IMPROVING BUILDING ACOUSTICS

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Received: 31.07.2021 / Accepted: 28.08.2021 / Revised: 27.10.2021 / Available online: 15.12.2021

DOI: [10.2478/jaes-2021-0018](https://doi.org/10.2478/jaes-2021-0018)

KEY WORDS: Noise Level, Acoustic Correction, Sound Comfort, Acoustic Insulation, Absorbent Treatments.

ABSTRACT:

One of the most significant aspects which need to be analysed in the case of a building consists in finding that the sound level perceived by listeners is a proper one (Daniela-Roxana Tămaș-Gavrea et al., 2012). Their inconsistent spreading can develop problems in audition which can be solved only by putting in work a number of measures of acoustic rehabilitation. The evaluation of the acoustic quality of a building is a delicate issue, because of the complex system of the sound field contained in closed spaces and the sound features of the outlining surfaces. This paper presents a research on improving the acoustic conditions of a building which initially had a technical-administrative destination and was then converted into an office building (Stanca S.E., 2021). The measures of acoustic protection were recommended with a view to mitigate the noise level under admissible limits in the functional unit under consideration.

1. INTRODUCTION

The acoustics of buildings concerns the study of the phenomena related to the propagation and reception of the acoustic energy in the functional units in the buildings, in order to provide sound comfort.

By optimally arranging absorbing and reflecting surfaces, it is possible to influence sound propagation, so that the listener is not disturbed by an exaggerated attenuation or, the opposite, by its inadequate reflectivity, Figure 1 (<https://www.confortsirenovare.ro/ro/Rigips-Fonic/>), Figure 2 (<https://sporulcasei.ro/izolatie-fonica-elemente-de-construc-tie-si-lucrari-de-fonoizolare-pentru-o-casa-linistita/>).

Figure 1. Rigips® Fonic subdivision systems designed to increase acoustic insulation in air noise transmission

Figure 2. Air sound propagation in the building

The acoustic climate can be optimized by designing and putting to work materials that reduce sound reverberation inside a room, that limit noise transmission from outside and minimize the background noise caused by heating, cooling and ventilation systems.

Acoustic sustainability is distinguished according to various aspects, be they cultural, social, economic and environmental (Stanca S., 2018, Stanca S., 2016).

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Establishing a balance among these features is, at present, one of the main concerns of the scientific community (<https://www.iso.org/home.html>), Figure 3:

Figure 3. Benefits of sustainable development

1. REDUCING NOISE BY ACOUSTIC INSULATION PROCEDURES

The noise level can be controlled by (<https://acustica.ro/izolarea-fonica-si-tratamentul-acustic/>):

- sound insulation,
- acoustic/sound correction.

Erecting buildings which are noise-efficient requires a thorough knowledge of the way sounds and noises propagate and are perceived, the analysis of the acoustic characteristics of the materials and elements composing the building, Figure 4 (https://issuu.com/fac.arhitecturasiurbanism.upt/docs/fizica_constructiilor_an_4_arh, <https://theconstructor.org/building/noise-control-in-buildings-acoustic/14640/>):

Figure 4. Noise sources in a building

In order to achieve an efficient sound insulation, it is necessary to minimize the sound passing through walls, partitions or ceilings.

Methods of sound insulation, Figure 5 (<http://www.siniat.ro/ro/documentatie-suport/ghiduri/izolarea-fonica-si-corectia-acustica#solutii-izolare-acustica>):

- developing constructive solutions, based on increased partition weight, through heavy duty gypsum plasterboard and/or double layers, considering "weight law";
- using lightweight plates and/or a material exhibiting a higher absorbing ability;
- sound insulation by mixing air voids among plates (cavities) and the plates weight, to increase acoustics.

Figure 5. Solutions for sound insulation, acoustic correction

The purpose of absorbing sounds lies in making an acoustic correction, diminishing the sound level in a room, an objective

that can be reached using materials that accept the dissipation of vibrations found in the air.

2. ABSORBENT ACOUSTIC TREATMENT PROCEDURES

Absorbent treatment procedures are dedicated to reducing parasite sound emitted inside a room.

Repeated reflectivity of tones in a closed in compartment lead to their intensified projection which has an unpleasant effect on the sound comfort. To avoid this phenomenon, constructive materials and solutions leading to increased absorbed energy detrimental to reflected energy, are used.

There are several procedures used to treat sounds, classified in accordance with the mechanism put to work (Andreica H. A., 2002, Andreica H. A. et. all, 2009):

✚ *Porous absorbers:* they change sound energy in heat through the friction due to air viscosity in the pores, Figure 6
(https://issuu.com/fac.arhitecturasiurbanism.upt/docs/fizica_constructiilor_an_4_arh):

Figure 6. Treatment with porous absorbers
a. Vertical section; b. Elevation
1. Wall; 2. Perforated mineral felt plates

Materials used are: mineral wool, mineral wool products (mattresses, strips, plane or perforated full core slabs), expanded cork, porous PFL, velvet or plush coverings (<https://sporulcasei.ro/3-motive-pentru-care-se-foloseste-vata-minerala-in-interiorul-peretilor-din-gips-carton/>).

✚ *Oscillating plate absorbers*

Such sound absorbing treatment can be performed with: plywood, cardboard, metal panels or wooden frames including thick cloth and a porous material (cotton wool). Plate type absorbing elements can be assembled providing free space

behind them or as felt. The absorbing capacity can be improved by dividing the space behind the panel with slits and felt or wool strips, Figure 7
(https://issuu.com/fac.arhitecturasiurbanism.upt/docs/fizica_constructiilor_an_4_arh):

Figure 7. Treatments with absorbers with oscillating plate
1. Wall; 2. Air; 3. Plywood; 4. Deep felt; 5. Wooden rulers

✚ *Air absorbers (resonators)*

This mechanism can be resembled to a bottle put on one side, with a free neck or filled with a porous material. Under sound incidence, the air in the resonator channel performs alternative oscillation movements, similar to a piston, and dissipated sound energy, in the context of inertia and viscosity. When in resonance, the speed of the air in the channel becomes very high, but when an absorbing material is fitted in the neck, friction makes the resonator become an active sound absorbent, Figure 8

(https://issuu.com/fac.arhitecturasiurbanism.upt/docs/fizica_constructiilor_an_4_arh,
<http://www.gcdataconcepts.com/helmholtz.html>):

Is the most impressive way to trap the frequencies. The bandwidth is often quite narrow but really very highly efficient. The principle is easy:

- holes on a panel are connected to a cavity covered with absorbent.
- The resistance of the air flow in the neck of the perforation gives the frequency tuning.
- The mass of the material and the springiness of the air determine the resonant system.

Figure 8. Air absorber treatments (a. Helmholtz resonator; b. Acoustic air absorber to a masonry wall)

3. CASE STUDY – ACOUSTIC REHABILITATION

The intervention supposes to convert the existing building superstructure from a technical and administrative purpose building into an office building, by making changes in the partitions of the interior spaces. The suggested destination: law offices (Stanca S. E. 2021).

The rooms have been grouped according to a functional criterion that demanded a clear-cut distinction between various areas of activities and a fluent communication among them (<https://www.worldarchitecturenews.com/2019>, Gheorghe Vais, 2008).

In order to estimate the building members capacity to insulate against air noise a calculation for the air noise insulation evaluation index R_w was performed for the homogeneous interior walls, by means of:

a) The graphical-analytical method – Determination by calculation of the air noise insulation evaluation index R_w for the homogeneous interior walls (C125-2013).

Dividing wall (<https://www.wienerberger.ro/>):

Product Technical Information - Porotherm Solid Brick

Work Size (mm) (LxWxH) 240x115x63

Individual Dry Brick Weight (kg) 3,25

Apparent density (kg/m³) 1850

Length $L = 4,15$ m; Height $h = 3,05 - 0,15 = 2,90$ m.

The wall is fitted to the top and bottom to 15 cm thick monolith reinforced concrete slabs.

The calculated brick masonry dividing wall separates two spaces, secretariat/waiting room, and is 11,5 cm thick, with $\rho = 1850$ daN/m³, plastered on both faces with 2.0 cm thick lime mortar of apparent density $\rho = 1700$ daN/m³.

The weight per surface unit of the building element is established:

$$m = 0,02 \times 1700 + 0,115 \times 1850 + 0,02 \times 1700 = 280,75 \approx 281 \text{ Kg/m}^2$$

The frequency range of the coincidence area $f_b - f_c$ is calculated, respectively the value of the attenuation index in the coincidence area $R_B = R_C$ in relation with the material from which the building element is made:

$$f_B = \frac{17000}{m} = \frac{17000}{281} = 60 \text{ Hz}$$

$$f_C = \frac{77000}{m} = \frac{77000}{281} \approx 274 \text{ Hz}$$

$$R_B = R_C = 37 \text{ dB}$$

Curve $R_i(f)$ is erected without taking into consideration the contribution of the indirect ways of sound transmission.

The effect of the sound transmission through indirect ways is inserted, displacing the built curve $R_i(f)$ with the value:

$$\Delta R_a = -20 \lg \left(\frac{Z_{med}}{Z_{m,med}} + 1 \right) [\text{dB}]$$

where:

Z_{med} – the mechanical impedance related to the building member under investigation, daN s/m³;

$Z_{m,med}$ – the average mechanical impedance of the adjacent building members that outline the reception space of the element under study, daN s/m³.

The dimensions of the interior wall are, Figure 9:

Figure 9. The dimensions of the interior wall

$$\begin{aligned} l_1 &= l_2 = 4,15 \text{ m} \\ m_1 &= m_2 = 0,15 \times 2500 = 375 \text{ Kg/m}^2 \\ l_3 &= l_4 = 2,90 \text{ m} \\ m_1 &= m_2 = 0,4 \times 1700 = 680 \text{ Kg/m}^2 \end{aligned}$$

$$\frac{Z_{med}}{Z_{m,med}} = \frac{mxP}{\sum_{i=1}^4 m_i' x l_i} = \frac{281 \times 2(4,15 + 2,9)}{2(4,15 \times 680 + 2,9 \times 375)} = 0,56$$

$$\Delta R_a = -20 \lg \left(\frac{Z_{med}}{Z_{m,med}} + 1 \right) = -20 \lg(0,56 + 1) = -20 \lg(1,56) = -20(0,193) = -3,86 \text{ dB} \approx 4 \text{ dB}$$

The air noise insulation evaluation index R_w for the partition element is introduced, by comparing the curve $R_i(f)$ with the standard curve of sound attenuation indices, according to the methodology given in SR EN ISO 717/1 (SR EN ISO 717-1:2013), Table 1, Figure 10:

Frequency [Hz]	R_i [dB] (37- ΔR_{a_i})	Standard curve [dB]	Reference values after translation with 8dB [dB]	Unfavorable deviation [dB]
100	33,14	33	25	8,14
125	33,14	36	28	5,14
160	33,14	39	31	2,14
200	33,14	42	34	-0,86
250	33,14	45	37	-3,86
315	33,14	48	40	-6,86
400	37,64	51	43	-5,36
500	42,8	52	44	-1,2
630	43,12	53	45	-1,88
800	43,64	54	46	-2,36
1000	44,34	55	47	-2,66
1250	45,94	56	48	-2,06
1600	46,94	56	48	-1,06
2000	47,64	56	48	-0,36
2500	48,14	56	48	0,14
3150	49,14	56	48	1,14
Suma = 28,52 < 32,0 $R'_w = 52 - 8 \text{ dB} = 44 \text{ dB}$				

Table 1. The air noise insulation evaluation index R'_w for the partition element

Figure 10. Sound attenuation indices curve

b) The own software Rebuild (Stanca S.E., 2021) which allows the comparison of the values of the air noise sound insulation indices $R'_{w,ef}$ with the minimal values of the air noise sound insulation indices $R'_{w,nec}$ for the elements separating various spaces belonging to the functional unit under investigation, $R'_{w,ef} \geq R'_{w,nec}$, Figure 11 (<https://visualstudio.microsoft.com/2019>, <https://visualstudio.microsoft.com/vs/2019>):

Figure 11. Comparing the insulation indices for the selected functional unit

4. CONCLUSIONS

The curve $R_i(f)$ where noise transmissions through indirect ways allows, by comparison with the standard curve of the sound attenuation index, to define the index for assessing the insulation to air noise R'_w .

The calculated value of the R'_w index is compared to the minimal value of the air noise insulation index R'_w for the building partitions. According to code C125-2013, the R'_w value corresponding to the selected functional unit is $R'_w = 41$ dB.

The calculated values show values in the insulation index to the aerial noise of $R'_w = 44$ dB. It yields that the wall proposed observes the protection conditions to air noise, Figure 12:

Figure 12. Designed solution

By comparing the values (insulation indices) found by calculation, it is evident that the wall proposed here fulfills the air noise protection requirements in the functional unit chosen.

The optimal solutions chosen by the author demand using sound insulation materials and techniques that provide the minimal values of acoustic insulation so that the conditions for the noise level outside the room/building as well as those required inside rooms are fulfilled (Stanca S. E., 2021).

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