BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Volumul 65 (69), Numărul 4, 2019
Secţia
CONSTRUCŢII. ARHITECTURĂ

ASSESSMENT OF THE ACOUSTIC PERFORMANCE OF BUILDINGS IN THE TOURISM SECTOR

BY

MARICICA VASILACHE and MARIAN PRUTEANU*

Technical University "Gh. Asachi" of Iasi,
Faculty of Civil Engineering and Building Services

Received: September 16, 2019
Accepted for publication: October 25, 2019

Abstract. Lately, in Romania it has been observed that in the design phase of buildings used in the tourism sector, specialists involved in project development pay particular attention to solving only certain essential performance requirements. Thus, other performance requirements are ignored or treated superficially, as is the case with noise protection. The article presents the steps to be taken in assessing the acoustic performance levels, as well as the admissible limits for the different parameters according to which the acoustic comfort is analysed. Also, a case study is presented where the acoustic performance of a hotel is checked.

Finally, conclusions are drawn regarding the assessment of acoustic comfort in the buildings within the tourist sector.

Keywords: hotels; acoustic performance; acceptable acoustic levels; case study.

*Corresponding author: *e-mail:* pruteanu_marian@tuiasi.ro

1. Introduction

The design phase involves adopting constructive solutions that meet the overall performance exigencies (of the essential requirements) imposed by The Law of quality in constructions, namely: Mechanical resistance and stability, Fire security, Hygiene, health and environment, Safety in exploitation, Protection against noise, Energy economy and thermal insulation and Sustainable use of the resources. In this context, the selection of acoustic protection solutions is frequently restricted by the performance criteria imposed by fire security or by energy economy and thermal insulation.

In what regards acoustic comfort, the specific performance criteria (mentioned in NC 001-99) are as follows:

– the noise level (equivalent/maximum/background) from outdoor sources;

– the noise level (equivalent/maximum/background) from indoor sources;

– the sound reverberation duration in a given room;

– the intelligibility degree within the given room;

– the airborne sound insulation index (exterior walls, carpentry, roof);

– impact sound insulation index (interior floors);

– improvement of impact sound insulation for floors;

– maximum strength of vibrations under the action of exterior forces;

– maximum strength of vibrations provided by transport installations.

From among them, the first four correspond to the essential requirement of Hygiene, health and the environment and the last ones correspond to the essential requirement of Protection against noise.

2. Theoretical Considerations

Performance levels imposed by standards. In case of the buildings for tourism, the adoption of the specific performance levels at European level is not correlated with the endowments of the building, namely a 2, 3, 4, 5 stars hotel or motel, but it refers to the entire category of buildings, meaning of hotels.

The maximum acceptable equivalent sound level from external sources, featured in Table 1, has different values in the Romanian standards (C125/2013) and in the United Kingdom or the USA.

The outdoor noise level of the building, placed in an urban area in an agglomeration with a population of more than 100,000 inhabitants, measured at 2.00 m from the face of the building (according to SR 6161-1 and SR 6161-1/C91) is determined differently, by the technical category of the streets (by the intensity of traffic). The values are featured in Table 2.

Table 1
Maximum Acceptable Equivalent Sound Level

No.	Functional unit	Maximum acceptable equivalent sound level, expressed in:	
		L_p, [dB(A)] – RO	L_{eq}, [dB] – USA
1	Rooms and/or flats*	35	
	During the day (07:00 - 23:00)		45
	During the night (23:00 - 07:00)		40
	Short-term noise (day, night) during the most noisy interval		50
2	Public eating places	50	
3	Multifunctional halls	35	40
4	Spaces for practicing sports activities	40	
5	Offices	40	

Table 2
The Outdoor Noise Level by the Technical Category of the Street

No.	Type of street	Equivalent sound level L_{eq}, [dB]	Noise rating curve value NR, [dB]	Peak noise level Li_o, [dB]
1.	4th category technical street, of service	60	55	70
2.	3rd category technical street, of collection	65	60	75
3.	2nd category technical street, of connection	70	65	80
4.	1st category technical street, masterly	75...85	70	85...95

The insulation parameters refer to the minimum values of the airborne sound insulation index, R'_w and of the impact sound insulation index, $L_{n,w}$, $L'_{n,w}$, (Standard C125/2013). The performance levels regarding the acoustic insulation parameters for the separating elements between the functional units, namely walls and floors, are featured in Table 3 and 4.

Table 3
Airborne Sound

No	Separating building elements between:		Estimated noise dose (indexed noise level), L_{10} dB(A)	The minimum values of the R'_w index dB
	Functional unit/ acceptable noise level dB (A)	Adjacent spaces		
1	Accommodation rooms [35 dB(A)]	Adjacent rooms	80	46
2		Corridors, shared hallways, stairwells and other similar spaces	80	46
3		Dry cleaners, laundry rooms, storage spaces, technical rooms	> 90	intermediary spaces
4		Garages, stores	> 90	intermediary spaces
5		Restaurants and other similar spaces	> 90	intermediary spaces
6		Meeting rooms, conference rooms, cinemas	> 90	intermediary spaces

Table 4
Impact Sound

No.	Separating building elements between:		The maximum values of the $L'_{n,w}$ Index [dB]
	Functional unit	Adjacent spaces placed on top of the functional unit	
1	Accomodation rooms	Adjacent bunk rooms	59
2		Corridors, shared hallways, stairwells and other similar spaces	55
3		Dry cleaners, laundry rooms, storage spaces, technical rooms	not acceptable
4		Garages, stores	not acceptable
5		Restaurants and other similar spaces	not acceptable
6		Meeting rooms, conference rooms, cinemas	not acceptable

The airborne sound insulation index R''_w (dB), for the exterior carpentry (windows, doors) by the technical category of the streets where the buildings are situated has minimum values ranging between 20 ...35 dB, (Table 5).

Table 5

No.	Type of building	Functional unit	Acceptable value of indoor noise level expressed in:		The minimum value of the airborne sound insulation index R''_w (dB) for the closing elements in the front spaces (windows, doors)			
			No. of the C_z curve	dB (A)	the technical category of the streets where the buildings are situated			
					I	II	III	IV
0	1	2	3	4	5	6	7	8
2	Hotels	accomodation rooms and flats	30	35	min. 35	30	25	20
		restaurant	45	50	min. 20	20	20	20
		conference halls	30	35	min. 35	30	25	20
		gym	35	40	min. 30	25	20	20

3. Assessment of Acoustic Performance Levels

The assessment of acoustic performance levels through calculation refers to the evaluation of the technical solutions chosen by the designer for the separating elements (walls, floors) and for the rooms functioning as conference halls, meeting rooms or ballrooms.

The degree of insulation to airborne sound from the exterior of the building or from the spaces adjacent to the main rooms is evaluated using the airborne sound insulation index R'_w, determined by the following relation:

$$R'w = Rw - c,\ [\text{dB}], \tag{1}$$

where: R_w is the airborne sound insulation index of the enclosing element, without the contribution of transmission using collateral ways, [dB]. The R_w index is appraised by mass per surface unit of the building element, using the diagram in Fig. 1 (the mass law). In case of multilayer elements, laboratory tests are conducted; c – the correction estimating the reduced capacity of insulation to airborne sound due to sound transmission using collateral ways, determined by using the following relation:

$$c = 10\log\left[\frac{z_m}{z_{m,\text{med}}} + 1\right], \text{ [dB]}, \quad (2)$$

where: z_m is the mechanical impedance of the joining element considered, [aN·s/m³]; $z_{m,\text{med}}$ – average mechanical impedance of the building elements adjacent to the enclosing element considered, [daN·s/m³].

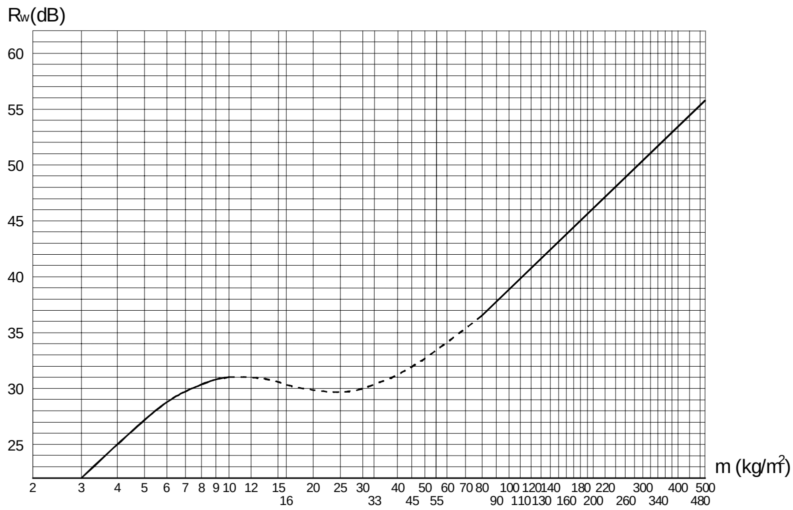

Fig. 1 – The mass law.

The $Z_m/Z_{m,\text{med}}$ ratio is determined through the relation below:

$$\frac{Z_m}{Z_{m,\text{med}}} = \frac{mP}{\sum_{i=1}^{4} m_i' l_i}, \quad (3)$$

where: m – mass per surface unit of the enclosing element considered, [kg/m²]; m'_i – mass per surface unit of the building element adjacent to the enclosing element considered, [kg/m²]; P – the perimeter of the enclosing element considered, [m]; l_i – the length of the contact side of the adjacent building element i with the enclosing element considered, [m].

Whereas the building element i adjacent to the enclosing element considered has different buildings make = ups (m'_{ie} in the emission room and

m'_{ir} in the reception room), the value m'_i sis determined by the following relation:

$$m_i^{'} = \frac{m_{ie}^{'} m_{ir}^{'}}{2}, \text{ [kg/m}^2\text{]}. \quad (4)$$

Impact sound insulation index, $L'_{n,w}$, is calculated as follows:

$$L'_{n,w} = L_{n,eq,o,w} - \Delta L_{n,w} < L'_{n,w,max} \text{ [dB]} \quad (5)$$

where: $L_{n,eq,o,w}$ is the impact sound insulation index of the gross concrete floor. $L_{n,eq,o,w}$ = 70,…,80 dB for reinforced concrete slabs of usual thicknesses and composition; $\Delta L_{n,w}$ – improvement insulation to impact sound issued by the floor with values ranging between 5,…,20 dB for usual compositions. For the floors made of carpet set in using floating tile on an elastic layer of rigid mineral wool, strain-hardened polystyrene or carpet with underlay $\Delta L_{n,I}$ = = 22…28 dB; $L'_{n,w,max}$ – the maximum value imposed for impact sound insulation index, ranging between 55…59 dB.

The calculation of the index of improving insulation to impact sound of the floors on floating tiles is made using the following formula:

$$\Delta L_w = L_{n,r,o,w} - L_{n,r,w}, \text{ [dB]}, \quad (7)$$

where: $L_{n,r,o,w}$ represents the values of the impact sound insulation index of the baseline floor; $L_{n,r,w}$ – impact sound insulation index of the baseline floor + floor on floating tiles.

The reverberation duration of the halls is appraised as follows:

$$T = 0.163V/A < T_{adm} = 0.8...1.3 \text{ s} \quad (8)$$

where: V is the volume of the room, [m^3]; A – the equivalent absorption area estimated by the formula:

$$A = \sum S_i \alpha_i + \sum a_i, \quad (9)$$

where: S_i is the area of the element; α_i – the acoustic absorption coefficients for the finishing elements and the objects; a – the absorption provided by persons and objects (armchairs).

Sound reduction index curve. The degree of protection against airborne sound in frequency bands is achieved by outlining the curve of sound reduction indices, in bands of 1/3 of an octave or of an octave. The decrease in the sound reduction index due to transmission on collateral ways is determined by the structure of the wall (one-layer or double) using the formula below:

$$\Delta R_a = -20\lg\left(\frac{Z_m}{Z_{m,\mathrm{med}}}+1\right)$$ for one-layer homogeneous structures or

$$\Delta R_a = -40\lg\left(\frac{Z_m}{Z_{m,\mathrm{med}}}+1\right)$$ for two-layer homogeneous structures.

The final curve $R_i(f) = R(f) + \Delta R_a$, [dB] is compared with the values of the indices within the baseline curve (the curve of reference).

4. The Calculation of the Acoustic Performances in a Future Hotel

The building is placed in Iaşi, the height regime is S + P + 12E + E_{tehn}, placed on a street within the technical category IV.

The evaluation of the insulation degree to airborne sound R'_w from the exterior of the building or from the spaces adjacent to the main rooms:

Reinforced concrete exterior wall

m = 1,047 kg/m^2;

$R'_w = R_w - c$;

$R'_{w,min} = R'_{w,nec} = 46$ dB;

Hypothesis – sound transmission on collateral ways.

The exterior wall has the following connections on the outlines:

– interior walls – reinforced concrete diaphragms, m = 1,025 kg/m^2, h = = 3.10 m;

– lower and upper floor, m = 550 kg/m^2, l = 7.10 m;

$$c = 10\log\left[\frac{Z_m}{Z_{m,\mathrm{med}}}+1\right] = 10\log\left[\frac{1,047(7.1\times 2+3.1\times 2}{1,025\times 2\times 3.1+550\times 2\times 7.1}+1\right] = 4.$$

According to the law of mass: $R_w = 57$ dB

$$R'_w = R_w - c = 57 - 4 = 53 \text{ dB}$$

Exterior wall of ACC

ACC carpentry 25 cm + thermal insulation of mineral wool 15 cm + uniglass wall

m = 235 kg/m^2, R_w = 48dB
links:

– concrete wall m = 1047 kg/m^2, h = 3.1 m × 2
– floors of reinforced concrete, m = 550 kg/m^2, l = 3.00 m

$$c = 10\lg\left(\frac{235(2\cdot 3{,}1+2\cdot 2)}{1047\cdot 2\cdot 3{,}1+550\cdot 2\cdot 3}+1\right)$$

$$R'w = Rw - c = 48 - 1 = 47 \text{ dB}$$

Light walls made of multiple cardboard and plaster slabs, phonically insulated with a mineral wool layer and an air layer, adopted on the fire resistance criterion, is characterised by favourable indices of insulation to airborne sound, while c = 0. R_w = 53...60 dB > $R'_{w,nec}$ = 46 dB

Intermediary floor

m = 459 kg/m^2
$R'_w = R_w - c > R'_{w,min}$
Floor with the following links on the outlines:

– Reinforced concrete wall, m = 524 kg/m^2, l = 6.10 m
– Light interior walls, m = 60.84 kg/m^2, l = 11.40 m
– Exterior wall type 1, m = 197 kg/m^2, l = 4.70 m

$$c = 10\log\left[\frac{Z_m}{Z_{m,\text{med}}}+1\right] = 10\log\left[\frac{459(4.7\times 2+6.4\times 2}{524\times 6.1+60.84\times 11.4+197\times 4.7}+1\right] = 4.93.$$

According to the law of mass: R_w = 54 dB

$$R'_w = R_w - c = 54 - 4{,}93 = 49{,}07 \text{ dB} > R'_{w,nec} = 46 \text{ dB}$$

4.2. The acoustic reduction indices curve in frequency bands

Reinforced concrete exterior wall

m = 1,047 kg/m^2, R_w = 57 dB

RB = RC = 38dB
f_B = 19,000/1,047 = 18.1
f_C = 85,000/1,047 = 60.41

$$\Delta R_u = -20\lg\left(\frac{Z_{m1}+Z_{m2}}{Z_{m,\text{med}}}+1\right) = -8 \text{ dB.}$$

The values are calculated in the following Table and refeatured in the Graph within Fig. 2.

f [Hz]	**25**	**50**	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**
R_w, [dB]	38	38	40	43	47	49	51	53	55	57	59	61
ΔR_a, [dB]	–8	–8	–8	–8	–8	–8	–8	–8	–8	–8	–8	–8
$R = R_w + \Delta R_a$	30	30	32	33	39	41	43	45	47	49	51	53
L – the curve of reference, [dB]					33	36	39	42	45	48	51	52
Unfavourable deviation					–	–	–	–	–	–	–	–

f [Hz]	**630**	**800**	**1000**	**1250**	**1600**	**2000**	**2500**	**3150**
R_w, [dB]	62.5	64	66	68	70	72	74	76
ΔR_a, [dB]	–8	–8	–8	–8	–8	–8	–8	–8
$R = R_w + \Delta R_a$	54.5	56	58	60	62	64	66	68
L – the curve of reference, [dB]	53	54	55	56	56	56	56	56
Unfavourable deviation	–	–	–	–	–	–	–	–

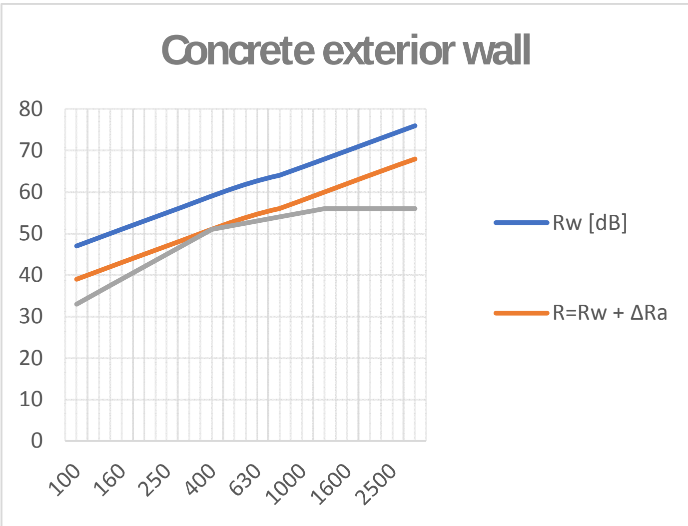

Fig. 2 – Sound reduction index curve $R_i(f)$ – reinforced concrete wall.

The curve of reference (the baseline curve is situated in the entire field under the R_w curve) and the unfavourable deviations are nonexistent.

An R'_w = 53 dB results (at the level of the frequency f = 500 Hz).

The calculation of the impact sound insulation index for intermediary floors

– $L_{n,eq,o,w}$ = 77 dB for a reinforced concrete slab of 14 cm;

– $L_{n,eq,o,w}$ = 76 dB for a reinforced concrete slab of 16 cm.

The contribution of the floors of carpets on floating tiles with elastic support depends on the thickness of the floating tiles and of the elastic layer and it is situated between $\Delta L_{n,w}$ = 22…28 dB.

– $L'_{n,w} = L_{n,eq,o,w} - \Delta L_{n,w} = 77 - 28 = 49$ dB < $L'_{n,w,max}$ = 59 dB in bunk accommodation rooms

– $L'_{n,w} = L_{n,eq,o,w} - \Delta L_{n,w} = 77 - 28 = 49$ dB < $L'_{n,w,max}$ = 55 dB spaces of access and circulations on top of accommodation spaces.

The calculation of the reverberation duration for a conference hall

The reverberation duration is assessed using the following relation:

T = 0.163 · V/A < T_{adm} = 1.1...1.3 sec (C125)

T = 0.163 · V/A < T_{adm} = 0.8 sec (E2003)

V = 410.33 m^3

The characteristics of surfaces, the absorption coefficients of the finishing materials used and the results of the calculations concerning the reverberation duration are featured in Table 8.

Table 8

No.	Name of the material	S [m^2]	Absorption coefficients α_i (f) at the frequencies [Hz]					
			125	250	500	1,000	2,000	4,000
1.	Woven carpet floor	110.9	0.14	0.16	0.18	0.33	0.50	0.70
2.	Coffered mineral ceiling	110.9	0.50	0.40	0.45	0.60	0.60	0.40
3.	Walls – plaster and cardboard slabs	128.4	0.02	0.02	0.03	0.03	0.04	0.05
4.	Curtain walls	49.4	0.03	0.03	0.03	0.03	0.02	0.02
5.	Fire door	7.56	0.05	0.05	0.05	0.05	0.05	0.05
6.	1 fabric-covered padded armchair	91 items	0.10	0.23	0.23	0.22	0.19	0.18
7.	Human agglomeration		0.72	0.89	0.95	0.99	1.0	1.0

Table 8
Continuation

No.	Name of the material	S [m²]	Absorption coefficients α_i (f) at the frequencies [Hz]					
			125	250	500	1,000	2,000	4,000
	A – the equivalent absorption area $A = \sum S_i \cdot \alpha_i + \sum A_j$		85.24	88.3	117.45	127.00	146.8	147.17
	T – the reverberation duration $T = 0.163 \cdot \frac{V}{A}$ [s]		0.785	0.757	0.57	0.527	0.456	0.454
	T_{max} [s]		0.8...1.3					

5. Conclusion

Acoustic comfort is very important, along with hygrothermal or light comfort. The achievement of such comfort is increasingly difficult in the conditions of the large urban agglomerations where the noise level exceeds 70…80 dB during both the day and the night.

The satisfaction of the essential requirement of protection against noise involves the assessment, in the designing phase, of the solutions proposed for the compartmenting elements or for rooms overall.

This paper features a series of assessments to be conducted in the designing phase, in order to ensure an optimal acoustic conformation of a building for accommodation.

REFERENCES

*** C125/2013 Normativ privind acustica în construcţii şi zone urbane.

*** SR EN ISO 717-1-2013 Acustică. *Evaluarea izolării acustice a clădirilor şi a elementelor de construcţii. Partea 1: Izolarea la zgomot aerian*.

*** SR EN ISO 717-2-2013 Acustică. *Evaluarea izolării acustice a clădirilor şi a elementelor de construcţii. Partea 2: Izolarea la zgomot de impact*.

EVALUAREA PERFORMANŢELOR ACUSTICE A CLĂDIRILOR DIN DOMENIUL TURISMULUI

(Rezumat)

În ultima perioadă, s-a observant că la proiectarea clădrilor civile din domeniul turisitc din ţara noastră, specialiştii implicaţi în dezvoltarea proiectelor acordă o atenţie

deosebită doar rezolvării anumitor cerinţe esenţiale de performanţă. Atfel, anumite exigenţe de perfromanţă sunt ignorate sau tratate superficial, cum este cazul protecţiei împotriva zgomotului. Articolul prezintă etapele care trebuie parcurse în verificarea nivelurilor de performanţă acustică, precum şi limitele admisibile pentru diferiţi parametrii în funcţie de care este analizat conortul acustic. De asemenea, se prezintă un studiu de caz unde sunt verificate performanţele acustice ale un clădiri cu destinaţia de hotel.

La final, sunt prezentate concluzii privind verificarea confortului acustic în clădirile din domeniul turistic.