Acoustics versus natural ventilation in southern Brazilian educational buildings

Marco Losso[1] and Elvira Viveiros[2]

[1]Post-Graduate Program of Civil Engineering - Federal University of Santa Catarina
CxP 476, CEP 88040-900, Florianópolis, SC, Brazil
Tel.: (+55 48) 331-9393 / Fax: (+55 48) 331-9550
Email: mlosso@terra.com.br

[2] Laboratory of Environmental Comfort - Department of Architecture and Urbanism
Federal University of Santa Catarina
CxP 476, CEP 88040-900, Florianópolis, SC, Brazil
Tel.: (+55 48) 331-9393 / Fax: (+55 48) 331-9550
Email: elvira@arq.ufsc.br

ABSTRACT: Educational buildings have special need for adequate environment, considering some aspects of architecture such as thermal, visual and acoustical comfort, air quality and others. Unfortunately, the acoustical requirements to provide low background noise levels almost always are against thermal comfort needs for buildings with natural ventilation. The reason for that is the need to isolate the classrooms to protect them against noise break-in, especially from traffic noise. This paper presents the study of 18 public schools in southern Brazil. A subjective assessment was carried out by means of a questionnaire submitted to students and teachers, where they were asked to evaluate the school, concerning its ventilation comfort and inside noise levels. Also, an architectural investigation of the buildings was performed, analysing many aspects than can influence their environmental comfort. The results of both surveys presented that ventilation has a better performance when compared to noise inside classroom.

Conference Topic: Design strategies
Keywords: Acoustics, natural ventilation, educational buildings

1. INTRODUCTION

The main purpose of a school is the education of children, young and even adults in some cases. It is undeniable that is has a great importance for the community. The school buildings should provide the adequate conditions for the students, teachers and workers. The adequate environment is a must considering the following aspects: protection in different climatic conditions, temperature, ventilation and humidity; acoustical quality, protection against external and internal noise, intelligibility for students and teachers; good visual and illumination conditions, natural or artificial, protection against air pollution and good internal air quality; structural stability, hygiene, security, comfort and others.

Nowadays, there is a decreased in learning quality, mainly in public state schools in Brazil. This is the result of many aspects such as low investment on planning the buildings, its design and infrastructure, for teachers qualification, for implementation of adequate and efficient pedagogical methodologies, for acquisition of materials or for general maintenance.

Considering two of the related aspects of environment needs, the acoustical quality and the natural ventilation are topics that have major importance to create adequate environments for teaching and learning. It is unquestionable that adequate acoustical conditions lead to a better environment, which give students and teachers a better architectural environment for their activities.

Concerning the ventilation, it is also undeniable that buildings that use natural ventilation strategies are much more energy-efficient, since the demand of energy is less than common in air conditioned buildings. Especially in developing and poor countries, the use of natural ventilation is important because it makes substantial savings on schools maintenance run by the government.

To design and build spaces that guarantee an adequate sound insulation and at the same time provide good natural ventilation is not easy. The features of these topics may have contradictions between them, which makes it sometimes very hard to get a good compromise.

The purpose of this paper is to evaluate the opinion of students and teachers about intrusive noise and natural ventilation in their schools. Also, an architectural evaluation of school buildings will be presented.

2. ACOUSTICAL NEEDS

The main acoustical need to provide environmental comfort that goes against natural ventilation design is the need of sound insulation of school spaces, especially classrooms. Noise can be produced outside or inside the school area, and even inside the classroom. In the following sections it will be discussed the sound insulation properties and the noise sources.

2.1. Sound Insulation

In general, the main target to provide sound insulation is the use of high density materials in building elements like walls, floors, doors, etc. According to Egan [1], the greater the weight, the greater the resistance to motion and less sound energy is transmitted. This is known as the "mass law". The efficient materials for this purpose can be heavy masonry, concrete, stone, steel, and others. Many materials used in the usual constructive systems may not achieve the desired sound insulation. These materials can be lightweight hollow brick, gypsum board, hollow core wood walls; materials used for sound absorption are not recommended also.

Another important point is the existence of opened areas such as doors, windows and louvres. Kinsler et al. [2] related, among many, some aspects that contribute to a poor insulation, such as gaps around wall penetrations, poor seal between walls and ceiling and floor and false ceiling.

Gerges [3] states that open areas (windows, doors) and gaps can decrease the partition efficiency for sound insulation, and in some cases it can even increase the noise level in certain frequencies. The author presented a graph where he shows that an opening of 1% in a wall can decrease the sound insulation properties from 30 dB to 19,6 dB. This case illustrates how difficult is to deal with openings when it is desired sound insulation.

2.2. Noise Sources

2.2.1. Traffic

The schools investigated in this study are mostly located in a urban area which the traffic from streets can be considered one of the main noise sources or even the main source in many cases [4,5]. Dockrell [6] carried out a research with primary students in two thousand schools in London and concluded that the following noise sources were heard inside classrooms, and the students were annoyed by it: cars (71%), sirens (61%), trucks (58%), motorcycles (56%), airplanes (55%), helicopters (54%), and buses (36%). In the same way, he concluded that the three first sources are annoying the students. Considering as a noise source, the traffic is not under the building planners responsibility. This one cannot do many actions on the way to control it on its source. So, the conclusion is that there is a necessity to create a barrier to the traffic noise in order to avoid it getting inside the school area or classroom.

2.2.2. Sports, recreational and circulation areas

In sports courts there is a great amount of noise being generated from steps, balls hitting the floor, players screaming, cheers and whistles. In many schools the space for the recreational activities is located in front of classrooms, in central halls, what is a very problematic situation [7]. Normally the doors and windows have not enough insulation and it makes one of the worse situations. It is easy to find schools where the noise from these areas is even worse than that from traffic.

The circulation areas [8] are also an important noise source inside schools. People passing, children running and talking, all of these activities are normal in corridors that link classroom to other spaces inside school. The patios are places where leisure, sports and general activities happen. These places are very noisy because it concentrates many people producing noise.

2.2.3. Other sources

Other harmful noise sources that can be found in or around schools are neighbours, canteens, cafeterias, snack bars [9], adjacent classrooms, electrical equipment and even the own students inside classroom.

3. NATURAL VENTILATION NEEDS

Lamberts et al [10] reported some strategies to maximise the use of wind for environmental comfort. These strategies are reported below.

3.1. Use of shape and orientation of the building

The shape of the building must create an easy way for the wind to get inside. Also, the orientation should consider the predominant direction of wind.

3.2. Vertical ventilation

Hot air tends to concentrate in higher parts of the building. To get rid of the hot air, it can be used opened roofs, ceilings and upper windows.

3.3. Elements that direct the wind toward the building

Many elements such as trees, bushes or other, located strategically around the building, can increase the speed and volume of the wind flow going inside the building.

Bogo [11] made another recommendation for school buildings, now specifically for those located in the city of Florianópolis. The author reported that natural crossed ventilation was a good strategy aiming the reduction of interior temperatures.

All of the related aspects require opened elements (windows, doors, and roofs) to be efficient or even to work. This is where it goes against acoustic needs.

It is interesting to say that in countries that have hot climates, the use of these strategies are more required than other with lower temperatures, where ventilation can be used only to renew the air. On hot climate countries there is the necessity of controlling the temperatures besides the renewed the air.

Considering the importance of the subject, Evans [12] states that architectural projects must incorporate solar systems and thermal characteristics without compromising functional, economic and visual quality. Also, the he states that the future passive and low-energy architecture in the region of South America must combine high thermal and environmental quality with excellence in architecture design. Theses goals will never be achieved without fully considering the two aspects presented in this paper: acoustics and natural ventilation.

In order to reach an adequate level of acceptability, the next section will present how these two aspects can be incorporated in the design of buildings.

4. COMBINED SOLUTIONS

A question that remains is how to solve the problem of conflicting aspects for an environmental comfort. It seems that when one aspect is solved, the other one is not. But it is possible to solve both at the same time and have a good final architectural appearance.

The first possible solution is to work on a bigger scale, it is to say in the urban planning [13]. Certainly, buildings that require more silence and at the same time require the use of natural ventilation should be located in quieter areas of the city. But this solution is far away from the architect responsible for one isolated building in a city. Normally at the time of the intervention of the architect, the building's site is already decided. But even thought, considering schools buildings, this solution should be considered since the location of schools can be planned in the urban tissue.

A second aspect is the correct planning of the building regarding its location, orientation and shape inside the site, considering not only aspects of natural ventilation, but also, the noise sources. This is an issue normally not addressed by architects that design the building, since the thermal comfort is the most considered parameter. Buildings openings such as windows should be orientated to quieter areas at the same time that consider the predominant wind direction. Also, the use of "buffer zones" is appreciated. These zones can separate quieter areas of noisy ones, as illustrated in Figure 1, at the same time that allow the use of natural ventilation. In this figure, a building with less important rooms (warehouse, restrooms, etc) is located in front of the main noise source (road), in order to block the noise or to minimise its influence in the classrooms.

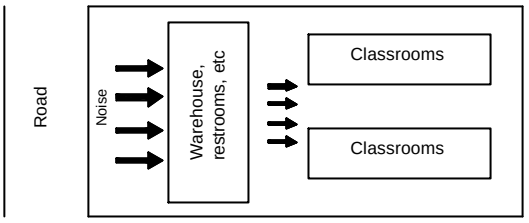

Figure 1: The use of "buffer zones" to minimise noise and allow natural ventilation.

Lastly, the use of elements that allow the wind pass through but partially block the sound carried out with it can lead to a good result. Researching a possible solution in this way, Viveiros [14] studied the performance of acoustic louvres. The acoustic louvre is a special designed louvre that allows the wind to go through and even illumination in some cases, at the same time that decreases the noise level incident on it, through different mechanisms, as illustrated in Figure 2. The use of this louvre would be a possible solution in cases where other alternatives are not feasible.

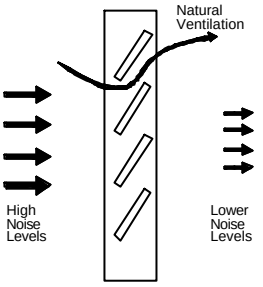

Figure 2: Example of an acoustic louvre. Section.

5. METHODOLOGY

The investigation made use of questionnaires applied to the users of schools, students and teachers, to evaluate their schools in these topics, and of the analysis of the architecture of the school buildings.

A subjective evaluation through questionnaires was undertaken in 18 public state schools in the city of Florianópolis, southern Brazil. It was decided that only 7th and 8th grade students would be part of the analysis because they have a better comprehension of the study. In pilot visits, it was concluded that younger students did not understand some aspects of the study. The classes of respondents for this study was divided as presented in the Table I. In the results, it was mixed the students in one class of data. The sample of respondents was selected to achieve the higher number of respondents as possible, considering the availability of them to answer it at each school. It was obtained very significant amount

of respondents, especially in the students, that reached 52,7% in the 7th grade.

Two main questions were asked for them to evaluate the noise and the ventilation conditions inside classroom: 1) How do you consider the noise in your classroom? And 2) How do you consider the natural ventilation in your classroom?

Table I: General data of subjective evaluation.

Class of Respondents	Amount of schools	Amount of people	Amount of respondents
7th grade	18	707	373 - 52,7%
8th grade	18	709	325 - 45,8%
Teachers	16	311	87 - 28,0%

The architectural investigation was made by means of layout evaluation, either through their archives (designs, pictures and so on) or, when there were none, site measurements. Also interviews with the architects that design the schools in the Santa Catarina Education Department were carried out. These analyses were made for 18 schools.

6. RESULTS AND DISCUSSION

6.1. Subjective evaluation

The results of the questionnaires are presented in the Figures 3 to 6. In Figure 3, it can be seen that a great part of the students consider the noise in their classroom as bad thing (34%). Most of them consider just average (54%) and the small percentage consider good or excellent (11%). The teacher's results have many similarities with the students. Most of them consider the situation just average (56%), a significant part consider bad (23%), and the small percentage consider good or excellent (14%), according to Figure 4.

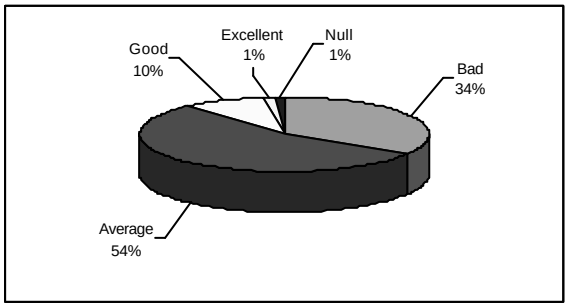

Figure 3: Results of students for the answer: How do you consider the noise in your classroom?

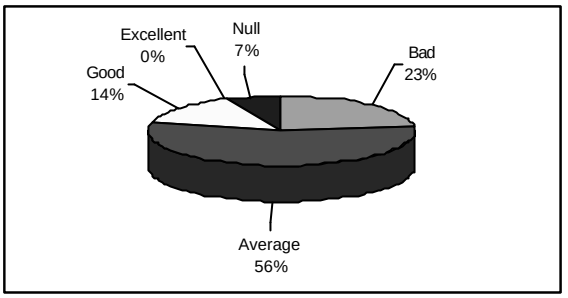

Figure 4: Results of teachers for the answer: How do you consider the noise in your classroom?

The ventilation results show the following situation as it is presented in the Figures 5 and 6: almost one third of the students respondents consider a bad situation (31%), almost another third consider average (30%) and most of them consider good or excellent (38%). The teacher results show that 17% consider the ventilation bad, 38% consider average and 39% consider good and excellent. Like the noise investigation, the results of ventilation are similar in the different classes of respondents. This ensures the results giving an aspect of reliable data.

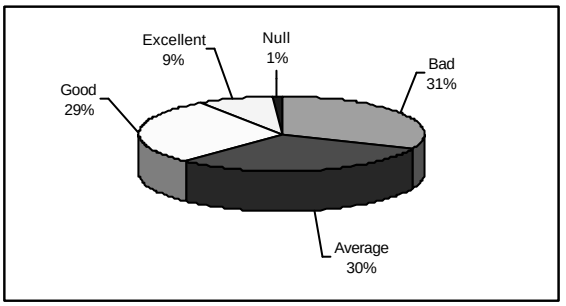

Figure 5: Results of students for the answer: How do you consider the natural ventilation in your classroom?

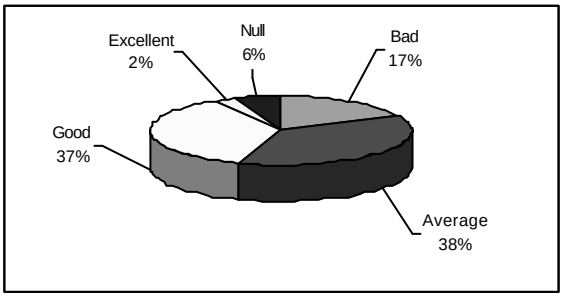

Figure 6: Results of teachers for the answer: How do you consider the natural ventilation in your classroom?

Comparing the noise and the ventilation, the first one seems to be a more problematic topic. The noise is considered bad to 34% and 23% of students and teachers respectively. Ventilation is considered bad to 31% and 17% respectively.

Noise is good or excellent to 11% and 14% and ventilation is good or excellent for 38% and 39%. There is a significant better situation in the user opinion for the ventilation in the classes. The acoustic satisfaction is very low when they were asked if it was a good or excellent situation.

6.2. Architectural investigation

The standard state schools have the following characteristics as it is presented in Figure 7. There is one main building where it is located the business and administrative rooms. Behind it, there is the patio, which is normally protected from rain with a roof, but it does not have walls on its sides. In the sequence, there are one or more blocks of classrooms linked with the patio through corridors with roof, opened in one side.

Acoustically speaking, there are many problems such as spaces with opposite noise characteristics very near to each other. The noise from the road, from the sports court and the patio influence the classroom, specially, when the doors and windows are opened.

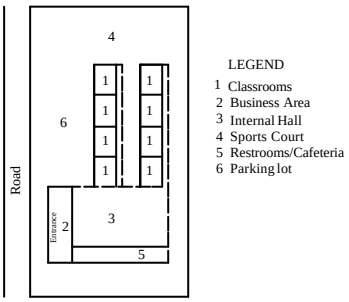

Figure 7: Standard school building.

There are not many actions to protect classrooms from the noise, using the design of building. The buildings do not have adequate acoustical performance, what it would be hoped since the interviews with the architects presented that their knowledge about acoustics were very poor.

The natural ventilation in classroom can be considered good. The worse situation is truly a good situation as it is sketched in Figure 8. The crossed ventilation is provided with the air passing through opened doors and windows located in opposite sides. In many other schools, it was found besides the door, windows in two opposite sides, what is a better situation for the ventilation.

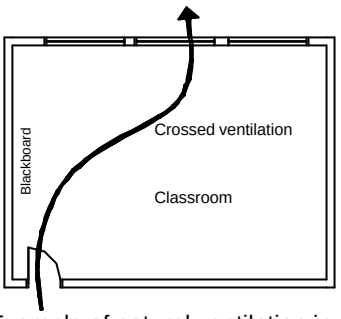

Figure 8: Example of natural ventilation in classroom.

The constructive materials used in the buildings are mostly brick masonry. Older school use structural masonry and new ones use common concrete structure with brick masonry in the walls.

The maintenance is very precarious; it could be found in many schools doors without lockers, windows with broken glasses, windows without glasses, roofs without proper sealing with the walls and other problems that contribute not only to bad sound insulation capacity but also to a worse appearance.

7. CONCLUSIONS

This paper presented the evaluation of public state schools in the city of Florianópolis, southern Brazil. The aim was to analyse the acoustical needs versus the natural ventilation needs, and how were the situation of the schools on theses topics, through questionnaires and architectural survey.

The results showed that students and teachers have similar opinion on the subject. They consider the ventilation in a better performance when compared to the noise in the classroom.

The architectural investigation lead to similar results. It was concluded that the buildings do not provide a protected noise environment. The architects interviewed had poor knowledge on acoustics.

Finally, the maintenance is bad, which collaborate to put acoustic in a worse situation.

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