24th INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
23–27 July 2017, London

ACOUSTIC COMFORT IN EDUCATIONAL BUILDINGS: LITHUANIAN CASE STUDY

Masiulytė-Vitkauskė Liepa, Bogdanienė Eglė Ganda, Lebednykaitė Miglė

Vilnius Academy of Arts, Department of Textile, Maironio g. 6, LT-01124, Vilnius, Lithuania
email: akustika@vgtu.lt

Jagniatinskis Aleksandras

Vilnius Gediminas Technical University, Laboratory of Acoustics, Scientific Institute of Thermal Insulation, Linkmenu 28, Vilnius, LT-08217, Lithuania

Mickaitis Marius

Vilnius Gediminas Technical University, Faculty of Civil Engineering, Sauletekio al. 11, LT-10223, Vilnius, Lithuania

To ensure the quality of teaching and learning process more attention should be paid to the room acoustics. Excessive reverberation time in educational purpose rooms causes the raised voices and poor speech intelligibility. Proper acoustic comfort needs to be ensured in the premises of newly constructed educational buildings, as well as in the premises selected for renovation. In practice the success of application of proper acoustical linings often depends on the ability of the designer to select a best solution of sound absorbing products. This article provides a comparison of the acoustic comfort requirements for educational buildings in different countries and Lithuania. The maximum acceptable reverberation time values in the educational purpose premises are defined in STR 2:01:07:2003 and expressed through the acoustic comfort class for the different room volume and the frequency range. Measurements performed in the rooms selected for renovation demonstrate a need to introduce additional sound absorption in all investigated cases. The acceptable reverberation time in these rooms were achieved after applying sound-absorbing surfaces designed from tested textile products. Reverberation time values obtained by in situ measurements in the different educational spaces were compared with the calculations performed under different methods. In presented case study it was found that in order to ensure the acceptable acoustic quality in educational buildings, in laboratory conditions designed textile solutions can be applied for the optimization of sound absorption properties by arrangement of designed constructions in the premises.
Keywords: sound absorption, reverberation time, textile products, acoustic comfort.

1. Introduction

The acoustic comfort of buildings in Lithuanian Building Regulations [1] defined in the rating form of the subjective assessment of the building acoustic quality. Acoustic comfort classification scheme shows to what extent is limited the disadvantages caused by excessive exposure of noise or fatigue resulting from the echoing sound interference to concentrate, communicate in educational buildings. In this case study acoustic comfort in educational purpose hall in historical building was analysed.

Hall of historic building, placed in the Old Town of Vilnius, is now used for conferences, important entertainment, teaching and occasional live music events. A few years ago reconstruction works in hall were performed, the interior was renewed, thermal and visual comfort characteristics

were improved. However, in a variety of events, the listeners are complaining about inappropriate hall acoustic properties. In their opinion, the room is dominated by excessive reverberation time, which reduces speech intelligibility and creates inappropriate acoustic climate. During reconstruction was an attempt to solve acoustical problems with the installation of the sound reinforcement system, but the situation has not improved. To determine the causes of unacceptable hall acoustic properties and eliminate them, acoustic analysis and measurements were performed.

2. Influence of architectural solutions on hall acoustics

2.1 A Brief Historical Overview of the Building

Historical data [2] indicate that in the current building site in the midst of the sixteenth century stood noble house. In nineteenth century the building was reconstructed into a three-storey residential house. In 1804 the building was bought by Vilnius University. Later, in 1810 the building was reconstructed, lecture theatre founded and equipped as chemical laboratory. In 1842, the hall was divided into two floors, dome-shaped ceiling was constructed.

In 1924, the palace and the hall were reconstructed and adapted for educational purposes. The hall was restored and acquired the present appearance: the ceilings were dismantled, instead of windows niches were made, hall lighting installed inserting arched Windows, portal of the hall was made, the niches and they bricked furnaces were uniformed, front door decorated with columns.

After the Second World War, in the palace and their hall is located a state institution. In 1974 the building was reconstructed. The last reconstruction of hall was carried out a few years ago.

2.2 Geometric characteristics of hall for acoustical assessment

Hall geometric characteristics play an important role in their acoustic parameters and are based on our architectural measuring results [3]. The shape of hall in plan is oval, length in longitudinal direction is 15.6 m and 14.1 m in the transverse direction. Total area of hall is 173 m^2. Hall oval shape is complementary to the four semi-oval niches. Roof (ceiling) construction is a dome. The largest height in room is in its centre and reaches 12.3 m. The Volume of the hall is about 1900 m^3. Floor plan and the general view of the hall interior are showed in Fig. 1.

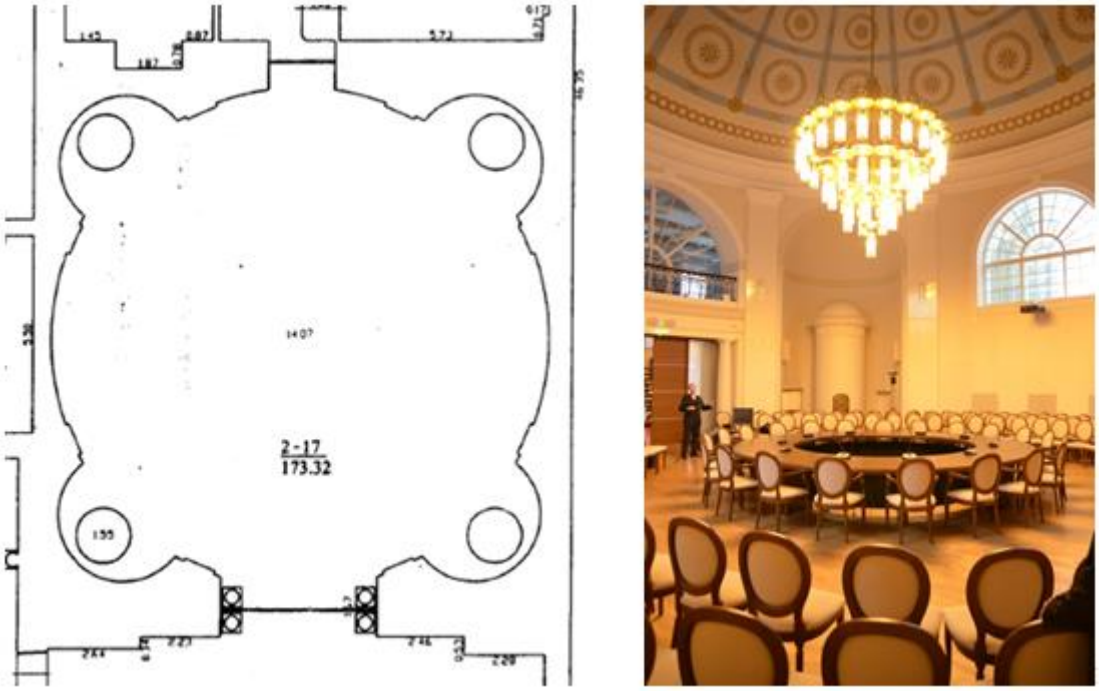

Figure 1: Floor plan (left) and the general view of the hall interior (right).

Level of hall ground floor is at unified altitude except niches contained a 0.1 m above. The height of vertical surfaces (walls) to dome bearing part is about 8.5 m. Set of two wooden doors are arranged on opposite sides of the hall: the main entrance to the hall and out into the corridor. On both sides of the door are formed four semi-oval niches, with a width of 3.8 m and a depth of 1.8 m.

In three planes of walls are arranged similar (3.6 m high and 3.8 m wide) compass windows. The inner surface of dome is relatively smooth, covered with decorative mouldings. Huge chandelier is suspended in the centre of the dome. Engineering systems are designed to maintain the proper microclimate in the hall (radiators, ventilation exhausters, cooling and other equipment) mostly equipped within four niches.

In the centre of hall is placed round (about 5.0 m in diameter and height of 0.76 m) wooden forum table with 3.0 m diameter hole in the middle. There are 20 upholstered chairs placed around table. On both sides of the hall are arranged 3 rows of upholstered chairs in semi circled position. The entire hall has about 190 upholstered chairs. The distance from the chairs at the forum table, to the audience chairs are about 2.2 m. The distance between the rows of the audience seats is about 0.5 m.

2.3 Subjective acoustic evaluation of objects and surfaces

Visual assessment of objects and surfaces acoustical behaviour is required to identify the materiality and ability to absorb, reflect or scatter sound energy in hall space. The properties of objects and surfaces in hall mainly determine target reverberation time values [4]. This information is also needed for decision making by improving acoustic quality. The subjective acoustical evaluation results of surfaces and objects in hall are shown in the Table 1.

Table 1: Subjective evaluation of halls surfaces and objects

Description of object or surface	Subjective evaluation of acoustical properties
1. The floor: wooden parquet	Medium sound reflection
2. The vertical surfaces (walls, niches): main part from massive elements covered with plaster, painted, partially covered with tiles	High sound reflection
3. The vertical surfaces: decorative elements around the doors and windows, the contour at the supporting of dome and upper part of column in niches	Medium sound diffusion
4. The columns (in niches): massive, covered with plaster and painted	High sound reflection (material) High sound diffusion (shape)
5. The ceiling (dome): massive, covered with plaster and painted, decorated with small mouldings	High sound reflection (material) High sound focusing (shape)
6. Doors and windows: wooden frames with panels	Medium sound reflection
7. Forum table: solid timber	Medium sound reflection
8. Chairs: good upholstered	High sound absorption
9. Suspended chandelier: fine metal and glass elements	High sound diffusion
10. Engineering systems elements: thin metal, partially perforated.	Sound reflection / absorption

2.4 Description of acoustic processes and their subjective evaluation in hall

The main acoustical purposes of hall are speaking, communication, discussion, etc. There is a need for rarely musical events, the hall has a grand piano. There are three main groups of speakers' positions:

- Speakers at the round forum table.
- Speakers from the rostrum (positioned near niche).
- Speakers from the rest sitting or standing places.

Summarized subjective assessments and observations of halls users are:

- Reverberation in hall is too high.
- Intelligibility of speech is unacceptable.
- Acoustical perception improves when a larger number of listeners occupy hall.

As subjective evaluation of hall acoustic quality was negative, sound enhancement tools were applied during the last reconstruction. The hall was equipped with 8 speakers, placed on both sides of each niche, at height of 1.0-1.5 m. Subjective evaluation concluded, that these measures insufficient improved speech intelligibility, and it is still far from sufficient.

From the overall negative subjective hall acoustics assessment concluded that investigation of reverberation time must be performed and solutions to improve the acoustic properties proposed.

3. Acoustic comfort requirements for communication rooms

Assurance of acoustical quality is one of the seven basic requirements for the building. Lithuania described and applied acoustic requirements for newly constructed and renewable buildings since 2004 by creating and publishing Building Regulation [5].

Table 2: The maximum permitted values of reverberation time in educational rooms (Lithuanian case)

Type of protected space or area	Reverberation time in seconds according the class, T_{60}		
	B	C	D
Classrooms in Educational purpose buildings, frequency range of estimation 500-2000 Hz	1.0	1.3	1.5
Halls (V < 3000 m³) in Educational purpose buildings, frequency range of estimation 125-2000 Hz	1.2	1.5	2.0

New educational purpose buildings are designed with at least "C" acoustic comfort class. It is possible to adopt the values set for improved acoustic comfort class "B" for new buildings and "D" acoustic comfort class in renovation case (Table 2).

4. Experimental investigation of reverberation time

In situ hall reverberation time measurements were performed in accordance with international standards [6, 7]. Were used computerized discontinuous pulse sequence sound field excitation and registration correlated signal.

The results of measurements were registered in wide frequency range (50-5000 Hz). Statistically representative selected sound source and receiver positions were used with the number of combinations, which is detailed in Fig. 2. Reverberation time results obtained by in situ measurements are presented in Fig. 3.

Comparing reverberation time values obtained by measurements and recommended, we see that they corresponds hall with poor communication quality. The worst thing is that the information transmitting sound reflections are concentrated in the centre at forum table area, thus significantly is disadvantageous for speech intelligibility and overall acoustic comfort feeling.

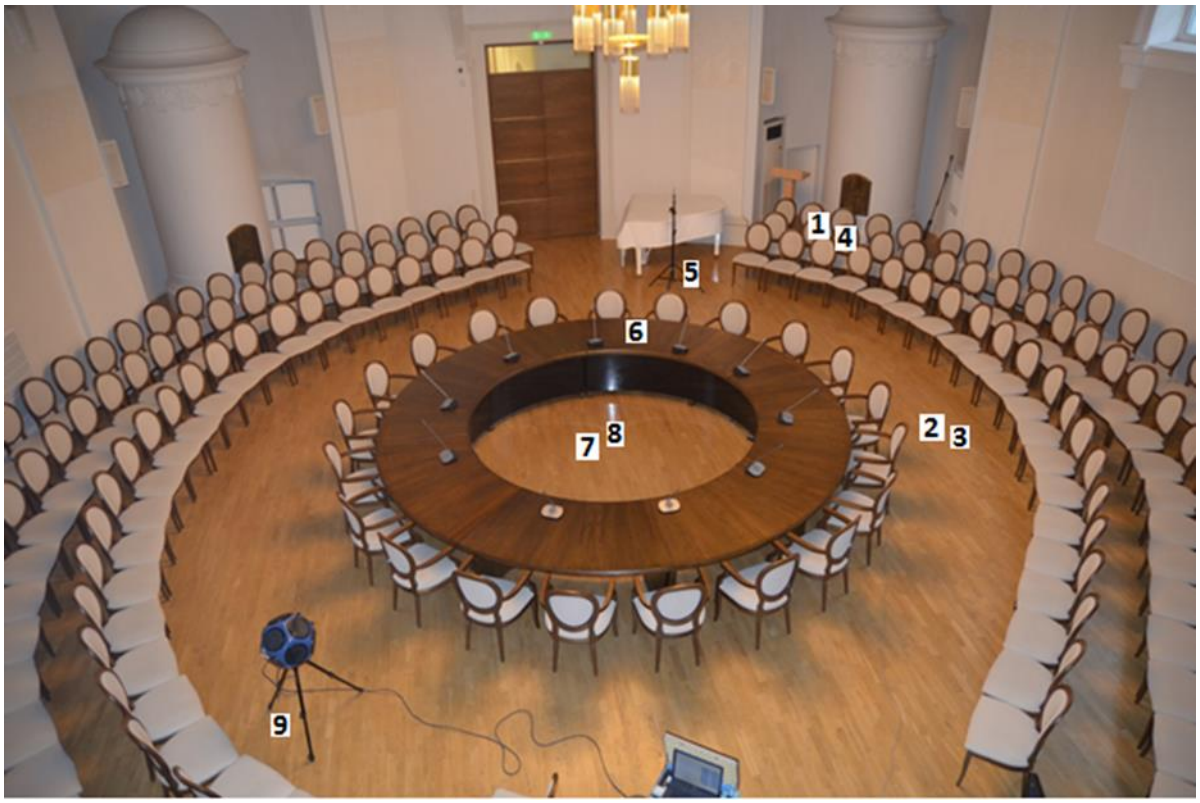

Figure 2: Reverberation time in situ measurements.
The positions of sound receivers (no. 1-8) and sound source (no. 9).

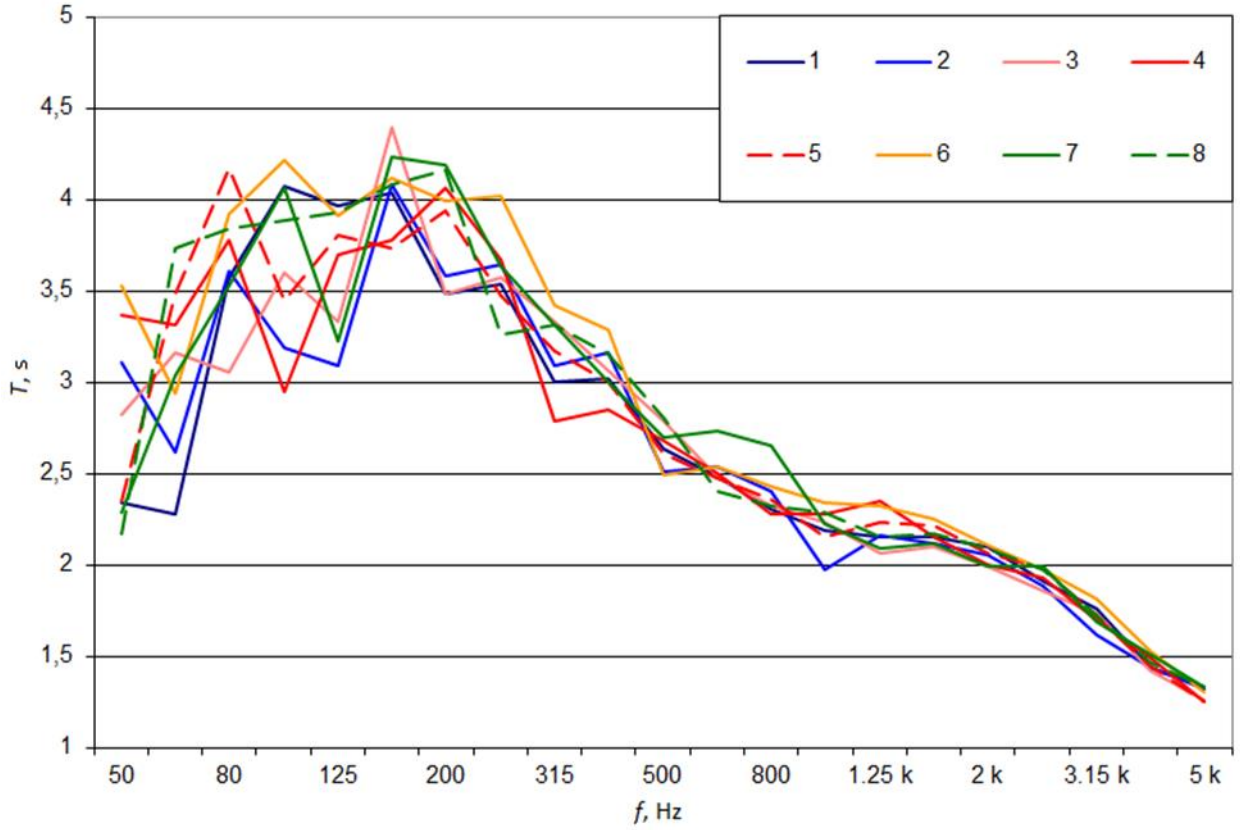

Figure 3: In situ reverberation time measurement results depending on measurement position.

5. Conclusions

In situ reverberation time measurements confirmed the subjective assessment of the acoustic quality: too long reverberation time leads to the interference of direct sound and the reflections from the walls and dome, and the effects causes insufficiently speech intelligibility.

Measured reverberation time distribution in one-third octave frequency range from 50 Hz to 5000 Hz which is important to linguistic information transmission shows excessive reverberation of existing hall.

The next stage of this study requires collaboration with interior designers for determination hall surface area (and / or space) suitable for sound-absorbing materials from textile, taking into account harmonious interaction between the technical and aesthetic characteristics of elements used for acoustical treatment.

REFERENCES

1 *STR 2.01.07:2003 Pastatų vidaus ir išorės aplinkos apsauga nuo triukšmo.* (Lithuanian building regulations. Protection against noise in buildings). Lithuania: Lietuvos Respublikos Seimas (2007).

2 Čerbulėnas, J. and Glemža, A. (1985). Vilniaus architektūra (Architecture of Vilnius), Vilnius

3 Kuttruff, H. (2009). *Room Acoustics* (Fifth Edition), Taylor & Francis, London, New York.

4 Mickaitis, M., Anuškevičius, J., Fiks, B., Skomskis, M. Investigation of reverberation time in different purpose rooms, Abstracts of the international conference „Acoustic climate inside and outside buildings“ held in conjunction with the workshop “Aircraft noise reduction by flow control and active. Vilnius, Technika (2014).

5 Jagniatinskis, M. Mickaitis, B. Fiks, Development classification scheme for evaluation dwellings sound insulation performance in Lithuania, Procedia Engineering, *11th international conference on modern building materials, structures and techniques (MBMST)*, May 16-17, 2013, Vilnius, Lithuania. Amsterdam: Elsevier Science Ltd (2013).

6 *LST EN ISO 3382-1:2009. Acoustics - Measurement of room acoustic parameters - Part 1: Performance spaces*.

7 *LST EN ISO 3382-2:2008 Acoustics - Measurement of room acoustic parameters - Part 2: Reverberation time in ordinary rooms.*