Practical experience in verification acoustic class for building in octave versus one-third octave frequency bands

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Summary
Among ten national schemes developed in EU for the sound classification of buildings, today only five is linked to the building code (regulatory requirements). Background in discussions about advantages of classification schemes is a relationship between subjective perception of acoustics comfort in premises and objective evaluation of the selected acoustic descriptors. Available consensus on selected indicators and appropriate limit values additionally should be expanded on procedures for verification of compliance with an acoustic class. In Lithuania developed sound classification scheme since 2007 year was enforced by mandatory pre-completing testing for new and renovated buildings. In the conformity assessment one of the more controversial aspects becomes selection of the appropriate standards provisions for field testing code. All criteria of the expected class in questions may be assessed applying procedures provided in series standards ISO 16283, ISO 10052 and ISO 717. From the point of economic implications for testing there is possibilities to carry out testing's in one third octave and alternatively in octave bands. Presented result of comparison measurements for a sound classification of a few new buildings in Lithuania shows possibilities select the octave band measurements only. Additionally this investigation allows justify the application in generally the standard ISO 10052 for verification of entire building. In such approach survey method becomes a general and application of engineering method from series standards ISO 16283 remain for doubt cases when individual results deviates from criteria adversely by more than 1 dB.

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1. Introduction

Acoustical comfort definition was introduced by United Nations Economic and Social Council in ECE Compendium of Model Provisions for Building Regulations [1]. In issued document was provided a list of acoustical comfort factors to be taken into account by developing national requirements. Acoustical comfort could be described as opportunities for acoustic activities with keeping privacy between neighbours. This could be achieved by absence of unwanted sound and presence of wanted sound with appropriate level and quality [2].

Acoustic quality defined by national or international sound classification schemes (SCS) for buildings facilitates links between authorities, developers, designers and end-users for purposes related to protection against noise. SCS ensure that information about acoustics comfort conditions in building premises the end-users obtain in easy understandable form with economically reasonable costs.

SCS‘s have two main applications [3]. Firstly, it expresses in the users friendly and easy understandable form protection against noise requirements for the buildings. Secondly, scheme is a tool for designer to select criteria of the suitable acoustic comfort in premises and also to label buildings according acoustic quality.
Insufficient acoustic quality of buildings due to poor sound insulation causes:
– Annoyance due to exposure of noise from the neighbour's (the receiver case);
– Annoyance due to restrains on activities looking be silent for neighbours (the source case).
Conflicts between neighbours in both cases are the same.

2. Sound classification schemes

Differentiation in real estate sector and in needs for quietness in working and living environment was realized through introducing the classification of acoustics performance with different limit values for sound quality. After realizing the project related to the standardization of SCS, the schemes were introduced in the Nordic countries - Sweden, Norway, Denmark, Iceland and Finland.
In Lithuanian case, SCS was developed looking for the best approach to implement one of the seven basic requirements for construction works, i.e. “Protection against noise”, which defined in European regulation No 305/2011. Lithuanian SCS were based on local acoustical investigation in the new and renovated buildings looking to harmonize the sound insulation requirements for dwellings. National classification scheme was issued as a Building technical regulation, STR 2.01.07:2003 in 2004 [4].
In Europe currently are 10 national SCS when its definition requires set of at least three sound classes with different sound insulation performance level. In five countries (Denmark, Iceland, Lithuania, Norway and Sweden) these schemes were linked to the national regulatory requirements and only in these countries are under practical application.
The harmonization of existing different schemes in European countries is an actual issue for the classification indoor acoustical quality of the buildings. The first attempt to define SCS for dwellings was formulated in the findings of the research network COST Action TU0901 [5]. The proposal is under development and to be released as an international standard.

Table I. Comparison of airborne sound insulation criteria between SCS requirements applied in Lithuania and proposed by COST.

Title	STR 2.01.07	COST proposal
Number of classes	5 and Not classified	6 and NPD
Descriptor for sound class C and lower	R'_{w} or D_{nTw}	$D_{nT,50}$
Descriptor for sound class B and higher	$R'_{w}+C_{50-3150}$ or $D_{nTw}+C_{50-3150}$	
Step between classes	3-5 dB	4 dB
Value between a dwelling and noisy premises: -the lowest -the highest	 52 dB 68 dB	 48 dB 68 dB
Value between two dwellings: -the lowest -the highest	 48 dB 63 dB	 42 dB 62 dB

Table II. Comparison of impact sound insulation criteria between different SCS requirements.

Title	STR 2.01.07	COST proposal
Number of classes	5 and Not classified	6 and NPD
Descriptor for sound class C and lower	$L'_{n,w}$	$L'_{nT,50}$
Descriptor for sound class B and higher	$L'_{n,w}+C_{50-3150}$	
Step between classes	2-5 dB	4 dB
Value between a dwelling and above noisy premises: -the lowest -the highest	 58 dB 38 dB	 58 dB 38 dB
Value between two dwellings: -the lowest -the highest	 60 dB 43 dB	 64 dB 44 dB
Value between dwellings above common rooms: -the lowest -the highest	 63 dB 48 dB	 70 dB 48 dB

An available classification schemes in general include requirements with three sound insulation indexes (airborne sound insulation for internal partitions and façade; impact sound insulation), noise control index (noise from service equipment) and reverberation time criteria.

For simplifying the formulation of acoustical requirements, classification schemes indicate weighted values for different acoustic descriptors. The single number quantities in general link the measured sound insulation value to subjective assessment of general impact of sound source in dwellings.
Comparison of airborne and impact sound insulation criteria between SCS requirements applied in Lithuania and proposed by COST is presented respectively in Table I and Table II.

3. Verification of compliance

Lithuanian SCS for building were published and come in force since the 2004 year. Implementation procedure of SCS requirements in building can be divided into three main stages: design, construction and pre-completing testing.
In the design stage mandatory or improved sound class for the building is selected and realized by calculating required building acoustic performance from the characteristics of elements according to series of standards EN 12345. Verification by calculation is mandatory only for design process.
After few years of successful implementation of Lithuanian SCS, it was enforced by mandatory pre-completing testing of new and renovated noise sensitive type of buildings. Verification by measurements must be applied in habitable premises (except in single family buildings), temporary residences (hotels, etc.) and non-residential premises (educational or medicine usage purpose, offices, industrial areas, large halls).
Acoustical properties for different purpose buildings (or their elements) depends on sound class and are defined through following descriptors: airborne and impact sound insulation, façade sound insulation, noise from service equipment and reverberation time in enclosed premises. Verification of acoustic class for building in this paper analysed considering airborne and impact sound insulation descriptors.
Lithuanian SCS requires performing measurements for at least 5% of the building and/or building elements to evaluate compliance of acoustic class criteria which are applicable for separating walls, floors, façades, entrance doors and common access areas. The minimum number of tested elements is three. By selecting representative structures and spaces for field measurements should be ensured that the critical constructions or premises are included. Verification of building acoustic performance by in situ measurements belongs to the quality control procedure and applied mainly to an entire building.
According to classification scheme, international and European standards ISO 16283 [6, 7] as well as ISO 10052 [8] could be applicable to carry out field measurement for conformity assessment. The series of ISO 16283 specifies different methods and procedures to determine airborne, impact and façade sound insulation with engineering accuracy. All parts of this standard describes a default procedure and an additional low-frequency procedure that shall be used for measurements in one-third octaves using fixed microphone, manually-held microphone, mechanized continuously-moving microphone or a manually-scanned microphone.
Different approaches describe influence of operators presenting in the rooms during the measurement. Presenting of the operator in the source room is mostly related to the hearing protection; meanwhile for the receiving room such participation could affect measured results. Although all measurement methods for different procedures are equivalent, in doubt cases, the acoustic properties determined using testing methods without an operator participation in the receiving room should be taken as the most accurate and trusted result. Defining of this issue is one of the main advantages introduced in series of ISO 16283 standards by canceling and replacing previously used standards ISO 140-4, ISO 140-5, and ISO 140-7. The standards ISO 16283 describes possibility to convert sound insulation index values in octave bands from the three one-third octave band values in each octave by calculation if needed.
Simplified test methods for field measurements of airborne, impact and façade sound insulation are described in ISO 10052. These procedures are intended for measurements of different acoustic quantities usual in octave bands.
Measured acoustic descriptors in accordance to both ISO 16383 and 10052 standards procedures are frequency-dependent and should be converted into a single number quantity using the rating procedures described in ISO 717-1 [9] and in ISO 717-2 [10].
Classification procedure is passed if each value of tested acoustic descriptor comply required criteria. Determined sound class of the building must be

confirmed by classification document which is based on test report from accredited testing laboratories. In case when pre-completion testing is failed, classification procedure may involve the additional measures to ensure mandatory or desired acoustic class performance. Depending on the case, could be applied additional acoustic measurements, improving of acoustical properties of failed elements or other measures taken. As practice shows, measurements results strongly depend on the proper design and technical supervision.

4. Comparison of verification methods. A case study

In order to compare results obtained by different measurement methods and evaluation procedures, the experimental measurements were carried out during the pre-completing tests in new erected buildings.

Four typical heavyweight floating floor structures with general thickness of 320 mm between dwellings were tested for airborne and impact sound insulation. Three of them were without covering and another one was with covering from hard wood. Measurements were performed in accordance to standard 16283-1 and 16283-2 requirements in one-third octave bands (frequency range 50–5000 Hz) and in octave bands (frequency range 63–4000 Hz).

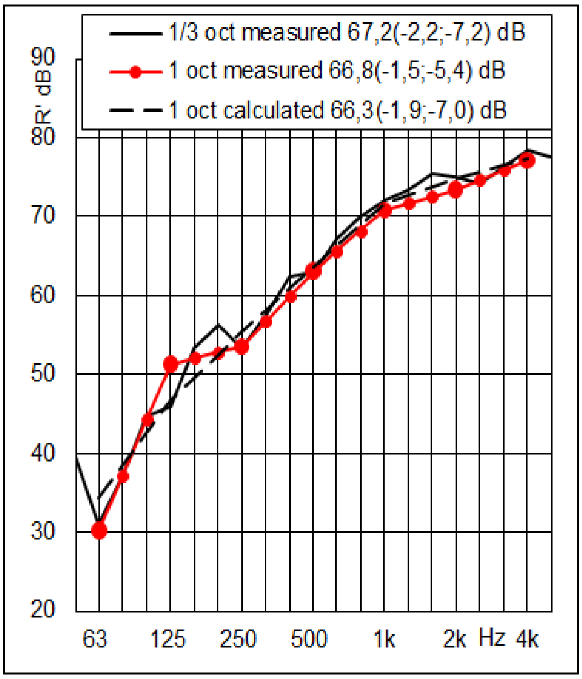

Figure 1. Curves and *R′*, rated values of airborne sound pressure level in one-third and octave bands.

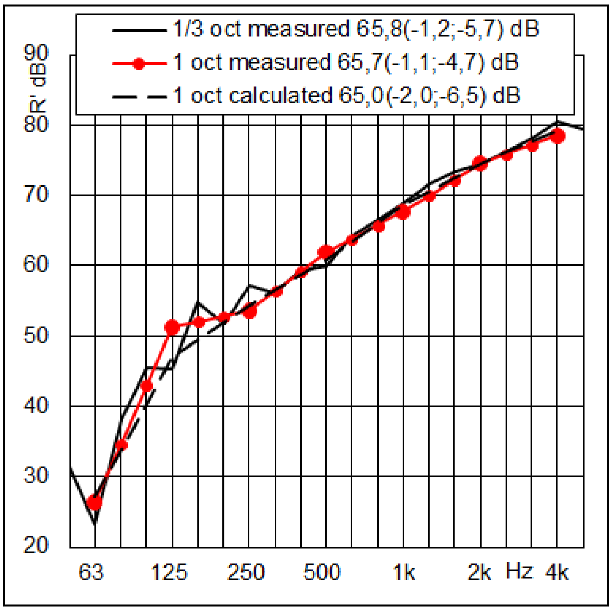

Figure 2. Curves and *R′* rated values of airborne sound pressure level in one-third and octave bands.

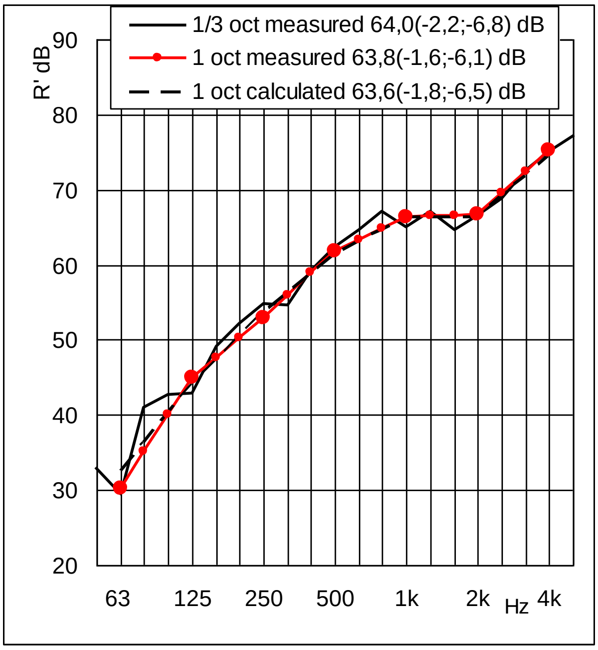

Figure 3. Curves and *R′* rated values of airborne sound pressure level in one-third and octave bands

Additional octave bands values were calculated by converting them from measured one-third octave band values in each octave following ISO 16283 methods.

In first two measurement cases, the horizontal common partitions were without covering and had surface area of 12-13 m^2 and volume of receiving room equal to 33-35 m^3. Measured airborne sound insulation results are given respectively in Figures 1 and 2 while impact sound insulation results presented respectively in Figures 4 and 5.

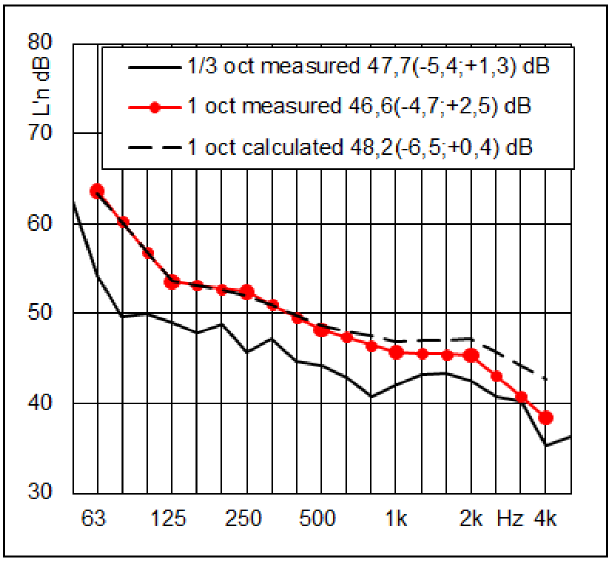

Figure 4. Curves and $L'_{n,}$ rated values of impact sound pressure level in one-third and octave bands.

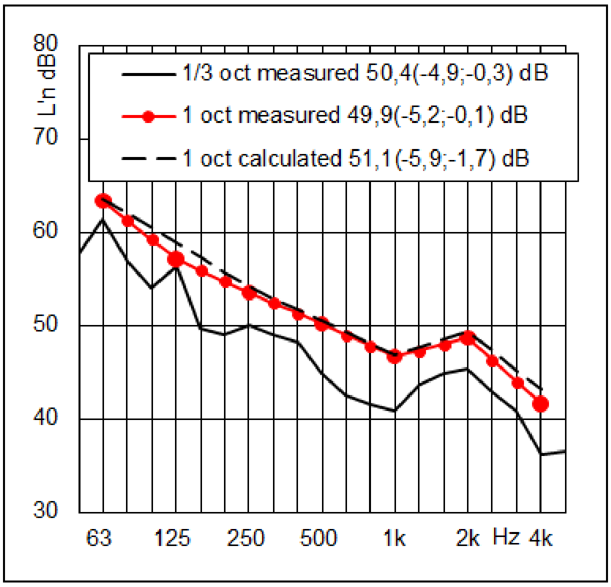

Figure 5. Curves and $L'_{n,}$ rated values of impact sound pressure level in one-third and octave bands.

Table III. Values of weighted single-number airborne sound insulation index from one-third and octave band curves.

Descriptor	No. of Figure		
	1	2	3
R'_w (1/3 octave, measured), dB	67	65	64
R'_w (1/1 octave, measured), dB	66	65	63
R'_w (1/1 octave, calculated), dB	66	65	63

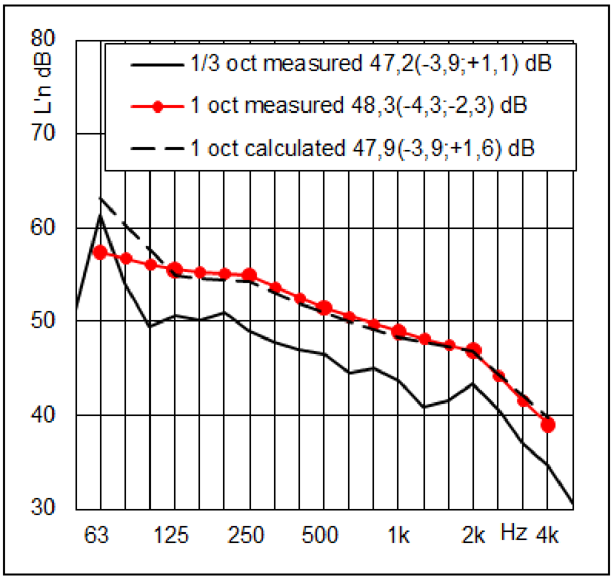

Figure 6. Curves and $L'_{n,}$ rated values of impact sound pressure level in one-third and octave bands.

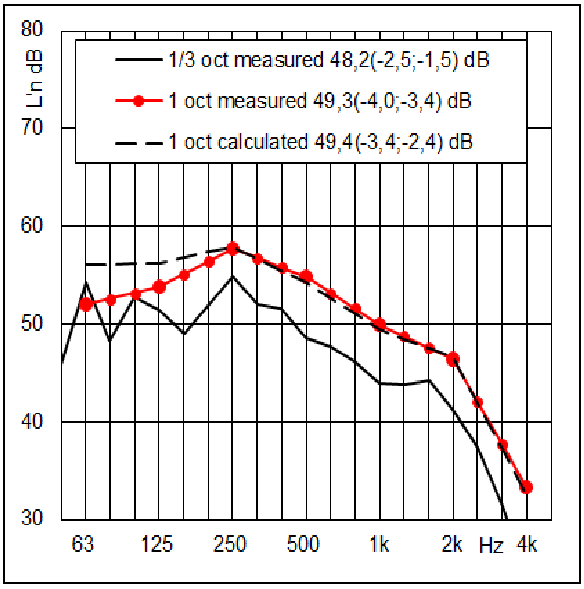

Figure 7. Curves and $L'_{n,}$ rated values of impact sound pressure level in one-third and octave bands.

Table IV. Values of weighted single-number impact sound insulation index from one-third and octave band curves.

Descriptor	No. of Figure			
	4	5	6	7
$L'_{n,w}$ (1/3 octave, measured), dB	47	50	47	48
$L'_{n,w}$ (1/1 octave, measured), dB	46	49	48	49
$L'_{n,w}$ (1/1 octave, calculated), dB	48	51	47	49

In next two measurement cases, the horizontal common partitions had surface area of 18 m^2 and volume of receiving room equal to 50 m^3. One of these horizontal partitions was without covering and measured airborne and impact sound insulation results are given respectively in Figures 3 and 6. In the last case one horizontal partition with floor covering was investigated only for impact sound insulation (Figure 7).

Measured results in one-third octave bands and in octave bands, as well as calculated in octave bands, were converted into a single number quantity in accordance to the rating procedures given in ISO 717-1 and ISO 717-2. Note that for the purposes of accuracy investigation in this case study, weighted values were evaluated in steps of 0.1 dB as it allowed by relevant standards. As could be seen from results given in Figures 1-7 and in Tables III-IV, different rules of number rounding are important by expressing the single-number value.

Measured curves of airborne sound insulation (Figures 1-3) shows that the spectral characteristics for one-third octave bands and as well as for octave bands are close. Measured curves of impact sound insulation (Figures 4-7) demonstrate difference both in high (Figure 4) and in low (Figures 5-7) frequency bands. However, discrepancy of 1 dB for weighted single-number values does not have considerable difference as presented in Tables III and IV.

5. Conclusions

Mandatory pre-completion acoustical testing of new and renovated buildings introduced in Lithuania looking for implementation essential requirement “Protection against noise” for construction works, ensured better acoustical comfort for citizens. In accordance with SCS linked to building code verification of compliance with acoustic class criteria should be done by field measurements for an entire building. Two different standards – ISO 10052 and series of ISO 16283 – describe procedures for field measurements acceptable by provisions of national regulation.

The standard 10052 defines simplified measurement procedures in octave bands, meanwhile acoustical testing using series of standards ISO 16283 could be presented in one-third or in octave bands. Results obtained during field measurement carried out for pre-completion testing shows that the same object tested under different standards gives 1 dB difference for the airborne and as well as for impact sound insulation expressed in single number rating value. Analysis of testing results with evaluation of uncertainties showed that practical application of standard ISO 16283 require more efforts while gives same conclusions as using simplified methods described in ISO 10052.

Procedures presented in ISO 10052 for field measurements in many cases become more acceptable for a sound classification of entire building. Therefore in Lithuania enforced guidelines for verification of compliance with an acoustic class based on the octave band measurements are on the same priority as one-third octave ones. For doubt cases or in case of dispute measurement procedures of ISO 16283 only without an operator inside the source and/or receiving room should be applied to obtain the reference result.

References

[1] Economic Commission for Europe: ECE Compendium of Model Provisions for Building Regulations. United Nations, New York and Geneva, 1996.

[2] J. H. Rindel: Sound Insulation in Buildings. Boca Raton: CRC Press, 2018.

[3] A. Jagniatinskis, B. Fiks, M. Mickaitis: Experience obtained during the ten years of the sound classification practical use for regulation building acoustics in Lithuania. The Journal of the Acoustical Society of America 141 (2017), 3666.

[4] STR 2.01.07: Pastatų vidaus ir išorės aplinkos apsauga nuo triukšmo (Lithuanian building regulations. Protection against noise in buildings). Lithuania, Lietuvos Respublikos Seimas, 2003.

[5] B. Rasmussen, M. Machimbarrena (Eds.): COST Action TU0901 – Building acoustics throughout Europe. Volume 1: Towards a common framework in building acoustics throughout Europe. DiScript Preimpresion, S. L, 2014.

[6] ISO 16283-1:2014 Acoustics – Field measurement of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation.

[7] ISO 16283-2:2015 Acoustics – Field measurement of sound insulation in buildings and of building elements – Part 2: Impact sound insulation.

[8] ISO 10052:2004 Acoustics - Field measurements of airborne and impact sound insulation and of service equipment sound - Survey method.

[9] ISO 717-1:2013. Acoustics — Rating of sound insulation in buildings and of building elements. Part 1: Airborne sound insulation.

[10] ISO 717-2:2013. Acoustics - Rating of sound insulation in buildings and of building elements. Part 2: Impact sound insulation.