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Technical note

Objective and subjective evaluation of the acoustic comfort in classrooms

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Abstract

The acoustic comfort of classrooms in a Brazilian public school has been evaluated through interviews with 62 teachers and 464 pupils, measurements of background noise, reverberation time, and sound insulation. Acoustic measurements have revealed the poor acoustic quality of the classrooms. Results have shown that teachers and pupils consider the noise generated and the voice of the teacher in neighboring classrooms as the main sources of annoyance inside the classroom. Acoustic simulations resulted in the suggestion of placement of perforated plywood on the ceiling, for reduction in reverberation time and increase in the acoustic comfort of the classrooms.

Keywords: Acoustic comfort in classroom; Reverberation time; Background noise; Sound insulation; Acoustic simulation; Subjective evaluation

1. Introduction

The acoustical conditions in classrooms appear to have attracted worldwide attention. Good acoustics is an indispensable requirement for verbal learning and therefore vital to all knowledge-based societies (Karabiber and Vallet, 2003).

The main scope of this work was to study the acoustical quality of classrooms in Brazilian public schools. In order to evaluate the acoustical quality of classrooms, three acoustical parameters have been investigated: background noise level, reverberation time and sound insulation. Teachers and pupils have also been interviewed with the purpose of evaluating the level of satisfaction of users of the classrooms.

As the classrooms studied were built lacking any absorbent materials in their interior, simulations have been performed of the placement of absorbent materials on the ceiling. The simulated materials were gypsum, plywood and perforated ply wood. Their influence on reverberation time was calculated.

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2. Description of the classrooms

The school under study has been built by the Secretary of Education of Paraná State, in its capital Curitiba, located in southern Brazil. In the last 8 years 400 public schools have been built in Paraná, with an investment of approximately USD$ 168 million.

The school project is named Standard 023. It has four classrooms separated by a central circulation corridor and it measures $7 \times 7 \times 3.1$ m. The walls separating the corridor and the classrooms have a ventilation opening and permanent illumination through glassy bricks. The maximum capacity of each classroom is for 40 pupils.

3. Background noise

Background noise is one of the parameters that affect the acoustical comfort of classrooms. There are established recommendations limiting background noise in several countries such as Brazil, France, Germany, United Kingdom and the USA. Limiting levels to the indoor background noise are shown in Table 1 (ANSI S12.60, 2002; Building Bulletin 93, 2003; Karabiber and Vallet, 2003).

Table 1
Background noise limits

Country	Noise descriptor	Year of the definition	Classroom	Library
Brazil	L_{Aeq}	1987	40–50	35–45
France	L_{Aeq}	2002	38	33
Germany	L_{Aeq}	1987	30–40	30–40
USA	L_{Aeq}	2002	35–40	35–40

Table 2
Recommendations for reverberation time RT (furnished, unoccupied rooms)

Country	Reverberation time (s)
Brazil	$150 \leqslant V < 300\,m^3$, $0.5 \leqslant RT \leqslant 0.7$ (for 500–1000–2000 Hz)
France	$V \leqslant 250\,m^3$, $0.4 < RT < 0.8$ (for 500–1000–2000 Hz) $V > 250\,m^3$, $0.6 < RT < 1.2$ (for 500–1000–2000 Hz)
Germany	$0.8 < RT < 1.0$ (for 500–1000–2000 Hz)
USA	$V < 283\,m^3$, $RT = 0.6$; $283\,m^3 < V \leqslant 566\,m^3$, $RT = 0.7$ (for 500–1000–2000 Hz)

4. Reverberation time

Reverberation time is an important parameter that interferes with the acoustical quality of a classroom. It is strongly dependent on: (1) room volume; (2) the sound frequency in the room, and (3) the total sound absorption in the room (Harris, 1994). Many national and international recommendations include reverberation time limits, as shown in Table 2 (ANSI S12.60, 2002; Building Bulletin 93, 2003; Karabiber and Vallet, 2003).

5. Subjective evaluation

In order to evaluate the level of satisfaction of teachers and pupils, users of classrooms of the Standard 023, questionnaires have been elaborated, targeted to each of the two groups. Sixty-two teachers and 464 students have been interviewed. In the teachers' questionnaire, some of the questions had to be answered based on a scale, according to the level of annoyance with respect to noise, ranging from 0 (low score—not annoyed) to 6 (high score—extremely annoyed). One of the questions to the teachers was: "Which class activity is most affected by noise?" The options offered were: lecture, understanding of the contents explained by the teacher, individual reading, and quizzes or examinations. Again using the 0–6 scale, the teachers should indicate the degree to which each of these activities were disturbed by noise in the classroom. Afterwards, values attributed to each alternative were added and divided by the number of interviewed teachers. Figures with the outcome of the interviews are presented in the Results and Discussion. The questionnaire presented to the pupils contained questions similar to the ones posed to the teachers. However, they were answered qualitatively, not using an evaluation scale.

6. Measurement of the background noise, reverberation time and sound insulation

Four classrooms built according to the Standard 023 have been evaluated. Reverberation time was measured for the following situations: (1) empty classrooms; (2) classrooms with 20 students; (3) classrooms filled to their maximum capacity, i.e. 40 pupils.

Background noise in the classrooms (closed doors and open windows) was measured for the following situation (see Fig. 1): (1) Measurement in room 03; room 01 with normal ongoing class; rooms 02 and 04 with children in silence, (2) Measurement in room 03; rooms 01, 02 and 04 with normal ongoing classes. Reverberation time was measured following International Organization for Standartization—ISO 3382 (1997). In all situations room 03 has remained empty and the other 3 rooms were filled to their full capacity, with 40 pupils.

Background noise was measured in 10 positions around the school. Measurements were taken during 5 min for each position. The equivalent sound level L_{eq}, expressed in dB(A), was measured in 5 positions inside each classroom. Background noise was also measured in 3 positions inside the classrooms and the measurement period was 5 min.

The weighted apparent sound reduction index (International Organization for Standartization—ISO 140-4, 1998) was measured for the wall separating the classroom from the corridor. This wall has the door and glassy bricks.

The equipments used were from Brüel and Kjaer (2003): (1) sound analyzer BK 2260, (2) sound amplifier 2271, (3) sound source, (4) building acoustic software BZ 7204, (5) building acoustic software Qualifier 7830, and (6) sound level meter Mediator BK 2238. All measurements were carried out under ideal meteorological conditions: no wind and no rain.

7. Simulation of reverberation time

The classrooms studied here were built without any acoustical treatment. Simulations have been performed with different types of materials, and their influence on the reverberation time was investigated. The materials tested for the simulation were: (1) gypsum, (2) plywood, and (3) perforated plywood.

8. Results and discussion

The school is located in the suburb of Curitiba, in an area classified as residential according to the local legislation. The local legislation establishes that the external background noise for daytime (7:00 am–7:00 pm) should not exceed 55 dB(A) (Zannin et al., 2002, 2003). The mean equivalent sound level for background noise was 53.5 dB(A) and this means that the school is located in a