Features of reverberation time criteria application for sound classification in Lithuania

Marius Mickaitis, Aleksandras Jagniatinskis, Boris Fiks
Vilnius Gediminas Technical University, Department of Civil Engineering, Saulėtekio ave. 11, LT-10223, Lithuania, marius.mickaitis@vilniustech.lt

Lithuanian sound classification scheme contains five sound classes and describes different acoustic quality of new, old and renovated buildings. Reverberation time is among descriptors used to express acoustic properties of different purpose building areas and building elements. In order to mitigate noise level in the rooms, the maximum permissible reverberation time values were set in octave bands at least in the frequency range 500–2000 Hz. The mandatory requirement was indicated for residential and some non-residential purpose buildings. Additionally expanded frequency range of estimation indicates more strict requirements and was dedicated for increasing clarity of speech and lowering tiredness in educational rooms. In case of teaching purpose rooms the lower limit of required reverberation starts from the 250 Hz octave band and in case of musical purpose rooms – from the 125 Hz. The experience obtained during more than 10 Years' of practical labelling conformity with the corresponding acoustic class requirements for new and renovated buildings shows necessity to take into consideration the application of the sound absorbing treatments already in early design stage. Few typical cases of conducted reverberation time measurements in different purpose rooms are presented.

1 Introduction

Excessive reverberation time of a room can be the cause of acoustic deficiencies in various purposes rooms. This negative acoustic effect in access areas as stairways, corridors, halls leads to increased background noise and therefore impacts on adjacent noise-sensitive areas. Improper reverberation is particularly damaging to activities in educational buildings: it reduces speech intelligibility, reduces attention and increases the fatigue of listeners. Reverberant office space can be the cause of lower employee productivity and disturbance of communication. Thus, insufficient acoustic quality of the premises due to improper reverberation time reduces the efficiency of the activities in buildings.

The reverberation time of a room is one of the acoustic comfort indicators presented in the Lithuanian sound classification scheme [1]. According to this document, acoustic comfort was defined as the subjective acoustic quality of a building. The class of acoustic comfort describes the degree to which is limited the discomfort caused by excessive noise exposure or the fatigue caused by the reverberant sound field interference to concentration or communication.

2 Reverberation time criteria in Lithuanian sound classification scheme

2.1 Limit values for reverberation time

Lithuanian sound classification scheme defines reverberation time limits for each of five acoustic quality classes, from the lowest class E to the highest class A. For newly built buildings class C criteria referred as a minimum legal requirement. Class A and class B requirements could be applied voluntarily while class D was intended for the case of old building renovation. Acoustic requirements including reverberation time criteria were described for residential and

some non-residential buildings. Reverberation time criteria in Lithuanian sound classification scheme are similar to applied ones in Nordic Countries [2].

Reverberation time limit for access areas was set for each octave band in frequency range from 500 Hz to 2000 Hz and is shown in Table 1.

Table 1: The maximum permitted values of reverberation time in different access areas

Type of protected space	Sound class and reverberation time (s) in room				
	A	B	C	D	E
In multi-storey dwellings	1.0	1.1	1.3	1.5	1.7
In medical treatment buildings	-	1.3	1.4	1.5	1.6
In short-term accommodation buildings	1.0	1.0	1.3	1.5	1.6
In educational purpose buildings	-	1.0	1.3	1.5	1.6

More strict requirements were set for reverberation in rooms which dedicated to speech communication. In addition to lower permitted reverberation times in octave bands these values should be ensured in extended frequency range from 125 Hz to 2000 Hz. The acoustic requirement for sport halls is applied for volumes up to 3000 m³ and is focused on health protection and safety during activities in that room. Reverberation time values for educational buildings in extended frequency range are shown in Table 2.

Table 2: The maximum permitted reverberation time values in educational buildings

Type of protected space	Sound class and reverberation time (s) in room				
	A	B	C	D	E
Teaching rooms except musical classes	-	0.6	0.8	0.9	1.0
Musical classrooms	-	0.5	0.6	0.6	-
Sport halls	-	1.2	1.5	2.0	-

According to the classification scheme, reverberation time values for office, administrative and similar purpose buildings could be adopted from the educational building requirements.

2.2 Basic requirements for design and testing

At the pre-design stage it is necessary to select sound class of the building and thereafter ensure the requirements of all indicators including the reverberation time. Standardized acoustic calculation methods are preferable to apply at the design stage. The acoustic characteristics of finishing materials and objects in the premises shall be assessed in accordance with Part 6 [3] of the LST EN 12354 series of standards which is intended for use by acoustic experts. The prediction method is based on Sabine's formula for regular rooms [4] and has an additional method for calculation of irregular shape rooms. This standard specifies that the acoustic data of materials or objects can be taken from laboratory measurements conducted according to LST EN ISO 354 [5].

According to the standard, calculations are performed in all adjustable frequency bands, assuming that the sound field of the room in consideration is diffuse. In the case of irregular shapes or very large spaces, the reverberation time values obtained on the basis of a standardized calculation method may be inaccurate. Actual sound class of new building should be labeled following in-situ acoustic measurements and include reverberation time results. According to the Lithuanian building regulation acoustic measurements should cover at least 5% of the building or its elements while the

lowest number of tested elements should be three. Measured reverberation time values in enclosed area cannot exceed values presented in Table 1 and 2 for each octave band.

3 Typical cases of reverberation time measurements

The possibility of practical implementation of acoustic requirements was analyzed on the results obtained during conducting in situ reverberation time measurements in different purpose buildings [6]. This paper briefly describes three typical enclosed areas case of reverberation time requirements and shows their practical validity.

In the first case study were investigated access areas in a new multi-apartment residential building. The second case study examined the classroom in a new built school and the third case was about the acoustic renovation of the performance hall.

3.1 Reverberation time in access areas

Measurements of the reverberation time in stairwells were carried out in order to get evidence of practical application of this indicator in residential building with dwellings. The intended sound class of the building was class C, thus the reverberation time should not exceed 1.3 s for any of the octave band in the 500 - 2000 Hz frequency range (green solid line in Figure 1a). The measurements were conducted by applying method described in standard LST EN ISO 3382-2 [7] according to the provisions of the Lithuanian construction regulation [1, 6, 8].

The integrated impulse response method (MLS) was used to obtain the sound decays. Selected measurements procedures ensured the survey method accuracy. Omni-directional sound source was used and placed at different position in one level of the stairwell. Two microphone locations were selected with the distances exceeding 2 m between them and 1 m from walls and other objects. Similar measurements were performed in three stairwells of the building under investigation.

The measurement results showed that the reverberation time in all three cases significantly exceeded the normative requirements (three dotted curves above in Figure 1a). The reason for this unacceptable result was explained by the ignoring of acoustic requirements in the design stage. Only hard and smooth sound-reflecting surfaces were used in the premises as was usual before sound classification scheme enforcement in Lithuania and none of acoustic products were applied.

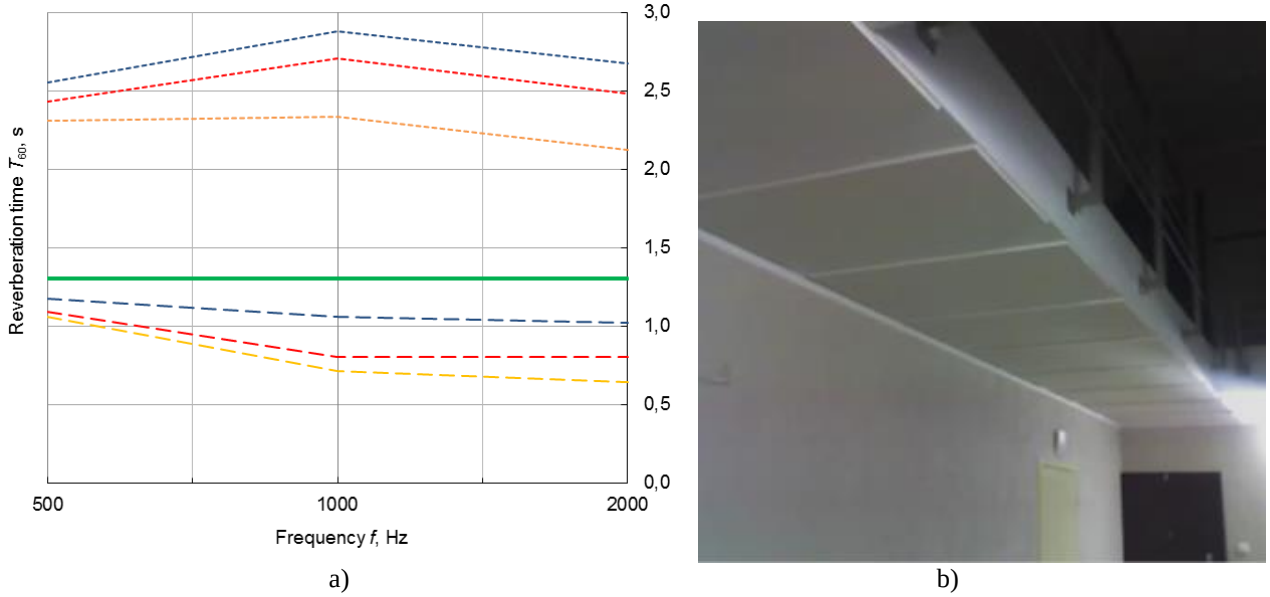

Figure 1: a) Reverberation time measurement results before and after acoustical treatment; b) Application of suspended acoustic ceiling mounted after the first failed test attempt

Remedial works were carried out for all affected areas of the building to meet the acoustic requirements. The required acoustic ceiling area was selected by measurement of the sound absorption coefficient in reverberation room according to LST EN ISO 354 [7] and determination the minimum values of the sound absorbing area in the stairwell. The reverberation time in stairwell was retested after the acoustic treatment as shown on Figure 1b. The obtained results confirmed that the normative reverberation time requirements in the common use premises were finally realized (three dashed curves below in Figure 1a).

3.2 Reverberation time in classroom

The next typical example is the implementation of more rigorous reverberation time requirements in an extended frequency range. The room under investigation with initial volume of about 180 m^3 was planned as a multipurpose classroom with additional musical purpose in a new construction building with design sound class C. According to the Lithuanian sound classification scheme the maximum permitted reverberation time value of 0.6 s shall be ensured for this case in the whole 125 - 2000 Hz octave frequency range (green solid line in Figure 2a).

Compliance with the criteria valid for these rooms was verified by in-situ reverberation time values measurement according to method and procedures described in standard LST EN ISO 3382-2. The integrated impulse response (MLS) option was used to obtain the sound decays. Omni-directional sound sources were placed at positions that are typical for teacher. Microphone places were selected where pupils are typically located. The initially measurement results in empty classroom (black dotted line in Figure 2a) and in classroom with objects (black dashed line in Figure 2a) showed that the acoustic requirements were underestimated during design and construction stages, as the determined reverberation time exceeded the requirements in the whole frequency range.

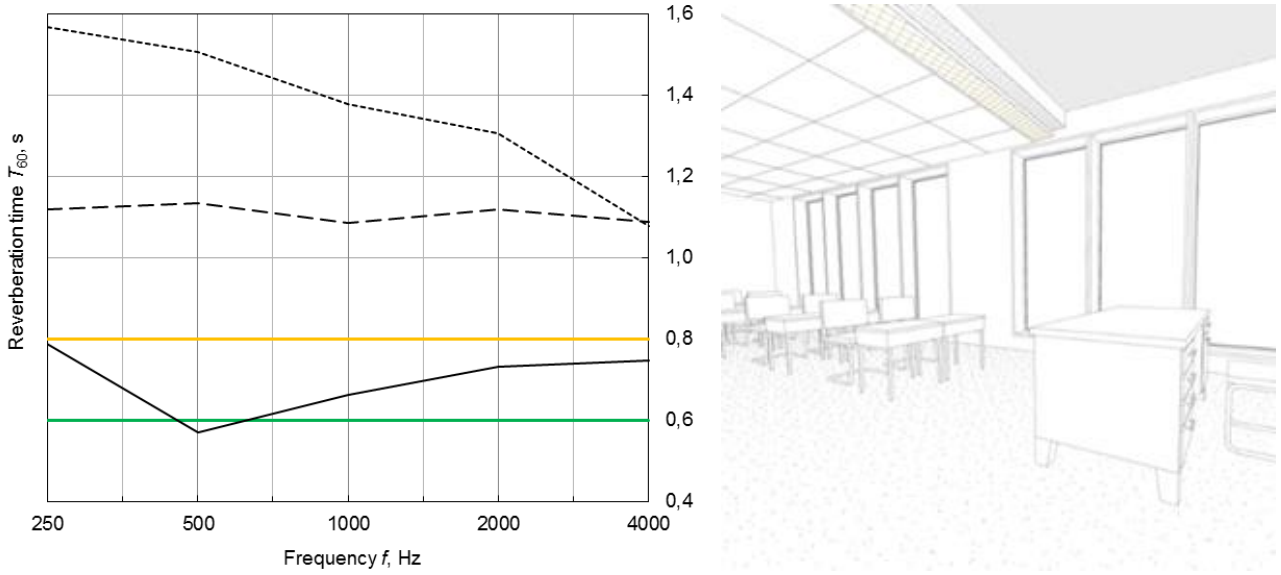

Figure 2: a) Reverberation time measurement results before and after mounting of acoustical ceiling; b) Main view of classroom for initial testing (right) and for retesting (left)

The results of the elimination of acoustic deficiencies showed that the reverberation time decreased after the installation of the acoustic ceiling (black solid line in Figure 2a). The analysis of the situation revealed that the height of the classroom did not allow achieving a better result - it was not enough to install the suspended ceiling structure of the required size. Although the measured values did not achieved requirements for musical purpose in classroom, the retesting results fully ensured conventional classroom criteria to not exceed 0.8 s in whole frequency range (orange solid line in Figure 2a).

3.3 Reverberation time in performance hall

The third example describes the acoustic renovation of a performance hall where speech and musical events take place. The Lithuanian sound classification scheme does not yet describe the requirements for acoustic performance halls. Therefore, in practice could be observed a variety of different attempts to determine the design acoustic indicators and their values.

The event hall with amount of 430 seats and volume of about 3000 m^3 was investigated. The design reverberation time descriptor for hall was selected as a single number value equal to 1.0-1.2 s. After the acoustic renovation, in-situ measurements were performed following the standardized procedures described in LST EN ISO 3382-1 [9] and the integrated impulse response option. Omni-directional sound source was placed at two positions on stage and for each was used more than 10 microphone locations which were evenly arranged through auditorium. Measured reverberation time values in octave bands are shown in Figure 3.

Design requirements used in some countries [10] for this acoustic purpose and volume rooms additionally was shown in Figure 3. From one side it shows that acoustic renovation ensured best result for speech purposes but was far from sufficient for musical ones. From other side it shows importance and demand of elaboration the Lithuanian acoustic requirements for performance halls and other buildings with evaluation their acoustical purpose, influence of frequency and volume.

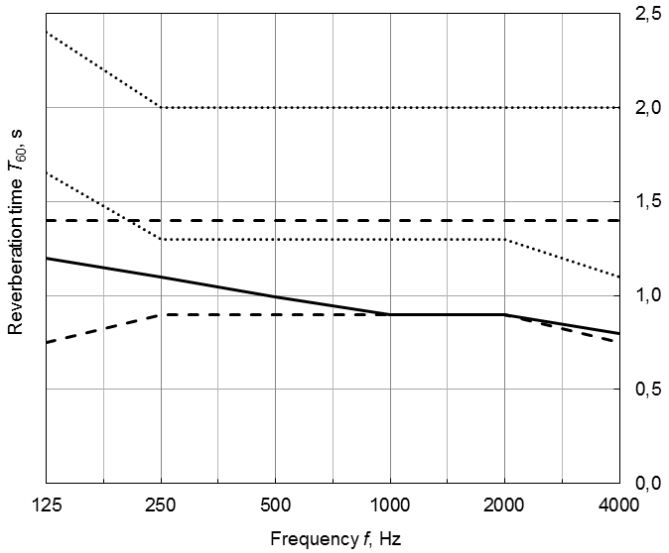

Figure 3: Reverberation time measurement results (black solid curve) and recommended values for musical purpose (black dotted curves) and for speech purpose (black dashed curves)

4 Summary

In Lithuanian sound classification scheme described reverberation time requirements were focused for different acoustic tasks - from noise mitigation to speech intelligibility enhancement. The results of conducted in-situ measurements confirm that the reverberation time is a significant descriptor in order to ensure acoustic comfort in buildings.

In rooms dedicated to speech purposes, it is important to assess the requirements for acoustic quality indicators already at the early design stage. The architectural solutions of these buildings need to provide enough space for mounting of sound-absorbing products. Otherwise, standard acoustic enhancement solutions will not ensure the required acoustic properties of the room.

Lithuanian sound classification scheme does not describe the requirements for some acoustically significant buildings, e.g. for cultural and performance purpose buildings, for administrative and office buildings, and others. In case of describing the required acoustic parameters it is important to determine the relationship of the descriptors at least with the acoustic purpose of the premises, their volume and frequency. It is also important to assess the demand for some descriptors, e.g. reverberation time, to provide not only the highest but also the lowest permitted values for indicators.

References

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

[2] B. Rasmussen, Sound insulation and reverberation time for classrooms - Criteria in regulations and classification schemes in the Nordic countries, *Proceedings of Joint Baltic-Nordic Acoustics Meeting*, Stockholm, 2016, #49.

[3] LST EN 12354-6:2004, Building acoustics - Estimation of acoustic performance of buildings from the performance of elements – Part 6: Sound absorption in enclosed spaces.

[4] LST EN ISO 354:2004, Acoustics - Measurement of sound absorption in a reverberation room.

[5] J. H. Rindel, *Sound insulation in buildings*, CRC Press Taylor&Francis Group, Boca Raton, 2017.

[6] A. Jagniatinskis, B. Fiks and M. Mickaitis, Experience obtained during the ten years of the sound classification practical use for regulation building acoustics in Lithuania, *Journal of the Acoustical Society of America*, *3rd joint meeting of the Acoustical Society of America and the European Acoustics Association: abstracts*, 141(5), 2017, 3666.

[7] LST EN ISO 3382-1:2009, Acoustics - Measurement of room acoustic parameters - Part 1: Performance spaces.

[8] A. Jagniatinskis, B. Fiks, M. Mickaitis and R. Šukys, Features of sound classification scheme designated to label buildings in Lithuania, *Journal of civil engineering and management*, 23(3), 2017, 409-420.

[9] LST EN ISO 3382-2:2008, Acoustics - Measurement of room acoustic parameters - Part 2: Reverberation time in ordinary rooms.

[10] Ch. Nocke, DIN 18041 - a German view, *Proceedings of Euronoise*, Crete, 2018, 1033-1038.