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Technical Note

Aspects concerning the acoustical performance of school buildings in Portugal

P.G. Pinho [a,b,c,*], M. Pinto [b], Ricardo M.S.F. Almeida [b], S.M. Lopes [a,b,c,d], L.T. Lemos [a,b]

[a] Center for Studies in Education, Technologies and Health (CI&DETS), Polytechnic Institute of Viseu, Campus Politécnico, 3504-510 Viseu, Portugal
[b] Polytechnic Institute of Viseu – School of Technology and Management, Campus Politécnico, 3504-510 Viseu, Portugal
[c] Monitar – MonitarLab[1]
[d] ADAI/LAETA, Association for the Development of Industrial Aerodynamics RuaPedro Hispano, 12, PT-3030-289 Coimbra, Portugal

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ABSTRACT

Acoustic measurements were performed in eight schools of different levels of education (from kindergarten to college) located in Viseu – Portugal. The acoustic evaluation was made in order to analyze the most common problems that may condition the acoustic environment inside school building.

The acoustics evaluation of school buildings was made by the measurement of: reverberation time in classrooms; sound insulation between classrooms and between classrooms and corridors; impact sound insulation of floors and airborne sound insulation of façade. The sound insulation of façade was made with all elements closed and with natural ventilation conditions (banners or windows tilt mode).

It was found that most of the studied cases revealed disabled constructive aspects in relation to the acoustic requirements of school buildings compromising the quality of education.

1. Introduction

It is crucial that acoustic and HVAC (Heating, Ventilation and Air Conditioning) designs may ensure good acoustic characteristics for school buildings or other learning spaces where oral communication is an important part of the learning process. Excessive background noise or excessive reverberation interferes with oral communication and represents impairment to learning. The negative interference in learning caused by inadequate acoustics of classrooms has been established in several studies (e.g. [1–3]) and the main effect of noise in classrooms is to reduce speech intelligibility. The most affected are younger students, students who are hearing impaired, with disorders such as attention deficit/hyperactivity disorder, and with speech and language difficulties.

2. Performance standards for the acoustics of school buildings

In order to improve the quality of teaching there were introduced performance standards for the acoustics of school buildings in most countries (e.g. [4–6]). In Portugal, performance standards for the acoustics of school buildings are currently defined in national law [7,8]. Table 1 presents Portuguese acoustic legal requirements for school buildings.

3. Characterization of studied school buildings

The project comprises 8 schools of different levels of education (from kindergarten to college) located in the town of Viseu – Portugal. Table 2 presents the characterization of studied school buildings.

4. Methodology

In each school building it was performed an acoustic evaluation of a typical classroom, i.e. the classroom which represents the largest number of classrooms in each school building. In each classroom it was evaluated the reverberation time, the airborne sound insulation and the airborne sound insulation of façade. The sound insulation of façade was made with all elements closed and with natural ventilation conditions (windows in tilt mode).

In addition to these parameters, in three school buildings, A (college), B (lower secondary) and D (lower secondary), the airborne insulation between the circulation corridor and the classroom was tested. The determination of impact sound insulation between classrooms was carried out in 5 of the 8 studied school buildings.

* Corresponding author at: Center for Studies in Education, Technologies and Health (CI&DETS), Polytechnic Institute of Viseu, Campus Politécnico, 3504-510 Viseu, Portugal.
E-mail address: ppaulo@estv.ipv.pt (P.G. Pinho).
[1] www.monitar.pt

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Table 1
Portuguese acoustic legal requirements for school buildings [7,8].

Parameter	Legal requirements
Airborne sound insulation of façade – $D_{1s,2m,nT,w}$	$\geqslant$33 (dB), in noisy areas $\geqslant$28 (dB), in quiet areas
Airborne sound insulation between classrooms – $D_{nT,w}$	$\geqslant$45 (dB)
Airborne sound insulation between classrooms and corridors – $D_{nT,w}$	$\geqslant$30 (dB)
Impact sound insulation between classrooms – $L'_{nT,w}$	$\leqslant$65 (dB)
Reverberation time in classrooms – T	$\leqslant 0.15V^{1/3}$ (s) (V – room volume)

The tests were performed by accredited test laboratory, MonitarLAB, according with the following standards: ISO 140-5 [10]; ISO 717-1 [11]; ISO 3382-2 [12] (for determination of airborne sound insulation of façade elements and façades); ISO 140-4 [13]; ISO 717-1 [11] (for determination of the sound insulation index to air sounds between two compartments); ISO 140-7 [14]; ISO 717-2 [15] (for determination of measurements of impact sound insulation of floors); ISO 3382-2 [12] (to determine the reverberation time).

5. Results

5.1. Reverberation time

The reverberation time, T, is the duration required for the space-averaged sound energy density in an enclosure to decrease by 60 dB after the source emission has stopped [12].

The reverberation time and the relationship between the signal (teacher's voice in classroom) and the background noise (signal-to-noise ratio (SNR)) are the most important parameters for the speech intelligibility (e.g. [4,16]). The reverberation time suitable for a classroom depends on the SNR, the volume of the room and auditors. Younger students need smaller reverberation time for the same SNR than older students, and children under the age of thirteen are particularly susceptible to this parameter [3]. There is not, however, a consensus about the maximum reverberation time and the SNR required for a classroom, with the requirements changing from country to country [4].

In Portugal, the threshold value defined to the reverberation time in classrooms depends on the room's volume. Table 3 shows the reverberation times measured in the eight studied rooms and the limit values set out in Portuguese legal requirements [7,8]. It should be noted that, according to these legal requirements, the assessments *in situ* designed to verify compliance with the acoustic requirements of buildings should take into account a factor of uncertainty, I, along with the determination of the parameter.

As it can be seen, only in three schools the compliance with the reverberation time requirements is verified. In three other schools the measured reverberation time is approximately twice the threshold value defined in legal requirements [7,8]. Note that only buildings C, G and H were built after publication of current legal requirements [7].

In addition to the classrooms studied from the most recent buildings-designated by G and H, also the classroom belonging to the building E meets current legal requirements for the reverberation time. Fig. 1 presents photographs showing the acoustic treatment of classrooms E5, G5 and H5.

5.2. Façade insulation

Background noise inside a classroom depends on the noise sources within the school (for example: contiguous rooms, corridors) as well as on noise from external sources to schools. For good speech intelligibility, the background noise should not exceed 35 dB (A) [2,5].

To minimize the neighborhood noise, two main aspects are to be considered: first, the location of the school building regarding external noise sources (e.g. highways, railways, airports, industries) and secondly, the façade insulation of school buildings.

Schools, according to Portuguese legal requirements [9] should be located in quiet areas. However, not all schools are located in

Table 2
Characterization of studied school buildings.

School code	Level of education	School year built	No. of students (2012/2013)	Distance from façade to the road traffic (m)
A	College	1993	2300	100
B	Lower secondary	1991	700	50
C	Kindergarten and primary	2004	90/290	140
D	Lower secondary	1968	950	200
E	Primary and lower secondary	1996	177/249	80
F	Primary	1958	166	240
G	Primary and lower secondary	2011	125/216	500
H	Primary and lower secondary	2011	85/160	1100

Table 3
Measured reverberation times and comparison with Portuguese requirements [7,8].

School and classroom code	Coatings with relevant influence on reverberation	Volume (m^3)	Legal requirement $T \leqslant 0.15V^{1/3}$ (s)	I (s)	T (s) measured	T measured – I (s)
A1	Floor: cork tile	160	0.81	0.20	1.8	**1.6**
B5	Floor: ceramics	112	0.72	0.18	1.7	**1.5**
C4	Floor: linoleum	151	0.80	0.20	1.1	**0.9**
D1	Floor: wood	168	0.83	0.21	1.7	**1.5**
E5	Floor: linoleum Ceiling: cork agglomerate	164	0.82	0.21	0.8	0.6
F4	Floor: wood	152	0.80	0.20	1.1	**0.9**
G5	Floor: linoleum Ceiling: plasterboard with absorption	173	0.84	0.21	0.6	0.4
H5	Floor: linoleum Ceiling (partial): perforated plasterboard with circular holes	154	0.80	0.20	0.9	0.7