BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LVIII (LXII), Fasc. 4, 2012
Secţia
CONSTRUCŢII. ARHITECTURĂ

CONSIDERATIONS REGARDING NOISE PROTECTION IN A HOTEL

BY

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Received: September 5, 2012
Accepted for publication: September 26, 2012

Abstract. This paper concerns the manner in which the rating of airborne sound insulation and impact sound insulation in buildings and of buildings elements is provided in a hotel. As an example, the results of the noise measurements, found for the rating of airborne sound insulation and impact sound insulation in some neighbouring rooms of a three star hotel from Baia Mare, at intermediate level and in the attic, are given. All the calculations were made according to the new standards and norms in force in our country that comply with the European Standards. The founded results show that the partition members in the hotel do not provide for the insulation at airborne sound, though they provide the insulation at impact sound. Therefore, it is necessary that the competent authorities in our country require the verification of the essential requirement “noise protection”, both during the design stage and in the final stage, by means of measurements made *in situ*.

Key words: rating; sound insulation; buildings; building elements.

1. Introduction

The present paper deals with the checking of the essential requirement regarding noise protection in the case of a hotel.

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The noise protection is mentioned as an essential requirement in the Directive of the European Council No. *89*/*106*/CEE and the Interpretative Documents approved on November 30th 1993 and in Romania is both a quality requirement (*F*) in the context of Law No. *10*/1995 and an essential requirement (*e*) in Law No. *123*/2007.

Acoustic measurements were performed in a hotel, in the central area of the city of Baia Mare, Maramureş County, Romania, to check the insulation levels of the partition walls and of the façade at airborne noise and of the floors to the impact noise.

The hotel building was erected in the year 1964. Initially, the building hosted the headquarters of a computer centre. Between 2004 and 2005, the building was consolidated and refurbished; it was extended horizontally with some new units (a cafeteria and a covered swimming pool) and also vertically, with an attic. Fully refurbished, the building changed destination as it became a three-star hotel (Fig. 1).

Fig.1 – The main façade of the hotel.

The hotel has today the following composition: S+P+2E+M; its structure is built with reinforced concrete frames, full brick masonry with outer walls of 30 cm thick and inner walls of 12 cm thick at the first and second level. The attic walls are built with 30 cm thick BCA outside and 15 cm thick inside. It includes 64 rooms, a conference hall, a restaurant, a cafeteria, a swimming pool, some administrative offices and a fitness gym. The façade was also refurbished and a heat insulation system of 10 cm thick polystyrene was laid. The former façade windows were also removed and replaced by double glazing thermal insulation windows which significantly improve both heat insulation and sound insulation against external noise. Measurements and calculations were performed to check the airborne and the impact noise insulation level as well as for the reverberation time of the hotel's rooms.

2. Equipment Used to Measure Noise Levels

The airborne and impact noise level measurements were performed with measuring equipment produced by the company Bruel & Kjaer, founded in

1942 in Denmark. For this purpose, were used the following devices sound and vibration multi-analysor “PULSE 3560B”, analysis software type PULSE “FFT&CPB Analysis 7700”, mounted to a Dell notebook, the all-direction noise source “OmniPower Sound Source 4292” equipped with a tripod, power amplifier “Power Amplifier 2716”, impact tapping machine type “Tapping Machine Type 3207” and a microphone type “Microphone 4189” also provided with a tripod.

3. Determination of Airborne Noise Level

3.1. Determination of Airborne Noise Level in Current Floors

In order to measure the airborne noise level in the hotel rooms we used frequency intervals between 20 and 20,000 Hz, but for computational purposes intervals of a third of an octave of the frequencies between 100 and 3,150 Hz are used. The partition walls of the hotel from the first and second floor are of full brick masonry, of ρ = 1,800 kg/m^3 and thickness of 12 cm, plastered on both sides with a 3 cm thick lime cement mortar, of ρ = 1,700 kg/m^3 (Fig. 2). The length of the partition wall between rooms is 5.45 m and the height is 3.00 m (Fig. 3).

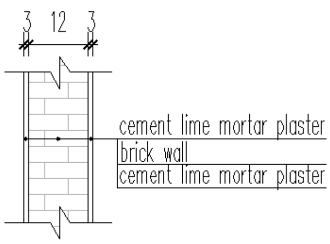

Fig. 2 – Detail of partition wall at the 1st and 2nd floor.

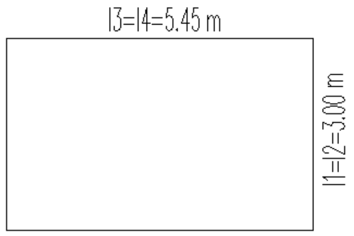

Fig.3 – Dimensions of the partition wall.

Two adjacent rooms were taken randomly in the first floor to be measured, namely 104 and 105, shown in Fig. 4.

The measurements in the reception room (first floor, room 105) were made with the microphone placed in five points (in the four room corners and in the middle of the room), at a height of 1.30 m measured from the flooring, according to the provisions in STAS 6161-89 and STAS 6162-89; the noise curves measured values represent the average of the measurements in those five points. The noise level was also measured in the emission room (first floor room 104) where the all direction noise source was put. The measurements were performed with the neighbouring rooms doors closed. Images of the two neighbouring rooms and of the central hall from the first floor of the hotel, where sound related measurements were made, are presented in Fig. 5.

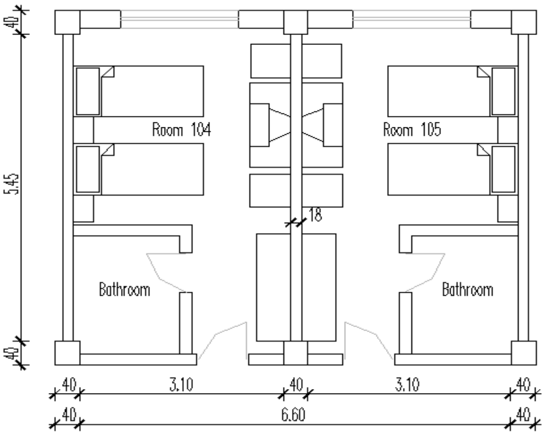

Fig. 4 – Rooms 104 and 105 from the first floor.

a *b* *c*

Fig. 5 – *a* – multidirectional speaker in emission room; *b* – amplifier, laptop with data processing software PULSE and frequency analyser; *c* – microphone in the receptive room.

The *in situ* sound attenuation indices, were determined according to the norms related to sound protection with relationship

$$R_i'\left(f\right) = L_1 - L_2 + 10\,\lg\frac{S}{A}\,,\ [\mathrm{dB}], \qquad (1)$$

where: L_1, L_2 are noise levels in the emission space, respectively in the reception space, [dB]; S – the wall surface, [m^2]; A – the equivalent absorption area, in the receptive room, [m^2].

The reverberation time, T, expressed in seconds, was measured and calculated, with a special Brüel & Kjaer software dedicated to this kind of measurements, in the receptive room (room 105). The equivalent absorption area, A, was found from the calculus of the reverberation time, T, determined according to the norms related to sound protection with relationship

$$T = 0.163\frac{V}{A}\text{, [s] ,} \tag{2}$$

where: V is the volume of the room, [m^3]; A – the equivalent absorption area, [m^2]. Hence

$$A = 0.163\frac{V}{T}\text{, [m}^2\text{].} \tag{3}$$

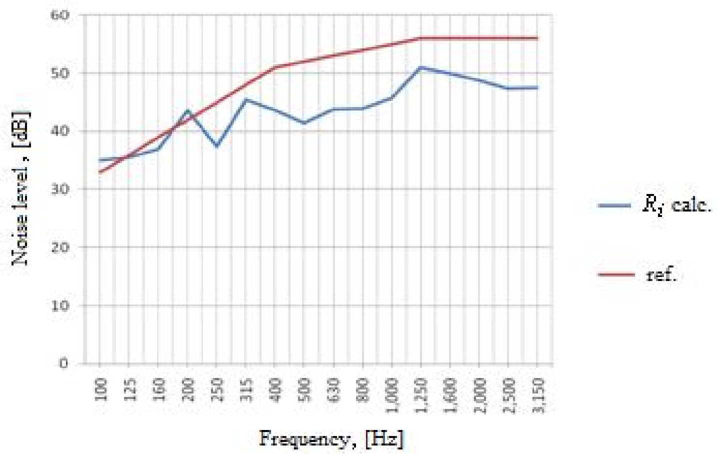

Fig. 6 – The curve of the acoustic damping coefficients $R_i^{'}(f)$ and the reference curve.

The surface of the partion wall between the emission room and the receptive room is S = 5.50 × 3.00 = 16.50 m^2 and the volume of the receptive room is V = 48.91 m^3.The rating of airborne sound was done according to existent standards. The airborne sound reduction index for the partition wall, noted $R_w^{'}$, is defined with the method presented in the standards, by comparing the curve of the acoustic damping coefficients $R_i^{'}(f)$, obtained in 1/3 octave bands over the range 100 Hz to 3,150 Hz and the reference (calibrated) curve of the sound damping coefficients . The curve $R_i^{'}(f)$ and the reference (calibrated) curve are presented in Fig. 6.

The comparison of the acoustic damping coefficients' curve $R_i'(f)$ and of the reference (calibrated) curve, presented in Fig. 6, is made in Table 1.

Table 1

The Comparison of the $R_i'(f)$ Curve with the Reference Curve

Freq. f Hz	The reference curve dB	Noise level L_1 dB	Noise level L_2 dB	Correction $10\lg\frac{S}{A}$ dB	$R_i'(f)$ dB	Deviations of the calculated curve *versus* the reference curve dB	Reference values after translation by 5 dB dB	Detrimental deviation dB
1	2	3	4	5	6=3–4+5	7=6–2	8	9
100	33	75.8668	40.5513	–0.309	35.0070	2.007	28	7.007
125	36	78.6962	40.1626	–2.985	35.5490	–0.451	31	4.549
160	39	78.1911	40.7570	–0.547	36.8875	–2.112	34	2.888
200	42	84.4469	40.2754	–0.577	43.5942	1.594	37	6.594
250	45	83.2096	40.8754	–3.039	39.2957	–5.704	40	–0.704
315	48	83.7485	39.6959	1.374	45.4271	–2.573	43	2.427
400	51	84.8883	39.4940	–1.695	43.6991	–7.301	46	–2.301
500	52	81.9374	37.3161	–2.157	42.4641	–9.536	47	–4.536
630	53	81.4797	35.1029	–2.527	43.8498	–9.150	48	–4.150
800	54	77.6290	32.0566	–1.695	43.8772	–10.123	49	–5.123
1,000	55	77.9088	30.8946	–1.242	45.7726	–9.227	50	–4.227
1,250	56	80.3687	28.3879	–0.964	51.0173	–4.983	51	0.017
1,600	56	80.4528	29.8981	–0.577	49.9774	–6.023	51	–1.023
2,000	56	80.6770	30.1495	–1.656	48.8720	–7.128	51	–2.128
2,500	56	80.9420	32.5327	–0.964	47.4458	–8.554	51	–3.554
3,150	56	81.4215	32.2948	–1.656	47.4712	–8.529	51	–3.529
						$\sum(-\Delta) = -91.394$		Sum 31.258 < 32.0 dB $R_w' = 52 - 5 = 47$ dB

The method through which the two curves are compared consists in displacing the reference curve (calibrated curve) with 1 dB steps, *versus* the measured and calculated curve, $R_i'(f)$, until the sum of the negative deviations reaches the highest value, but does not exceed 32.0. The deviation is seen as negative, at a certain frequency, if the measured or calculated value is lower than the reference value. Only negative deviations are considered. If the movement follows the mentioned procedure, the value of the reference curve, expressed in dB at 500 Hz, is R_w'. In our case we have

$$R_w' = 52 - 5 = 47 \text{ dB}.$$

According to Norms related to sound protection the admissible value of the airborne sound reduction index for the inner partition walls in a hotel is 51 dB. It yields that

$$R'_w = 47 \text{ dB} < R'_{w,\text{nec}} = 51 \text{ dB},$$

therefore the wall does not ensures the insulation against the airborne sound.

A comparison of the curves of acoustic attenuation indices, $R_i^{'}(f)$, with the curve Cz 30 was also made. This comparison is given in the normatives as the admitted limit of the inner airborne sound in dwelling rooms or sleeping rooms in a hotel (Fig. 7).

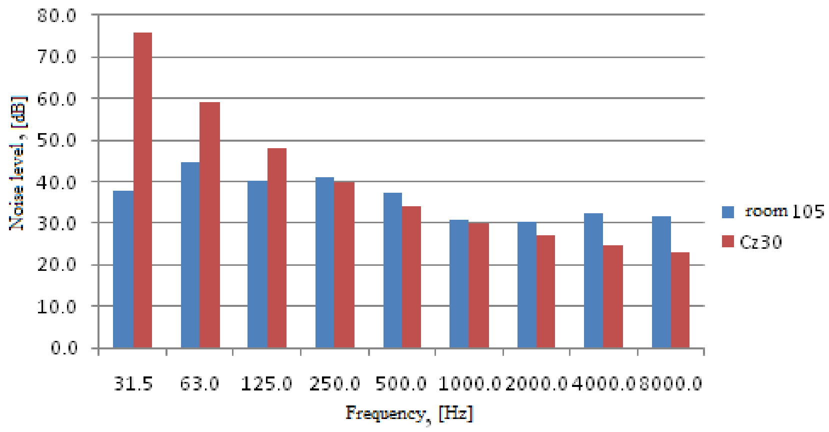

Fig. 7 – Noise levels compared with admissible noise curve limits Cz30.

Comparing the noise level in room 105 with the reference curve Cz 30, one notices that, at higher frequencies (250, 500, 1,000, 2,000, 4,000, 8,000 Hz), the admitted values are exceeded by 0.98, 3.32, 0.89, 3.25, 7.81 and, respectively, 8.77 dB.

As a conclusion, from the point of view of the acoustic measurements, the partition wall between rooms 104 and 105 do not provide the sound insulation level required. This means that measures should be installed for additional sound insulation. A rehabilitation solution, from an acoustic point of view would have been the plating of the initial wall with a metallic skeleton, mineral wool of minimum 5 cm thickness, inserted in the metallic skeleton and over the profiles gypsum plaster plates, on both sides of the existing wall.

3.2. Determination of Airborne Noise Level in The Rooms in the Attic

In the attic of the hotel, the partition walls are made with BCA masonry, of ρ = 800 kg/m^3 and thickness of 15 cm, plastered on both sides with a 1.5 cm thick lime cement mortar ρ = 1,700 kg/m^3 (Fig. 8). The length of the partition wall between rooms 306 and 307 is 5.45 m and the height is 2.70 m (Fig. 9).

Two adjacent rooms were taken randomly in the attic to be measured, namely 306 and 307, shown in Fig. 10.

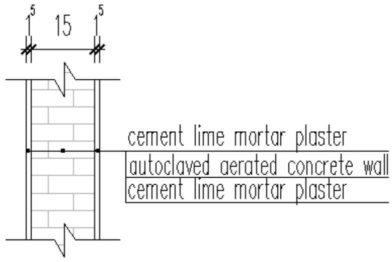

Fig. 8 – BCA attic partition wall.

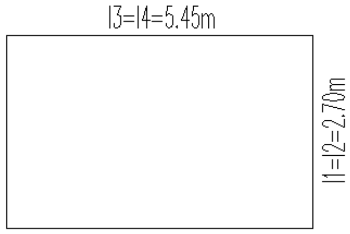

Fig. 9 – Dimensions of the attic partition wall.

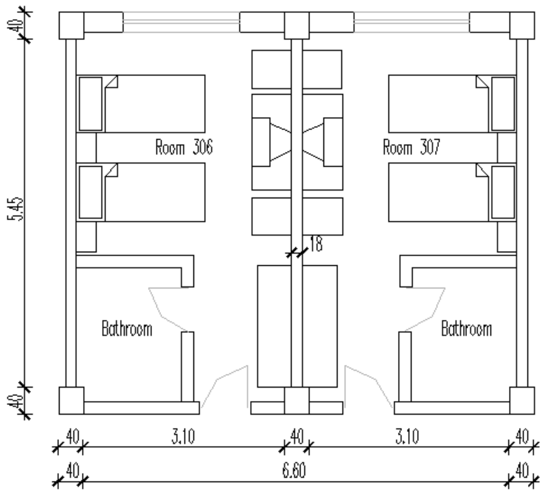

Fig. 10 – Rooms 306 and 307 in the attic.

3.2. Main Results

The *in situ* sound attenuation indices, $R_i^{'}(f)$, [dB], were determined with relationship (1). The equivalent absorption area, *A*, [m^2], in the receptive room 307, were found with relationship (3), with the special Brüel & Kjaer software for the determination of the reverberation time, *T*.

The surface of the partion wall between the emission room and the receptive room is $S = 5.45 \times 2.70 = 14.72$ m^2 and the volume of the receptive room is $V = 44.55$ m^3. The curve $R_i^{'}(f)$ and the reference (calibrated) curve are presented in Fig. 11.

The comparison of the acoustic damping coefficients' curve, $R_i^{'}(f)$, and of the reference (calibrated) curve, presented in Fig. 11, is made in Table 2.

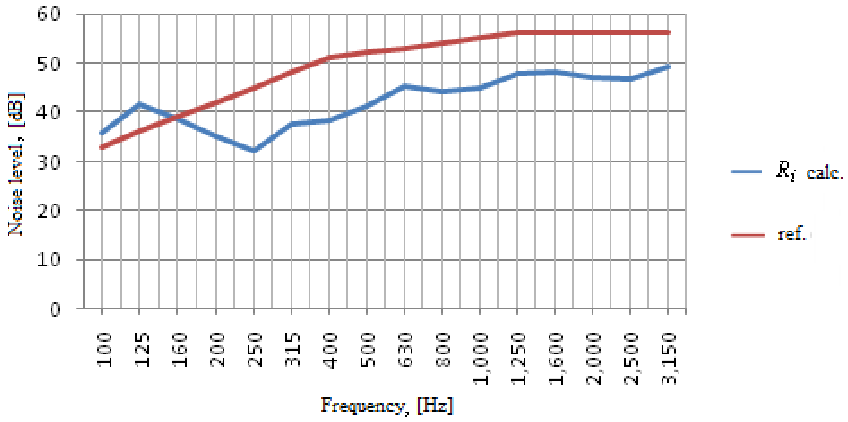

Fig. 11 – The curve of the acoustic damping coefficients $R_i^{'}(f)$ and the reference curve.

Table 2

The Comparison of the $R_i^{'}(f)$ Curve with the Reference Curve

Freq. f Hz	The reference curve dB	Noise level L_1 dB	Noise level L_2 dB	Correction $10\lg\frac{S}{A}$ dB	$R_i'(f)$ dB	Deviations of the calculated curve *versus* the reference curve dB	Reference values after translation by 8 dB dB	Detrimental deviation dB
1	2	3	4	5	6=3–4+5	7=6–2	8	9
100	33	70.9905	34.5205	–0.661	36	2.809	25	10.809
125	36	82.7964	38.9945	–2.166	42	5.636	28	13.636
160	39	85.1142	41.6067	–4.962	39	–0.454	31	7.546
200	42	84.2106	47.0902	–3.091	34	–7.971	34	0.029
250	45	80.2087	44.2393	–3.671	32	–12.701	37	–4.701
315	48	82.1110	42.2009	–2.166	38	–10.255	40	–2.255
400	51	81.8215	42.4412	–0.949	38	–12.569	43	–4.569
500	52	81.4142	38.3507	–1.669	41	–10.605	44	–2.605
630	53	81.0437	35.6007	–1.366	44	–8.923	45	–0.923
800	54	78.7513	32.4088	–2.036	44	–9.693	46	–1.693
1,000	55	79.6113	33.3808	–1.366	45	–10.136	47	–2.136
1,250	56	81.2615	32.5812	–1.016	48	–8.336	48	–0.336
1,600	56	83.4627	34.4687	–1.708	47	–8.714	48	–0.714
2,000	56	81.9356	32.6020	–2.122	47	–8.788	48	–0.788
2,500	56	83.4830	35.1785	–1.669	47	–9.364	48	–1.364
3,150	56	84.6331	33.8384	–1.366	49	–6.572	48	1.428
						$\sum(-\Delta) = -125.082$		Sum 22.086<32.0 dB $R_w^{'}$ =52–8 = 44 dB

In our case we have $R'_w = 52 - 8 = 44$ dB.

According to normatives the admissible value of the airborne sound reduction index for the inner partition walls in a hotel is 51 dB. It yields that

$$R'_w = 44 \text{ dB} < R'_{w,\text{nec}} = 51 \text{ dB},$$

therefore the wall does not ensures the insulation against the airborne sound and this means that measures should be installed for additional sound insulation. It can be applied the acoustic rehabilitation solution proposed in §**3.1**.

Measurements were also performed in this hotel to check the insulation levels of the façade's walls at airborne noise from the street. The conclusion is that there are no problems with the noise level from outside.

4. Rating the Impact Sound Levels in the Rooms

4.1. Current Floor Flooring

In order to measure the impact noise in the rooms of the hotel frequency intervals between 20 Hz and 20,000 Hz are used, though, for calculation purposes, frequency intervals of 100 Hz and 3,150 Hz are used for a third of an octave. The found values are compared to the values listed in normative. The measurements were performed in room 205 (emission room) at the second floor, respectively in room 105 (reception room) at the first floor, in three different positions of the impact hammer and the calculations took into account an average of the three measurements. An image of the impact hammer is presented in Fig. 12. The flooring concerns a 12 cm thick reinforced concrete layer, of 3 cm thick, equalizing concrete layer and fire-free wall-to-wall carpet (Fig. 13).

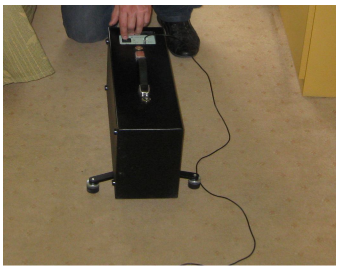

Fig. 12 – The impact hammer in room 205.

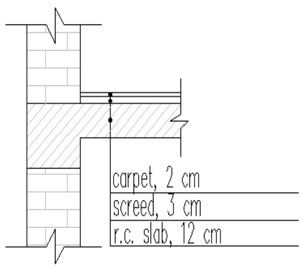

Fig. 13 – Current floor floring.

The rating of impact sound was done according to standards. The level of the normalised impact sound (L_n) is calculated with the relationship

$$L_n = L_i + 10 \lg \frac{A}{A_0}, \text{ [dB]}, \tag{4}$$

where: L_i is the sound level in the reception room (room 105), [dB]; A – equivalent area for acoustic absorption in the reception space, [m^2], calculated function of the reverberation time measured in room 105; A_0 – equivalent area of reference for acoustic absorption (A_0 = 10 m^2).

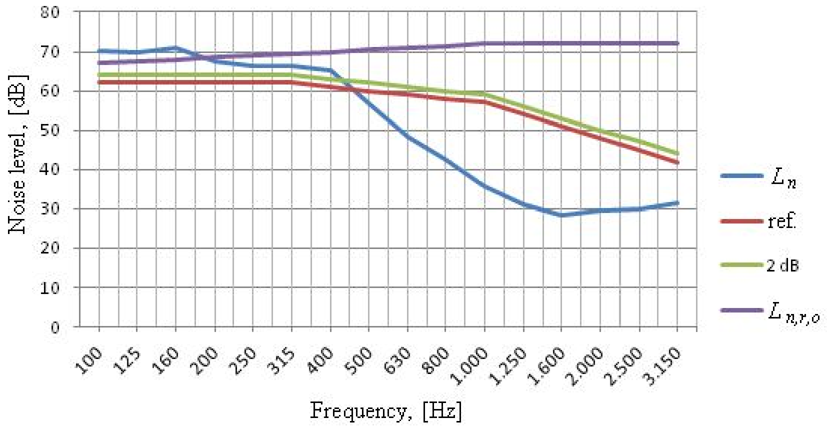

Fig. 14 – Rating index $L_{n,r,w}$.

Table 3

Curve $L_n(f)$ Compared to the Reference Curve

Freq. f Hz	The reference curve dB	Noise level L_i dB	Correction $10\lg A/A_0$ dB	L_n dB	Deviations of the calculated curve *versus* the reference curve dB	Reference values after translation by 2 dB dB	Detrimental deviations dB
1	2	3	4	5=3+4	6=2–5	7	8
100	62	67.6059	2.483	70.0893	–8.089	64	–6.0893
125	62	64.7744	5.159	69.9338	–7.934	64	–5.9338
160	62	68.2500	2.721	70.9714	–8.971	64	–6.9714
200	62	64.8182	2.752	67.5703	–5.570	64	–3.5703
250	62	61.1426	5.213	66.3560	–4.356	64	–2.3560
315	62	65.5408	0.800	66.3412	–4.341	64	–2.3412
400	61	61.4461	3.870	65.3161	–4.316	63	–2.3161
500	60	52.5213	4.332	56.8533	3.147	62	5.1467
630	59	43.4690	4.702	48.1709	10.829	61	12.8291
800	58	38.7341	3.870	42.6041	15.396	60	17.3959
1,000	57	32.3541	3.416	35.7705	21.229	59	23.2295
1,250	54	28.0462	3.138	31.1846	22.815	56	24.8154
1,600	51	25.6063	2.752	28.3584	22.642	53	24.6416
2,000	48	25.7810	3.830	29.6114	18.389	50	20.3886
2,500	45	26.8104	3.138	29.9488	15.051	47	17.0512
3,150	42	27.5573	3.830	31.3877	10.612	44	12.6123
					$\sum(-\Delta) = -43.578$		Sum 29.5781<32.0 dB $L_{n,r,w}$ = 62 dB

The curve of the normalized levels, $L_n(f)$, which corresponds to the constructive unit made up of the reinforced concrete + flooring, was calculated with relationship (4); the curve $L_n(f)$ was compared to the reference curve from Fig. 14 and Table 3.

A reference flooring is taken (12 cm thick reinforced concrete flooring), where the values of the normalised impact noise, $L_{n,r,o}$, and the impact sound insulation index, $L_{n,r,o,w}$ = 78 dB, are known. The reference curve is displaced up and down so that the sum of detrimental deviations nears as much as possible to the value of 32 dB, but does not exceed it; the impact sound insulation index ($L_{n,r,w}$) represents the value found at 500 Hz on the reference curve (moved with 2 dB), to overlap curve $L_n(f)$. The index regarding the improvement of the impact sound insulation (ΔL_w) for the single reinforced concrete flooring is calculated with the relationship

$$\Delta L_w = L_{n,r,o,w} - L_{n,r,w}. \tag{5}$$

In our case we have ΔL_w = 78 – 62 = 16 dB.

According to Norms related to sound protection, the condition for a flooring to provide impact sound insulation is given by

$$L'_{n,\mathrm{eff}} \le L'_{n,\max}\,;\; L'_{n,\mathrm{eff}} = L_{n,r,w} = 62 \text{ dB};\; L'_{n,\max} = 62 \text{ dB (for a hotel)};$$
$$L_{n,r,w} = 62 \text{ dB} = L'_{n,\max} = 62 \text{ dB}.$$

Calculations show, by comparing curve $L_n(f)$ with the reference curve, that the floor between rooms 105 and 205 provides the necessary impact sound insulation, at minimum level. In brief, considering measurements, the impact sound insulation of the flooring needs not improvement.

4.2. Last Floor Flooring

Measurements were made in room 307 (emission room), respectively room 207 (reception room), with three different positions of the impact hammer. The flooring is made of 10 cm thick lightweight concrete with vegetal aggregates, with an equalizing layer of 3 cm of cement mortar, covered with a fire-free wall-to-wall carpet (Fig. 15).

A reference flooring is taken (12 cm thick reinforced concrete flooring), where the values of the normalized impact noise, $L_{n,r,o}$, and the impact sound insulation index, $L_{n,r,o,w}$ = 78 dB, are known. The curve of normalized levels, $L_n(f)$, corresponding to the unit formed from the reinforced concrete floor + the flooring was calculated with relationship (4); the curve $L_n(f)$ was compared to the reference curve in Fig. 16 and Table 4.

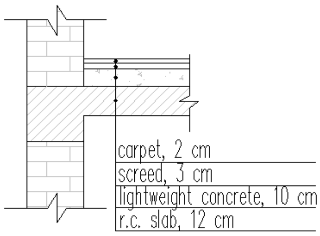

Fig. 15 – Last floor flooring.

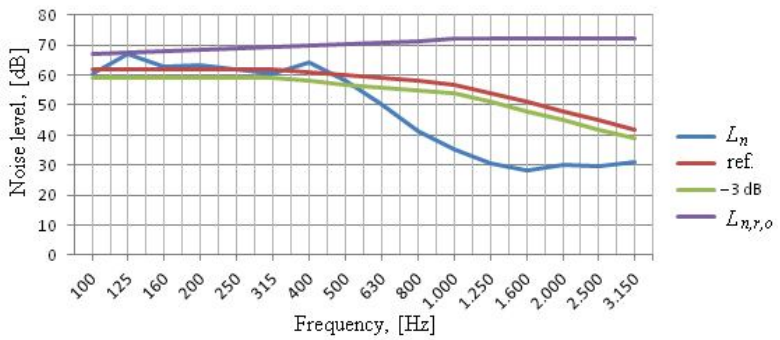

Fig. 16 – Rating index $L_{n,r,w}$.

Tabel 4

Curve $L_n(f)$ Compared to the Reference Curve

Freq. f Hz	The reference curve dB	Noise level L_i dB	Correction $10\lg A/A_0$ dB	L_n dB	Deviations of the calculated curve *versus* the reference curve, [dB]	Reference values after translation by 3 dB dB	Detrimental deviations dB
1	2	3	4	5=3+4	6=2–5	7	8
100	62	58.1513	2.483	60.6347	1.365	59	–1.6347
125	62	61.6813	5.159	66.8407	–4.841	59	–7.8407
160	62	60.1972	2.721	62.9186	–0.919	59	–3.9186
200	62	60.8080	2.752	63.5601	–1.560	59	–4.5601
250	62	56.4881	5.213	61.7015	0.299	59	–2.7015
315	62	59.9368	0.800	60.7372	1.263	59	–1.7372
400	61	60.2443	3.870	64.1143	–3.114	58	–6.1143
500	60	53.8781	4.332	58.2101	1.790	57	–1.2101
630	59	45.3010	4.702	50.0029	8.997	56	5.9971
800	58	37.5466	3.870	41.4166	16.583	55	13.5834
1,000	57	31.8466	3.416	35.2630	21.737	54	18.7370
1,250	54	27.4770	3.138	30.6154	23.385	51	20.3846
1,600	51	25.5554	2.752	28.3075	22.693	48	19.6925
2,000	48	26.0579	3.830	29.8883	18.112	45	15.1117
2,500	45	26.3700	3.138	29.5084	15.492	42	12.4916
3,150	42	27.3099	3.830	31.1403	10.860	39	7.8597
					$\sum(-\Delta) = -10.434$		Sum 29.7172<32.0 dB $L_{n,r,w} = 57$ dB

The reference curve is moved upwards or downwards so that the sum of detrimental deviations goes as close as possible to the value of 32 dB, without exceeding it. The impact sound insulation index ($L_{n,r,w}$) represents the value reached at 500 Hz on the displaced reference curve (with 3 dB), overlapping curve $L_n(f)$. In our specific situation

$$\Delta L_w = L_{n,r,o,w} - L_{n,r,w} = 78 - 57 = 21 \text{ dB}.$$

According to Norms related to sound protection, the condition for a flooring to provide impact sound insulation is given by $L'_{n,\text{eff}} \le L'_{n,\max}$. In our case

$$L'_{n,\text{eff}} = L_{n,r,w} = 57 \text{ dB and } L'_{n,\max} = 62 \text{ dB (for a hotel)};$$
$$L_{n,r,w} = 57 \text{ dB} < L'_{n,\max} = 62 \text{ dB}$$

Calculations show, by comparing curve $L_n(f)$ with the reference curve, that the floor between rooms 207 and 307 provides the necessary impact sound insulation. In conclusion, the floors of the hotel provide a good impact sound insulation.

5. Conclusions

1. One can appreciate that the partition walls of the rooms in the hotel under investigation, both at current floors and in the attic, do not correspond in so far the requirements for external noise protection are concerned.

2. As impact sound insulation is achieved in the hotel, the hotel needs only sound rehabilitation measures for improving the airborne sound insulation. The simplest measure would be the plating with a frame, mineral wool and gypsum plaster plates on both sides of the initial walls.

3. In civil purpose buildings, in general, and especially in hotels, it is extremely necessary to perform a verification of their sound insulation. Unfortunately, this is not a current preoccupation for the hotels in our country.

4. The verification of the essential requirement “protection against noise” should be performed both during the design stage and in the final building stage, with *in situ* measurements.

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CONSIDERAȚII PRIVIND IZOLAREA ÎMPOTRIVA ZGOMOTULUI LA UN HOTEL

(Rezumat)

Se studiază modul în care este efectuată evaluarea izolării acustice la zgomot aerian şi la zgomot de impact a clădirilor şi a elementelor de construcții la un hotel. Ca un exemplu, sunt prezentate rezultatele obținute prin măsurarea nivelului de zgomot în câteva camere învecinate ale unui hotel din Baia Mare, la un nivel intermediar şi în mansardă. Toate calculele s-au efectuat conform noilor standarde şi normative în vigoare în România, care sunt în concordanță cu Standardele Europene. Rezultatele obținute arată că elementele de construcție despărțitoare ale hotelului nu asigură izolarea acustică împotriva zgomotului aerian, dar asigură izolarea acustică împotriva zgomotului de impact. De aceea este necesar ca organele competente din țara noastră să solicite verificarea cerinței esențiale – "protecția împotriva zgomotului", atât în stadiul de proiectare cât şi în stadiul final, prin efectuarea măsurătorilor *in situ*.