Perception of teachers and pupils to the acoustics of classrooms

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The present survey has evaluated the acoustic characteristics of classrooms in public schools. The study has focused on the background noise, reverberation time, noise insulation and interviews with teachers and pupils. The subjective acoustic comfort of classrooms has been evaluated through interviews with 62 teachers and 464 pupils. Acoustic measurements have revealed the poor acoustic quality of the classrooms. The walls between the classrooms and the corridor have permanent ventilation openings on glassy bricks. The measured weighted apparent sound reduction index R'_w for the wall, with a door and glassy brick, was 17 dB. The low value of the weighted apparent sound reduction index contributes significantly to the noise transmission from one room to the other, contributing to the elevated levels of background noise inside the classrooms. Interviews with teachers and pupils have shown that the main noise sources noted in the classrooms originate inside the school: voices of students and of the teacher of the neighboring classroom.

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.

2   Background Noise (Ambient Noise)

Background noise (ambient 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 S12.6; Building Bulletin 93, 2003; Karabiber and Vallet, 2003).

Table 1: Background noise limits according to the type of room.

3   Reverberation Time RT

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 S12.6; Building Bolletin 93, 2003; Karabiber and Vallet, 2003; Hohmann et.al, 2004).

Table 2: Recomendation for reverberation time (RT).

4   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). 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.

5   Measurement of Reverberation Time, Background Noise 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 (50% occupied); 3) classrooms with 40 students (100% occupied).

Background noise in the classrooms (closed doors and open windows) was measured for the following situation: 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 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 minutes 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 minutes.

The weighted apparent sound reduction index (ISO 140-4) 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 & 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 BK 7830, 6) sound level meter BK 2238.

6. Results and Discussion

The school is located in the suburb of Curitiba. 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. 2001, Zannin et al. 2002). The mean equivalent sound level for background noise was 53.5 dB(A) and this means that the school is located in a quiet urban zone where the limit of sound immission is respected.

Background noise was measured in classroom 03, as room 01 was with a class going on, and rooms 02 and 04 were occupied, but with students and teacher in silence. The mean equivalent sound level from the 3 positions inside the room was Leq = 56.2 dB(A). In another simulation, background noise was measured in room 03, but now with all other rooms with ongoing classes, and the measured Leq was 63.3 dB(A).

In both situations, the background noise levels inside the rooms are above the limits shown in Table 1. Therefore, the studied classrooms can be considered as uncomfortable by these criteria. Another finding arising from the measurements is that the noise generated inside the other classrooms is responsible for the background noise inside the observation classroom 03. It should be remembered that the school is located in a quiet zone. Therefore, the background noise is not an environmental problem for this school. The school is a problem in itself. Figure 1 shows the results of the interviews with the teachers concerning the question: "What are the sources of noise that interfere with your class?"

Figure 1: Teachers' answers to the question: "What noise sources most interfere with your class?"

It can be seen that teachers refer to the noise generated by students in neighboring classrooms as the main source of noise, producing a high level of annoyance (level 4). The second main noise source is the voice of the teacher in the neighboring classroom, with level 3 of annoyance. Then what follows is the noise generated in the classroom itself, with level 2 of annoyance.

The same question has been posed to the pupils. For them, the main sources of noise were: 1) the noise generated inside the classroom itself (35%); 2) the noise generated in neighboring classrooms (33%); 3) the voice of the teachers in neighboring classrooms (24%); and 4) other sources (cars, trains, planes, horns, alarms, construction sites, neighbors) (8%). The results of the interviews confirm the sound measurements, indicating that the noise perceived inside the classroom indeed comes from neighboring classrooms.

The walls between the classrooms and the corridor have permanent ventilation openings on glassy bricks. The measured weighted apparent sound reduction index R'_w (ISO 140-4; ISO 717-1) for the wall, with a door and glassy brick, was $R'_w = 17$ dB. This is a very low value.

The low value of the weighted apparent sound reduction index $R'_w = 17$ dB contributes significantly to the noise transmission from one room to the other, contributing to the elevated levels of background noise inside the classrooms. The required sound reduction index between a classroom and corridor in other countries such as Germany is $R'_w = 52$ dB (Bobran, 1995). The recomendation of the Building Bulletin 93 – "Acoustic Design of Schools", from United Kingdon (BB93, 2003), is a value of $R'_w = 55$ dB for the airborne sound insulation between corridor and Primary/Secondary classroom. In Brazil there is no legislation for sound insulation with respect to exterior noise for classrooms and for the internal sound insulation upon room function.

Another question directed to teachers and pupils was: "In your opinion, which of the activities developed in the classroom is most affected by noise?".
For teachers, the affected activities are: 1) teacher's lecture, degree of annoyance 5 – "intense"; 2) individual reading, degree of annoyance 4.7 - between "intense" and "very much"; 3) exams, degree of annoyance 4.3 - "very much". For students, the activities mostly affected by noise inside the classroom are: 1) individual reading, 40%; 2) exams, 40%; and 3) teacher's lecture, 20%. Thus, for both teachers and students, in class activities that require concentration and communication are largely affected by noise.
Figure 2 shows the results of the answers of the teachers to the question: "What does noise elicit in you?". From the data shown in Figure 2, it is noted that routine professional activities performed by the teacher are much affected by noise, such as loss of ability to concentrate, and the need to speak each time louder. The need to speak louder leads to vocal fatigue, as evidenced by Frangos (2003): "According to the National Center for Educational Statistics (USA), teachers miss about two days per year due to vocal fatigue, caused by raising their voices to talk over the ambient noise in and around the school classroom". Both teachers (98%) and students themselves (89%) believe that noise hampers the students' school performance.
Table 3 shows the data on the measurement of reverberation times. As can be observed, measured reverberation times are above the recommended limits displayed in Table 2. The high reverberating times are an indication of the lack of absorbing materials inside the classrooms, resulting in poor acoustical quality. Reverberating environments affect concentration ability and speech intelligibility, forcing teachers to speak louder. This result matches the outcome of the interviews (Figure 3), where the teachers have indicated loss of concentration ability and the need to speak louder.
The Brazilian classroom studied only reaches adequate reverberating times when the classroom is fully occupied, i.e. with 40 students. A high reverberation time increases the background noise levels and hampers speech intelligibility.

7   Conclusions

The present survey has evaluated the acoustic characteristics of classrooms built as modular classrooms. The study has focused on the background noise, reverberation time, noise insulation and interviews with teachers and pupils.

Values of background noise and reverberation time have been compared with the prescribed values according to the Brazilian standars and to several standards in effect in different countries as well. Background noise levels measured in the classrooms were much higher than the values recommended by both national and international standards. The probable explanation for the high levels of background noise inside the classrooms is the low acoustical insulation between the classrooms and the corridor.

Regarding the reverberation time, it could be shown that Brazilian classrooms do not satisfy any of the technical standard recommendations cited in this study. Only when the classrooms are fully occupied, with 40 pupils, do the classrooms offer adequate reverberation times. It is then obvious that the classrooms are characterized by the lack of absorbing materials, confirmed by high reverberation times. Interviews with teachers and pupils have shown that the main noise sources noted in the classrooms originate inside the school: voices of students and of the teacher of the neighboring classroom.

References

ANSI S12.60-2002 – American National Standard – Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, 2002.

Brazilian Association for Standardization NBR 12179 – Acoustic comfort in closed rooms, 1992. (in Portuguese).

Brazilian Association for Standardization – NBR 10152 - Noise levels for acoustic comfort, 1987. (in Portuguese).

Building Bulletin 93, United Kingdon. www.teachernet.gov.uk/_doc/5649/ACF12DC.pdf, 2003.

Bobran, H. W., 1995. Handbuch der Bauphysik. 7. völlig neubearbeitete Auflage, Stuttgart

Brüel & Kjaer, 2003. Measurements in Building Acoustics. http://www.bk.dk.

EPA - Environmental Protection Agency, Curitiba, Municipal Law 10625, 2002 (in Portuguese).

Frangos, A., 2003. School Districts Spend to Ensure Good Acoustics. Wall Street Journal Jul 30, pg B1. New York, N.Y.

Harris, C. M., 1994. Noise Control in Buildings. McGraw-Hill, Inc. New York, USA.

Hohmann, R., Setzer, M.J., Wehling, M. Bauphysikalische Formeln und Tabellen. Werner Verlag, 4. Auglage, 2004 (in German).

International Organization for Standardization – ISO 3382. 1997. Acoustics - Measurement of the reverberation time of rooms with reference to other acoustical parameters.

Iinternational Organization for Standartization – ISO 140-4, 1998. Acoustic – Part 4: Field measurementes of airborne sound insulation between rooms, Geneva.

International Organization for Standartization – ISO 717-1, 1996. Acoustic – Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation, Geneva.

Karabiber, K, Vallet M., 2003. Classroom acoustics policies – an overview". In: Euronoise Naples 2003, Italy.

Shield, B.M., Jeferry, R.L., 2001. A Survey of Noise Levels in and around Primary Schools in London. In: International Congress on Acoustics Rome, Italy.

Shield, B., Dockrell, J., 2003. The Effects of Classroom Noise on Children´s Academic Attainments. In: Euronoise Naples, Italy.

Zannin PHT, Diniz FB, Environmental noise pollution in residential areas of the city of Curitiba. Acustica 87, 625-628.

Zannin PHT, Diniz FB, 2002. Environmental noise pollution in the city of Curitiba, Brazil. Applied Acoustics 63, 351-358.
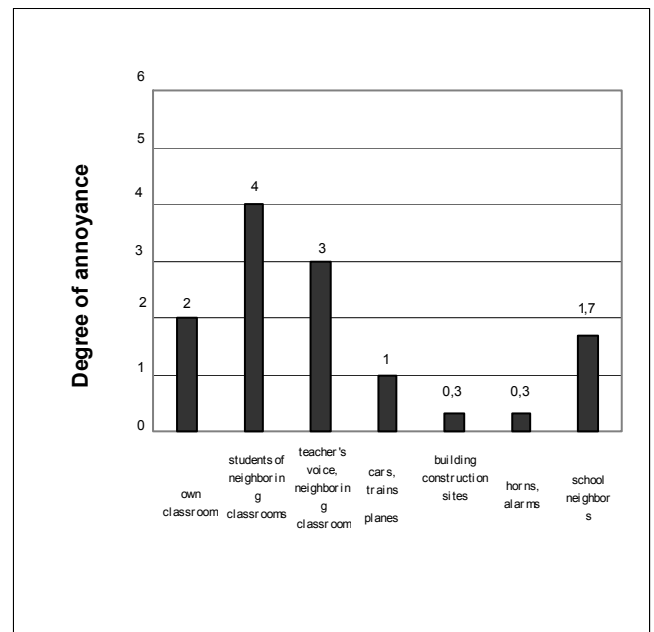
Figure 1: Teachers' answers to the question: "What noise sources most interfere with your class?"
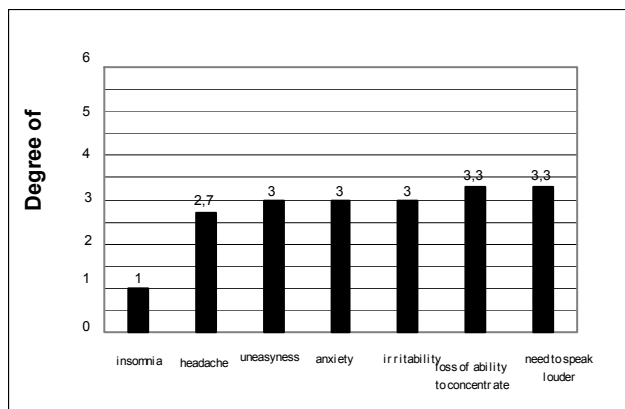
Figure 2: Teachers' answers to the question: "What does noise provoke in you?"

Table 1: Background noise limits – Equivalent continuous sound level L_{Aeq} dB.

Country	Noise descriptor	Classroom	Library
Brazil	L_{Aeq}	40 - 50	35 – 45
France	L_{Aeq}	38	33
Germany	L_{Aeq}	30 – 40	30 – 40
USA	L_{Aeq}	35 - 40	35 – 40

Table 2: Recommendations for Reverberation Time RT

Country	R T (s) (furnished, unoccupied classrooms)
Brazil	$120 \leq V \leq 300$ m³, $0.5 \leq RT \leq 0.6$ (for 500 Hz)
France	$V \leq 250$ m³, $0.4 < RT < 0.8$ (for 500-1000-2000 Hz) $V > 250$ m³, $0.6 < RT < 1.2$ (for 500-1000-2000 Hz)
Germany	RT between 0.8 - 1.0; V up to 250 m³ RT between 0.9 - 1.1; V up to 500 m³ (RT values are for the mean in 2-octave bands including 500 and 1000 Hz)
USA	$V < 283$ m³, RT = 0.6; 283 m³ $< V \leq 566$ m³, RT = 0.7 (for 500-1000-2000 Hz)

Table 3: Reverberation time for classroom Standard 023 (furnished classroom).

	Reverberation Time (s)		
Classroom 01	Frequency (Hz)		
	500	1000	2000
Empty	1.7	1.7	1.4
20 students (50% occupied)	1.2	0.9	0.9
40 students (100% occupied)	0.8	0.7	0.6