 dB in gymnasiums. This limit is 40 dB when the source is not continuous.

In France the equipment noise must not exceed 33 dB in A-weighted sound pressure level (continuous noise) in rooms where a low noise level is required (classrooms, libraries, health care rooms) and 38 dB for other spaces. When noise is not continuous the limit values are 38 dB and 43 dB, respectively.

In Portugal, the regulation imposes a noise level limit of 35 dB in A-weighted sound pressure level in classrooms, library areas, and health care offices; 40 dB in craft-rooms and laboratories; and 45 dB in canteens, corridors and swimming pools.

The standards in Belgium indicate that equipment noise must not create acoustical transient noise more than 6 dB above ambient noise levels, except when the background level is not exceeding 33 dB in A-weighted sound pressure level.

The Swedish requirements on sound levels indoors from installations are 30 dB in A- weighted sound pressure level, for sound with long duration, and 35 dB in $L_{Amax}$ for sound with short duration.

## 3. SOUND INSULATION

### A. Sound insulation for interior and exterior walls

It is necessary to control the noise insulation from the exterior to achieve an acceptable indoor ambient noise level. However only the German regulations take this into account, for classrooms, as shown in Table 2.

In France, the sound insulation values are expressed according to external noise, for all buildings that provide housing, educational settlements, health care, and offices, so as to limit the impact of the noise around airports. For the main rooms, the insulation value is 35 dB in A- weighted

TABLE 1 – Background noise limit according to room use.

| **Country** | **Bel** (1) | **Fra** | **Ger**(4) | **Ita** (2) | **Por** | **UK** (3) | **Swe** | **Tur** |
|---|---|---|---|---|---|---|---|---|
| Noise descriptor | $L_{Aeq}$ | $L_{Aeq}$ | $L_{Aeq}$ | $L_{Amax}$ | $L_{Aeq}$ | $L_{Aeq}$ 1h | Leq | $L_{Aeq}$ |
| Year of definition | 1977/87 | 1995 | 1983 | 1975 | 2000 | 1997 | 1995/ 2001 | 1986 |
| Type of definition | Standard | Decree | Standard | Standard | Draft standard | Guideline | Standard | Regulation |
| Type of activity | | | | | | | | |
| Classrooms | 30/35/ | | | | | | | |
| | 40/ 45 | 38 | 35-40 | 36 | 35 | 40 | 26/40 | 45 |
| Library | | 33 | 30-35 | | | 40 | 35 | |
| Music-rooms | 30/30/ | | | | | | | |
| | 35/40 | | | | | 30 | | |
| Hall, Corridors | | | | 40 | | 50 | | |
| Dinning, gymnasium | 35/40/ | | | | | | | |
| | 45/50 | 43 | 45-50 | 40 | 40-45 | | 40 | 60 |

*(1) The ambient noise levels limits depend on the external noise in the area, classified in 4 categories, which are:*
*1. $L_{Aeq}$ <55 dB, 2. 55dB <$L_{Aeq}$<65 dB, 3. 65 dB <$L_{Aeq}$<75dB, 4. $L_{Aeq}$>75 dB.*
*(2) In Italy some new regulations are being prepared.*
*(3) Maximum background noise levels in all rooms for teaching the hearing impaired should be at least 10 dB lower than these standards.*
*(4) Noise from outdoors and from ventilation and air conditioning.*

sound pressure level. In zone C of the "Plan d'Exposition au Bruit" (noise map for urban planning); this zone is limited by a contour line corresponding grosso modo to 60 dB in A-weighted equivalent sound levels, free field. The insulation is measured from a pink noise source, restricted to the octave bands from 125 to 4000 Hz.

In standards, as in practice, the most usual parameter is the insulation between interior walls. The main limit values are shown in Table 3.

### B. Sound insulation for impact noise

For impact noise, the directives limit the acoustic pressure perceived in a room when impact occurs in a room exterior to that room. An ISO tapping machine is used to evaluate this effect. The recommended values evaluated by operating this machine in the exterior room are nearly equivalent in France (noise limit of 67 dB in A-weighted sound pressure levels) and in Italy (68 dBL'n,w), but the requirements are more severe in Germany (53 dBL'n,w as the maximum). Only the French regulation has adopted the A-frequency weighting network as representative of the human perception.

The rule in Belgium is more complex. It considers spectral levels for impact noise (measurement by octave bands, centered on the frequencies 125, 250, 500, 1000, 2000, 4000 Hz) according to floor category. These categories depend on both the room function and on the function of the room upstairs.

In Sweden the general recommendations on impact sound insulation in rooms for teaching in schools, are given for weighted normalised impact L'n,w; and the maximum recommended value is L'n,w = 64 dB.

TABLE 2 – Levels of required isolation in relation to exterior noise (Germany).

| External measured noise in A-weighted sound pressure levels | Façade isolation |
|---|---|
| Up to 55 dB | 30 dB |
| 56 to 60 dB | 30 dB |
| 61 to 65 dB | 35 dB |
| 66 to 70 dB | 40 dB |
| 71 to 75 dB | 45 dB |
| 76 to 80 dB | 50 dB |
| Above 80 dB | Needs a special study |

## 4. REVERBERATION TIME AND OTHER ROOM ACOUSTIC DESCRIPTORS

Reverberation time along with signal to noise ratio (S/N) are the most significant parameters for speech intelligibility. A child with normal hearing, recognises 80, 71 and 54% of monosyllabic words, with RT 0.0, 0.4, 1.2 seconds, when the S/N is 6 dB. In the same conditions the scores are respectively 60, 52, 27% of the identified words for a hearing impaired child (in ref 3, p 156). So the recommendations must include a reverberation time limit.

In Portugal the existing standard is:

- for normal hearing children: 125-250Hz= RT < 1 s
  250-4000Hz= RT 0.6-0.8 s
- impaired hearing children: RT: 0.4 - 0.6 s
- speech therapy rooms: RT: 0.4 s

The future standard to be applied in Portugal is presented Table 4.

In France the decree dated 9/1/1995 provides the RT to be respected, according to the rooms' function and their size (Table 5). In Belgium reverberation times are given as a function of the acoustical frequencies and of the size of the rooms (Fig. 1).The Sweden design guideline has adopted a

TABLE 3 – Required internal sound insulation as a function of room type.

| Country | Bel (1) | Fra | Ger(2) | Ita | UK | Swe |
|---|---|---|---|---|---|---|
| Noise Index | R Dn | DBA | R'w | R, D | R'w | R'w |
| Insulation between | 1/3 octave | 1995 | DIN | DM | BS | SCBR94 |
| a classroom and | 100 – 3150 Hz | | 4109 | | 8233 | 1996 |
| | | | 1989 | | | |
| Another room | 25 – 49 | 44 | 47 | 40 | 38 | 48 |
| Another room with a door | | 42 | 32 | | 28 | 30 |
| Staircases | 15 – 39 | 44 | 52 | 42 | | 44 |
| Loud rooms such as craft rooms | | 56 | 55 | | 48 | |
| Gymnasium | 42 – 66 | 52 | 55 | | 28 | |
| Canteens | | 40 | 57(3) | | | 60 |
| Music room | 42 – 66 | | 55 | | | 52 |
| Health care office | | 44 | 45(4) | | | 52 |

*(1) Dependent on the exterior noise category (given in Table 1).*

*(2) Requirement on the wall construction (in DIN 4109 there are also requirements on the ceiling (R'w and L'n,w), e.g. sound insulation and impact noise requirements.*

*(3) Dependent on the A-weighted sound pressure level in the room (75-80 dB); an alternative case for an interior sound pressure level of 81 – 85 dB the requirement on the sound insulation of the wall and the ceiling in R'w = 62 dB and the impact noise is L'n.w=43 dB for all.*

*(4) Requirement according to the supplement sheet 2 of DIN 4109: "Sound insulation in buildings; Guidelines for planning and execution; Proposal for increased sound insulation; Recommendations for sound insulation in personal living and working areas.*

specific recommendation, in a practical way, about the coverage of ceilings with acoustical treatment of absorbing material. The percentage of the surface to be covered varies among 40% for offices and conference rooms, 60% for corridors and staircases, 90% for classrooms and 100% for gymnasium and swimming pools. The quality of absorbing material and the mounting depth could vary.

The indoor acoustical quality for speech communication of the educational rooms, may also be characterised with specific indexes, like Articulation Index (AI) or RASTI (Rapid Speech Transmission Index), all of which are affected by ambient noise. However these indices are not yet quoted in the existing European standards. Potentially useful metrics in the school classroom area might be, in addition to the Articulation index and the Rapid speech Transmission Index, the new U.S ANSI Standard S3.5- 1997: "Methods for Calculation of the Speech Intelligibility Index".

TABLE 4 – Future standard to be applied in Portugal for Reverberation Time, RT.

| | Reverberation Time (RT) | |
|---|---|---|
| Type of room | 125 Hz ≤ f ≤ 250 Hz | 500 Hz ≤ f ≤ 4000 Hz |
| Classrooms | RT ≤ 1.0 s | 0.6 s ≤ RT ≤ 0.8 s |
| Music rooms | RT ≤ 1.3 s | 0.6 s ≤ RT≤ 1.0 s |
| Canteens | RT ≤ 1.3 s | 0.8 s ≤ RT ≤ 1.1 s |
| Gymnasium | RT ≤ 2.8 s | 1.3 s ≤ RT ≤ 2.3 s |

## 5. CONCLUSIONS

This review of standards and guidelines shows that comparable recommendations exist in Europe to take into account the acoustical problems in educational buildings. The requirements concern firstly the background noise level in the classrooms as defined in some countries, as well as the external noise levels, and the wall insulation depending on the external noise levels. The insulation between different rooms is also defined in some countries. The requirements for continuous noise emitted by indoor equipment in classrooms are very similar in different countries, between 30 and 33 dB in A-weighted equivalent sound levels. Finally, for the room acoustical characteristics of school buildings, a reverberation time of 0.4 to 0.7 sec, in the frequency range from 500 to 4000 Hz is recommended, and a little bit higher reverberation time is recommended for other types of rooms.

In several European countries, efforts have been made to reduce the ambient noise inside the classrooms,[5] especially near airports, and in the canteens. Some comparative before-after studies are showing some improvement in speech intelligibility[6] when noise from equipment is reduced, after renovation in classrooms, and also in cognitive performances[7] when outdoor noise is almost suppressed. These data are proving *a posteriori*, the positive impact of good acoustical renovation and of the precautionary measures as required by the different policies, which are useful for the design of new classrooms. The cost to design and build new classrooms with good acoustics seems to be lower than the cost needed for renovation of existing classrooms. The control of the actual noise levels in existing buildings is worth developing, by carrying out immediate and systematic noise surveys. Such

TABLE 5 – French standard for Reverberation Time; RT

| Rooms with furniture, no occupants | Mean reverberation times in seconds, in the octave bands 500, 1000, 2000 Hz |
|---|---|
| Children garden (exercise, rest rooms) | 0.4 < RT < 0.8 s |
| Classrooms, music rooms < 250 $m^3$ | 0.4 < RT < 0.8 s |
| Health care, libraries, office rooms | 0.6 < RT < 1.2 s |
| Music rooms, classrooms > 250 $m^3$ | 0.6 < RT< 1.2 s |
| Dinning room, hall | 0.6 < RT < 1.2 s + specific studies |
| A specific study determines the acoustical treatment of the room that allows a good intelligibility in all places in the room. | |

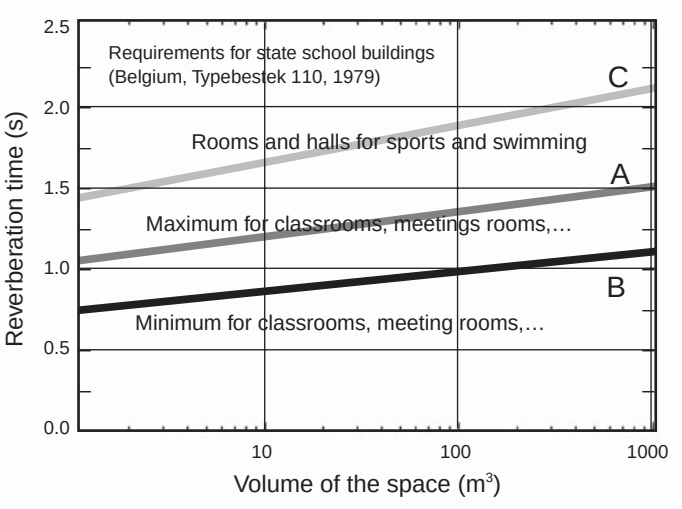


*Fig. 1– Reverberation Time requirements in Belgium (courtesy G. Vermeir).*

surveys should evaluate the degree of compliance of the existing acoustical levels with the recommendations from standards and guidelines.

## 6. REFERENCES


1 J. Lambert and M. Vallet, "Study related to the preparation of a communication on a future EC Policy," INRETS report n° 9420, Lyon, France (1994).

2 I. Finitzo-Hieber and T Tillman, "Room acoustics effects on monosyllabic word discrimination abilities for normal and hearing—impaired children," in Speech Hearing Research **21**, 440-458 (1978).

3 Acoustical Society of America, "Workshop on eliminating acoustical barriers to learning in classrooms," Los Angeles (1997).

4 A. Franchini, P. Giacomin, L. Menini, M. Poli, and R. Pompoli, "Inquinamento sonoro e prestazioni acustiche negli edifici scolastici;" Associazione Italiana di Acustica, Rumore e ambiante scolastici edited by, A. Peretti, R Pompoli Ferrara, Italy 17-32, (1995).

5 World Health Organisation—Regional Office for Europe, Pamphlet n°38, "Noise in schools," D. François, M. Vallet: Bonn, Germany (2001).

6 M. Hodgson, "Effect of design and renovation on the speech conditions in university classrooms," Proc. INTERNOISE 2000, CD- Rom edited by D. Cassereau (INRETS and SFA, Paris 2000).

7 S. Hygge, G. Evans, and M. Bullinger, "The Munich airport noise study-Effects of chronic aircraft noise on children's perception and cognition," Proc. INTERNOISE 2000, CD-Rom edited by D. Cassereau (INRETS and SFA, Paris 2000).


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