ACOUSTICS AND NOISE IN SCHOOLS

PhD Arch Ivanova Elitsa

University of Architecture, Civil Engineering and Geodesy, Sofia, Bulgaria

Abstract. *Clearly, a loud noise will interfere with the conduct of the class. Students will get distracted, losing interest in the subject. The teacher can also find themselves is in an unpleasant situation, striving to attract the children's attention, help their focus and outshout the loud background noise coming from the outside of the school building or generated inside it.*

Keywords*: Acoustics, Noise, Sound*

Noise is a strong or weak sound with an indeterminate and inconstant frequency that can be heard. For example, when the leaves rustle in the wind; when many people are talking at the same time; when various objects are rubbing against each other.

Noise is a sound wave. The human ear can pick up sound in the range from 16 Hz to 20,000 Hz, and this range decreases with age. Mechanical waves less than 16 Hz are called infrasound, and waves greater than 20 kHz are ultrasound. Both ultrasound and infrasound are inaudible to humans.

Some noises can damage hearing, while other noises can be pleasant: chirping of birds, a stream running through the forest, the song of a nightingale.

Table 1. Rated noise levels in classrooms. Admissible sound pressure levels by octave bands and sound levels in rooms in residential and public buildings

Pupose of the rooms	Geometric frequencies in octave frequencies - Hz Sound pressure level dB								Sound level dB **A**
	63	125	250	500	1000	2000	4000	8000	
Classrooms and auditoriums in schools, educational	63	52	45	39	35	32	30	28	40

Clearly, a loud noise will interfere with the conduct of the class. Students will get distracted, losing interest in the subject. The teacher can also find themselves is in an unpleasant situation, striving to attract the children's attention, help their focus and outshout the loud background noise coming from the outside of the school building or generated inside it.

The main concern in the design of school buildings is to:

A. Reduce the interference of background noise coming from any sites, buildings, streets, playgrounds, etc. located near the school.

B. Prevent noise generation and propagation within the building.

An environment conducive to learning requires:

- A background noise level which is low enough not to interfere with the wanted sounds, speech or music in the learning process;
- A sufficiently loud wanted sound (speech or music) for effortless hearing;
- A reverberation time* which is short enough to avoid echo and long enough to avoid any mixing;
- Sounds that propagate properly in space.

*Reverberation (in English: Reverberation or colloquially: Reverb) is, unlike echo, continuous reflection ofsound waves (acoustic reflection)) indoors or in a naturally confined space.Any emitted sound is reflected from various surfaces, depending on their type. Smooth and soundproof surfaces will reflect sound in a similar fashion to a mirror reflecting light. The angle of incidence equals angle of reflection. Rough surfaces tend to reflect sound in many directions. A rougher material will cause a greater diffused reflection. The extent of reflection depends on the wave frequency and material properties of the reflecting surface. A hard material tends to absorb sound waves much less. Conversely, a soft material will absorb much more. It is relatively easy to observe reverberation in large halls without any absorbing surfaces, such as in cathedrals, indoor pools or caverns, especially if no additional measures are taken to allow for a greater absorption.

A reverberation is created when a sound is reflected causing a large number of reflections to build up and then decay with time. The decay is caused by each reflection converting some of the energy into heat (since there is no such thing as a perfectly soundproof material). On the other hand, some of the sound is lost with the sound propagation in air (air particle oscillation leads to friction). The time it takes for the sound pressure, when the sound source suddenly stops, to drop by 60 decibels, is the reverberation time T60, designated in English with the uppercase letters RT (which stand for reverberation time). One drop by 60 dB corresponds to a decrease in the acoustic intensity down to one thousandth part of the original value. Being frequency dependent, the reverberation time provides important information about the acoustics of a room and its suitability for speech and musical performances. A room with a greater reverberation potential is not fit for speech performances. A shorter reverberation time will allow for better speech hearing and understanding in the room. Larger rooms with high reverberation potential ought to be selected for any musical performances. This will ensure more natural sounding, and even some inaccuracies in the performance can go undetected. A reverberation time of 1.2 to 1.6 s is recommended for chamber music, 1.7 to 2.2 s for orchestral music, and even longer time for organ music.

Table 2. Maximum reverberation time T,s in unoccupied, furnished classrooms and in other learning spaces. (Regulation on the design, construction and commissioning of buildings for public services in education, science, health care, culture and arts)

№	Learning space	Maximum reverberation time for sound pressure levels in octave bands with average frequencies of 500, 1,000 and 2,000 Hz, s
1.	Main learning spaces with a total interior volume $< 283\ m^3$	0.6
2.	Main learning spaces with a total interior volume $> 283\ m^3$ and $\leq 566\ m^3$	0.7
3.	Main learning spaces with a total interior volume $> 566\ m^3$, and any auxiliary learning spaces	0.7 to 1.1 (≤ 1.5)

The most important thing for the first task (A) is to select a big school site away from noise sources. The rapid expansion of cities have left many schools (which were previously away from noise sources) close to first-class streets, entertainment venues, shops, playgrounds, etc. Opportunities to reduce loud and unpleasant noises using additional funds are needed in this case. All kind of sounds can enter the building through ceilings, walls, floors, provided that these components are not designed to withstand sound levels. Even if these components are sound absorbing noise can propagate through doors, pipes, ventilation ducts, etc. The easiest path for the noise to enter a building is through an open window.

Holes in the surrounding surfaces are important for natural ventilation and lighting, however, these holes are the easiest path for the noise to enter. Various environmental components may be used to reduce noise through the windows. This can significantly improve lighting and ventilation (fresh air getting into the rooms).

Position 1 shows how a tree planted between a room with a window and a neighboring building which reflects the sun's rays can impact the flow of light and lighting in the room.

Position 2 shows how a tree location can impact the airflow.

Position 3 shows a significant reduction of the noise propagation to the room by placing a low thick noise barrier and tall tree in the path of the noise.

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Noise reduction in the building can be achieved through the proper use of materials for the surrounding components. A balance needs to be struck between smooth (reflective) and absorbing surfaces.

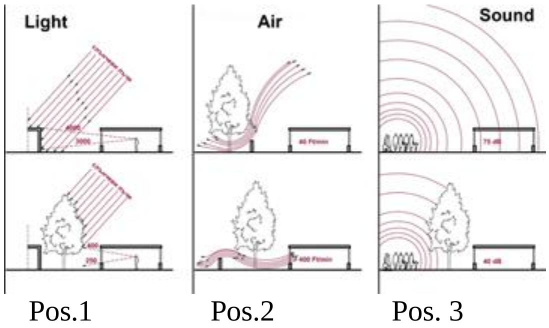

Fig.1. Impacts of environmental components on the light,airflow and noise

The hallway is the biggest source of noise in schools with hallways. The longer the hallway is, the more noise it will generate. The hallway appearance and features are changing with new trends for improving hallway dimensions and functionality (recreational functionality, place for talks, individual activities), which is increasing the hallway noise levels. Various activities mix together in hallways with extra features – physical activities (running, jostling, yelling) and mental activities – places for individual work. The use of lightweight partition walls, sliding windows or showcases in the flexible modern spatial planning (block – sectional, carpet-like and pavilion-like) cannot reduce the noise propagation. Many scientists (researchers) assert this is not even necessary in view of the new trends in conducting classes with the introduction of discussions, etc. Noise is very often perceived as a stimulating irritant due to noise uniformity. Remember that a high-pitch shrill noise or complete silence are almost equally mentally straining and unbearable.

Appropriate absorption materials can be used to ensure a good acoustic environment. For example:

- For ceilings – suspended ceilings with porous surfaces;
- For walls - brick cladding, wooden paneling;
- For floors – rubber floor covering or carpet.

The purpose of using all these materials is to ensure an optimal background noise lower than 45 dB, and reverberation for good audibility depending on the room.

Reverberation time depends on the interior volume of the room.

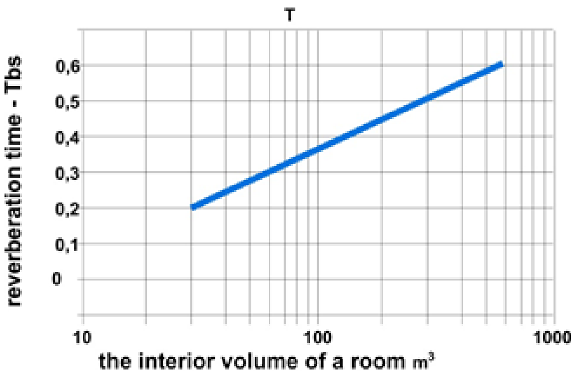

Fig. 2. Relationship between the interior volume of a room and reverberation time

The use of sound absorbing and reflecting surfaces is not enough for a good acoustic environment. It is very important exactly where these materials will be used, what is their size and type of surface (geometric shape), and finally in what sequence the various (sound absorbing and reflecting) materials will be used.

An optimal communication process over medium and longer distances at a normal voice level output will require a direct, speaker-to-listener sound transmission. The primary reflection (R) has a positive effect on the distinctness of speech, since it enhances the effect of the direct sound wave (D).

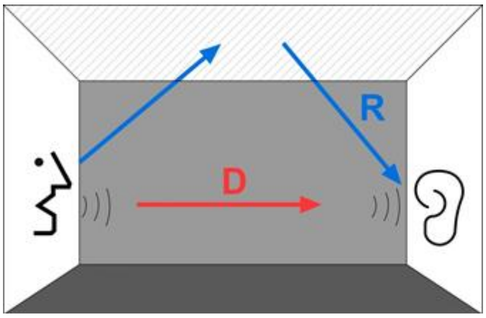

Fig.3. Sound propagation – a direct sound wave and reflection

*Sound absorption is a material's ability to absorb acoustic energy. The sound absorption factor is the ratio between the amount of the sound energy which strikes the material and the energy absorbed by the material. This factor can take values between 0.0 (all acoustic energy is reflected) and 1.0 (all acoustic energy is absorbed).

According to BS EN ISO 354 the sound absorption factor is designated by the letters, αs, and measured in the100-4000Hz range. Sound absorption is expressed as a sound absorption single value, αw, in order to enable an easy comparison between various materials. Thus materials are classified into sound absorption classes from A to E in Appendix B of BS EN ISO 11654.

Acoustics and background noise levels in classrooms are important for the good audibility of the teacher's voice for the students, on the other hand, it is also important to focus the students' attention on the teacher and keep the focus for a longer time. Interestingly, amphitheatric seating arrangement is part of the educational processes in some countries. The teacher will get in the front row, as much in the students' visual field as possible. Then an object – a ball or something with a bright color (preferably red) is placed in the hands of the speaker. No one can interrupt the speaker until they finish and hand over the object to somebody else. This will ensure better audibility and the students' attention will remain focused on the person speaking. The discovery of the need for a propagation medium for sound waves made by Robert Boyle is well-known, therefore, one does not hear anything in the vacuum of space. And we know from the ancient Greeks that sound propagates in space in the form of spherical compression waves. This can explain the architectural design of the ancient Greek theaters. This is the reason why semicircular classrooms and auditoriums with amphitheatric seating arrangement provide the best audibility.

Speech intelligibility in classrooms and auditoriums is an important requirement – interior acoustic design should ensure uniform speech transmission to the listeners in the entire room.

Optimal sound propagation and speech transmission in the room can be achieved through appropriate positioning of the sound absorbing and reflecting surfaces to avoid excessive damping or, conversely, to avoid excessive reflection, causing a reverberation.

It has been found that sound absorbing materials should be used at the top of the walls, and not on the ceiling. The ceiling of a room where lessons are taught should have a hard reflective surface for the sound to bounce off and propagate deep into the interior of the room. Although perfectly smooth ceiling surfaces can lead to a poor audibility. A balance should always be sought when using one or another material, therefore, it is not possible to have a classroom made entirely of glass or one lined entirely with a textile fabric.

The architectural form of all elements of the interior needs special attention. A recessed rear wall of the room can focus the sound only at certain locations. Parallel running walls, parallel floor and ceiling cause the sound to bounce like a tennis ball, reflecting off them. Better acoustic performance can be achieved even by slightly changing the walls and ceiling in order to avoid them running parallel. Various moving surfaces can be used in the middle to improve the acoustics – for example, a rotating blackboard.

The school canteen is one of the noisiest rooms in schools – incessant talking, chairs moved, clatter of cutlery. With so much noise around it is difficult to communicate in the canteen, staying there is unpleasant and students tend to get out of there as quickly as possible. An optimal acoustic solution for school canteens is conducive to the children's communication and contributes to applying the principles of proper nutrition.

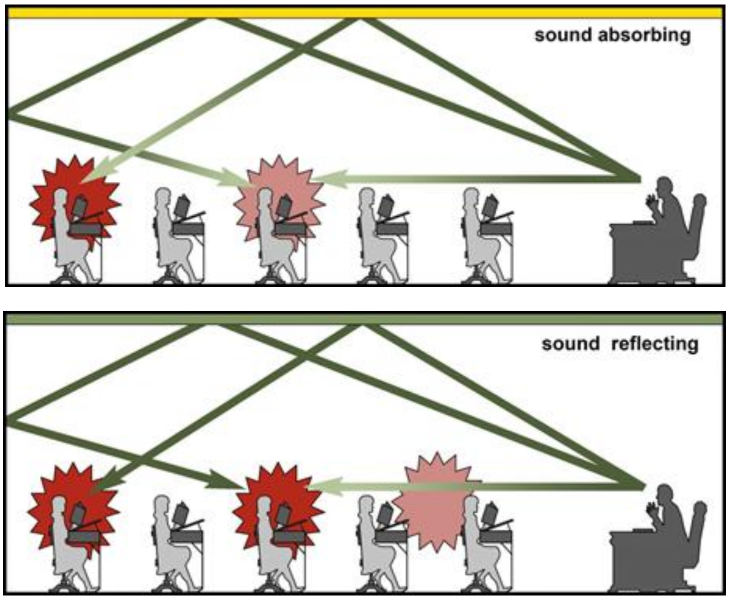

Fig.4. Examples of a poor acoustic environment - bad audibility

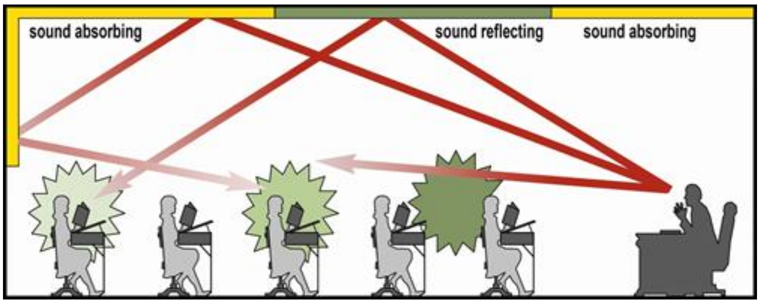

Fig.5. An example of a good acoustic environment - good audibility

One cannot rely solely on textile floor coverings and tablecloths – the choice of sound absorbing materials for lining walls and ceilings is critical. Another option is to separate this area from the learning spaces that require silence. This is often done by designing the canteen and auxiliary rooms as an annex building on the side of the main school building. The canteen is often designed to open to the landscaped school's courtyard as much as possible, featuring a covered terrace with tables for outdoor dining.

The easiest way to reduce noise generation in a school building during classes is to prepare a course syllabus so that all students have exercises at the same time. Students should not be allowed to wander around hallways and rooms, not attending their classes, while others are studying.

All the parameters are statutory. Measurements of the following acoustic parameters of the building take place prior to the commissioning of schools:

1. Soundproofing of walls, floors, doors and windows from airborne noise, including:
a) Airborne Sound Insulation Index, R'w, expressed in dB;
b) Normalized Sound Pressure Level Difference, Dn, expressed in dB;
2. Soundproofing of floors from impact noise; Impact Sound Insulation Index L'_{nw} expressed in dB;
3. Noise levels in the rooms from engineering and sanitary facilities in the buildings;
4. Sound pressure level expressed L_p in dB in octave frequency bands from 63 to 8,000 Hz;
5. Noise level, L, expressed in dB(A);
6. Reverberation time.

The minimum requirements for soundproofing of walls, floors/ceilings from airborne noise, soundproofing of floors from impact noise, and for noise levels from technical equipment (engineering and sanitary facilities) are set out in the Regulation on the abatement of harmful noise levels (applying soundproofing measures during the building design stage), and in the rules and standards for noise emitted during construction activities at building sites.

Several conclusions can be drawn from this study:

1. A school building should be located away from constant noise sources – first-class streets and highways, business enterprises, playgrounds, amusement parks/areas
2. Select an appropriate layout of the various teaching rooms, self study areas, sports areas, dining halls, music rooms, rooms for industrial arts/arts
3. Use various materials to reflect or absorb sound, as appropriate, to ensure a good acoustic environment.
4. Use environmental components to reduce noise levels entering the learning spaces.

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