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Comparison Criteria and Performance Levels for Soundproofing Panels Made in Different Constructive Variants

This paper presents an analysis of the performance lavels and comparison criteria for panels made from different soundproofing materials, in different constructive variants. Setting the performance level, on the basis of normative and regulatory documents, for soundproofing materials contained inside of noise reduction devices, is determined so that it can be defined, tested and established feasible technical solutions for sound absorbing protection, through a dissemination of obtained results as well for ensuring requirements for implementing the technology transfer for manufacturing.

***Keywords**: soundproofing materials, noise reduction devices, performance levels*

1. Introduction

Noise reduction devices (soundproofing barriers) are designed to reduce noise levels existing or predicted in sensitive areas at this parameter, located in close proximity of buildings or built spaces (factories, warehouses, etc.). what is constituted in harmful sources of noise pollution, as well as those which are located close proximity to important communication paths (highways, roads with intense traffic), having a high level of road traffic. Under these conditions from conceptual point of view, noise reduction devices can be defined as an obstacle placed between the noise source road traffic) and receiver (built spaces, highways, the population located in close proximity of communication paths) which modifies the sound wave propagation and which by reflection, refraction and absorption reducing sound levels, as shown in the following figure:

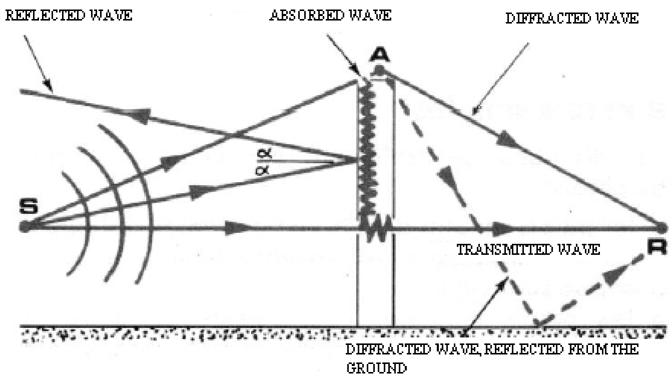


Figure 1. Transmission of sound waves in presence of noise barrier, [1]

As we can see in the figure above, a part from wave is reflected by the soundproofing screen (reflected energy is the energy worn by the waves reflected by the bounding surfaces of the screen), other part, from wave is absorbed, another part, from wave, is transmitted through the screen by receiver (transmitted energy represents a fraction of the energy emitted by a certain source and and transmitted beyond of its bounding elements) and the last part, from wave, is diffracted. For avoid the disrupting of some neighborhood by the reflected wave, figure. 2 (a) it should be directed beyond the area that must by protected, figure 2 (b). For diminish the reflected wave it can act through the application of sound absorbing materials on the screen surface that is directed towards the sound source, figure 2 (c):

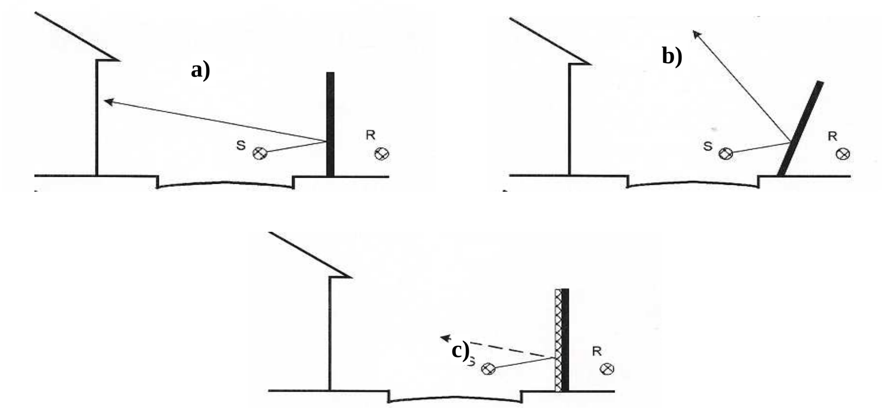


Figure 2.

Taking into account the modalities for diminishing the noise transmitted is defined sound insulation characteristic and sound absorption characteristic of noise reduction devices, such as, [2]:

- ✓ Impossibility for a part of acoustic energy crossing the certain materials, similar to other materials that are poorly conductive by heat and power *represents the sound insulation capacity of a material*. This ability is determined by the mass of material, being limited by certain mechanical characteristics which, for some frequencies, have as a result a transparency for sound, causing resonance effects.
- ✓ The ability of a material to convert acoustical energy into thermal energy (vibrations), reflecting a minimal part, *represent sound absorption characteristic of the material*. Based on experiments carried out by researchers in the field, it was noted that in areas built with traditional materials like marble, brick or glass, which do not possess a high soundproofing capacity, is observed the echo phenomenon , due the reflection of sound waves, resulting a overall increase of noise level with serious consequences for the occupants of those spaces. In sound protected spaces it can highlight a sensation of sound acoustic comfort.

Sound insulation and sound absorbing screens are used for protection against noise made by stationary sources (stadiums, schools, markets - for ensuring the acoustic comfort) and also can be mounted at the edge of a street, can be installed as a screen in industrial areas with noisy technologies (example: separation of parts of a hall with noisy equipment from another part with quieter equipment), on traffic roadways (mounted on the edge of national roads, highways, railways, in airports), with double role: sound insulation - for receptors located on the opposite side from the source (on the edge of traffic roadways) and sound absorption - for receptors situated on the same side as the source (vehicles in traffic).

2. Sound absorption capacity

Characteristics of sound waves propagation have a decisive role in the processes of distribution, attenuation or amplification of sound energy.

At the propagation of sound waves through a medium, in addition to the phenomenon of attenuation appears and the phenomenon of absorption. Sound absorption defines the way in which composition surfaces of enclosed areas behaves in relation to the incident sound waves. The sound waves lose gradually of their energy, this turning it into heat. The sound absorption is highly dependent on his frequency, the higher sounds (higher ν) are more strongly absorbed than those low. This phenomenon is because the energy emitted by the source is distributed on spherical surfaces with increasing rays, such as energy intensity per unit area decreases with the square of the radius of the sphere, respectively the distance between source and receiver.

3. Soundproofing materials

Knowledge of absorbing material, and their structure, is essential for noise control. The main feature that defines absorbing materials is their porous structure, pores communicating with each other through channels or openings of the material. Because of the viscosity of air, both between the particles of air, and between them and the pore walls occur friction forces which irreversibly transformed into heat energy a part from acoustic energy of waves, [8]. Thermal conductivity of air helps dissipate at acoustic energy waves which crossing sound-absorbing material. Along with the air are put in motion fibres of material, they suffer bending movements. Internal friction of the fibers of material, that occur due their deformations, lead to increasing sound absorption material, [8].

Acoustical absorption of sound absorbing materials is in close contact with a number of physical characteristics, of which the most important are the porosity and resistance to air flow through them.

4. Experimental results for constructive variants subjected to tests

In order to study the ability of noise absorption for noise reduction device placed on the road traffic, we are subjected to test two types of absorbing elements as follows:

- first variant – acoustic element made from concrete coated with wood fiber bonded with cement, with dimensions L = 5 m; l = 0,5 m; H = 0,22 m (from which 9 cm represent wall thicknes of the absorbent made from wood fiber bonded with cement (5 cm thicknes of wood fiber cement bonded and 4 cm thicknes of mineral wool, and 12,5 cm represent thicknes of layer concrete);
- second variant – acoustic element made from two sheets of aluminum alloy, thickness of sheet of aluminum alloy 1,2 mm, with insertion of mineral wool layer, thicknes of mineral wool 5 cm, with dimensions L = 4 m; l = 0,5 m; H = 0,115 m. Front element (side facing the source of acoustic noise) has a perforation with holes with ø10 mm at a distance of 8-14 mm. Sheets of aluminum alloy, perforated, are mounted alternatively with unperforated sheets, 2 by 2, layers of mineral wool are mounted inside of the formed pannel toward the perfored side.

Were performed tests for determining the sound absorption coefficient at normal incidence in conformity with the requirements from reference standard SR EN ISO 10534-2:2002, [4]. Sound absorption is characterized by "*sound absorption coefficient*, α" defined as the ratio of the total amount of transmitted energy and total energy absorbed and total energy incidence of sound waves. Absorption coefficients are used to evaluate the effectiveness of a material to absorb the sound. Sound absorption coefficient is expressed on standardized frequencies or by classes of absorption and is calculated using the equation, [4]:

$$\alpha = \frac{E_i - E_r}{E_i} = \frac{E_a + E_r}{E_i} \qquad (1)$$

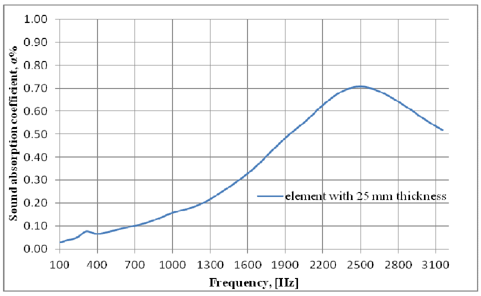
Sound absorption coefficient will be 0% if all the energy of sound waves is reflected at the impact with a surface. If energy is absorbed or passed on, sound absorption coefficient will be 100%. The values are usually provided in the specialty literature at standard frequency by 125, 250, 500, 1000 şi 2000 Hz, [4].

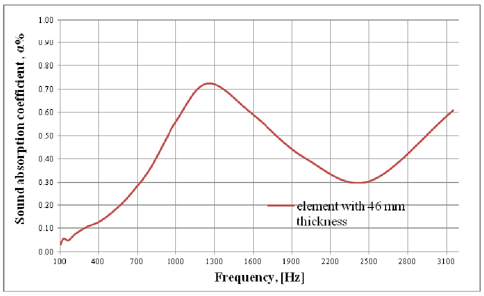
Sound absorption phenomenon may occur, in generally, for any of the following cases: porosity (seen in materials with a fibrous structure such as wood based products), cavity resonance (seen at noise barriers perforated or slotted) or membranes (membranes can be made of rubber, plastic sheets, fabrics, etc.and depending on the material used for filling Structure can give the same absorption properties as in the case of the cavity resonance).

Sound insulation, also called transmission loss, is the ability to prevent the transmission of sound energy because a part of the acoustic energy is "hindered" to cross certain materials, similar with other conductive materials that are poor heat and electricity. This ability is determined, in general, by material mass *m* [kg/m^2] and sound frequency *f [Hz]*, being limited by certain mechanical characteristics which, for certain frequencies, resulting in a "transparent" for sound, causing resonance effects.

For acoustic element made from concrete coated with wood fiber bonded with cement measurements were performed on two samples of acoustic element with different thicknesses of 25 mm and 46 mm, and for acoustic element made from aluminum alloy and mineral wool, measurements were performed on a sample taken from it, diameter of the sample were 63,5 mm. The samples were mounted in the impedance tube without air gap, and the method used for determination is the method of stationary waves, or determinations method with Kundt tubul.

The results obtained for determining the sound absorption coefficient, α, are presented below:





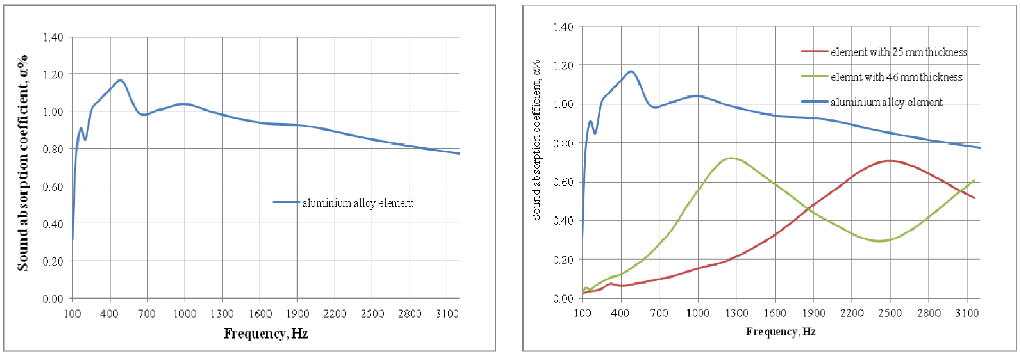


Figure 3. Variation of sound absorption coefficient depending on frequency for variants of acoustic elements considered

Note: The values of the absorption coefficient shown in earlier pro tables are determined based on method of transfer function - FFT analysis.

For acoustic element made from concrete coated with wood fiber bonded with cement can be observed that for sample with 25 mm thickness, the sound absorption coefficient has the values increasing until the frequency of 2500 Hz, point in which reaches the maximum value of 0,708, after which it values starts decreasing. For sample with 46 mm thickness, it can be observed that has the values increasing until the frequency of 1250 Hz, point in which reaches the maximum value of 0,724, after which it values starts decreasing forming a curve until the frequency of 2500 Hz, after which the values start to rise again. Analyzing the graphs of sound absorption coefficients for the two samples of material considered can be observed that they have high values and covers the whole range of frequencies considered.

For acoustic element made from aluminum alloy and mineral wool can be observed can notice that it has much higher values for the entire range of frequencies considered in comparison with acoustic elements made of concrete coated with wood fiber bonded with cement. Maximum value of 1,12 for sound absorption coefficient is achieved at frequency of 400 Hz compared with acoustic elements made of concrete, with 25 mm thickness, at which maximum value of 0,708 for coefficient is achieved at frequency of 2500 Hz, and for sample with 46 mm thickness maximum value of 0,724 for coefficient is achieved at frequency of 1250 Hz.

For determining the air noise isolation index tests were performed in conformity with the requirements from reference standards SR EN 1793-1,2,3:1999, [3, 5, 6] and SR EN ISO 10140-2:2011, [7]. According Cap. 5 and Cap. 5.1 from reference standard SR EN 1793-2:1999, [5] (SR EN ISO 10140-2:2011, [7]) air noise isolation defines the action through which seeks as separators elements between two media must reducing airborne sound transmission between spaces on which separate them. Noise reduction shall be effective in both directions of transmission noise. In this case it is useful to consider one room as the source room (emission) and one room as the reception room (reception). Measurements were made between two rooms, one emission room in which was generate white noise and a reception room where is measured the response of tested materials to subjected at noise emitted, after it has crossed the samples of material under tested. Both rooms have the same size, as 4100x3200x2900, (*Lxlxh*, mm), and the volume is 38 m^3. The size of the test sample is 10 m^2. According to reference standard SR EN 1793-2:1999, index "*R*" for air noise insulation is calculated by the formula:

$$R = L_1 - L_2 + 10\lg\frac{S}{A}\ [\text{dB}] \tag{2}$$

where:

L_1, L_2 represents noise levels in emission and reception spaces, [dB];

S represents sample surface, m^2;

A represents equivalent absorption area, in reception room, m2, calculated by the formula:

$$A = \frac{0,161 \cdot V}{T} \tag{3}$$

where:

V is the volume of reception room, expresses in m^3;

T is reverberation time, expressed in s.

Unique index of evaluation DL_R is an suitable element, in particular, to characterize the air sound insulation in situations where the incident sound received by screen, comes directly from the flow of traffic without having undergone on surfaces reflections or has been diffracted on the edges of anti-noise screens or barriers, [3].

Unique index of evaluation for performance of air sound insulation DL_R, in dB, is calculated by the formula, [5]:

$$DL_R = -10 \cdot \lg\left|1 - \frac{\sum_{i=1}^{18} 10^{0,1L_i} \cdot 10^{-0,1R_i}}{\sum_{i=1}^{18} 10^{0,1L_i}}\right| \tag{4}$$

where:

R_i is the sound reduction index in the frequency band "i" to 1/3 octave;

L_i is standardized sound pressure level, weighted A, normalised, for spectrum of noise from road traffic, in the frequency band to 1/3 octave, expressed in dB.

For classification of results obtained for sound absorption performance, the following categories are used, in conformity with the requirements of reference standard SR EN 1793-2:1999 [5] and shown in table 1, such as:

Table 1.

Category	DL_R *[dB]*
B_0	NPD
B_1	<15
B_2	15...24
B_3	>24

Below are presented the values obtained for airborne sound insulation index obtained for the two variants of the acoustic element considered such:

Table 2.

a) Acoustic element made from concrete coated with wood fiber bonded with cement				
Frequency, [Hz]	L_1, [dB]	L_2, [dB]	T, [s]	R, [dB]
100	87,1	62,7	1,07	27,6
125	91,2	69,1	1,95	28,0
160	98,3	73,5	1,47	29,4
200	101,0	75,7	1,33	29,6
250	103,7	77,8	1,35	30,2
315	102,7	77,4	1,50	30,0
400	101,3	74,9	1,01	29,4
500	98,7	70,3	0,92	31,1
630	99,3	65,2	1,26	38,1
800	97,7	62,9	1,46	39,4
1000	98,0	59,3	1,59	43,7
1250	95,6	51,1	1,75	49,9
1600	97,7	48,7	1,95	55,0
2000	97,8	44,6	2,05	59,3
2500	96,2	43,5	2,00	58,7
3150	94,7	39,2	1,87	61,2

b) Acoustic element made from aluminum alloy with insertion of mineral wool layer				
Frequency, [Hz]	L_1, [dB]	L_2, [dB]	T, [s]	R, [dB]
100	93,3	81,3	1,72	13,1
125	95,0	81,8	1,96	14,8
160	95,1	80,3	1,63	15,7
200	93,5	78,2	1,64	16,1
250	93,1	75,4	1,84	19,0
315	92,7	70,8	1,59	22,6
400	92,1	66,8	1,59	26,0
500	92,1	63,2	1,66	29,7
630	91,1	60,3	1,56	31,4
800	91,6	58,2	1,48	33,8
1000	91,6	56,2	1,43	35,7
1250	92,8	56,6	1,52	36,7
1600	92,1	56,3	1,57	36,5
2000	93,4	54,8	1,59	39,2
2500	92,3	54,6	1,56	38,3
3150	92,6	55,9	1,51	37,3

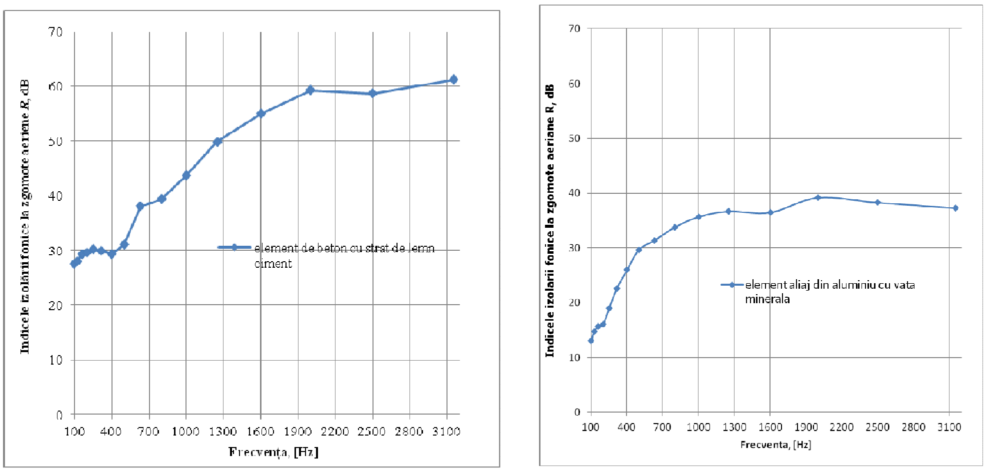


Figure 4. Air noise insulation index

Using relation (4) and weighted sound pressure levels, provided by normalized traffic noise spectrum according to standard SR EN 1793-3:1998 and presented in table 3, [6], has been determined unique index of evaluation for performance of airborne sound insulation DL_R for the two variants of acoustic elements considered and was obtained the following values:

- for acoustic element made from concrete coated with wood fiber bonded with cement, $\boldsymbol{DL_R}$ **= 35 dB**, B_3 category (according to SR EN 1793-2);
- for acoustic element made from aluminum alloy with insertion of mineral woolayer, $\boldsymbol{DL_R}$ **= 25 dB**, B_3 category (according to SR EN 1793-2);

Table 3

f_i [Hz]	L_i [dB]
100	-20
125	-20
160	-18
200	-16
250	-15
315	-14
400	-13
500	-12
630	-11
800	-9
1000	-8
1250	-9
1600	-10
2000	-11
2500	-13
3150	-15
4000	-16
5000	-18

For acoustic elements considered was calculated unique index of sound absorption performance evaluation DL_α, in accordance with the requirements of reference standard SR EN 1793-1, [3]. Unique acoustic absorption index is established for indicate the performance of absorbing for elements considered and is calculated using the equation:

$$DL_\alpha = -10 \cdot \lg \left| 1 - \frac{\sum_{i=1}^{18} \alpha_{Si} \cdot 10^{0,1L_i}}{\sum_{i=1}^{18} 10^{0,1L_i}} \right| \qquad (5)$$

where:

α_{Si} is the absorption coefficient in the frequency band "i" to 1/3 octave;

L_i = is standardized sound pressure level, weighted A, expressed in dB, of noise from road traffic in the frequency band to 1/3 octave.

For classification of results obtained for performance of air sound insulation index, the following categories are used, in conformity with the requirements of reference standard SR EN 1793-1:1999 [3] and shown in table 4, such as:

Table 4

Category	DL_{α} [dB]
A_0	NPD
A_1	<4
A_2	4…7
A_3	8...11
A_4	>11

The values obtained are presented in table 5.

Table 5

Frequency , [Hz]	Acoustic element made from concrete coated with wood fiber bonded with cement, α_{Si}	Acoustic element made from aluminum alloy with insertion of mineral wool layer, α_{Si}
100	0,57	0,32
125	0,31	0,75
160	0,42	0,91
200	0,46	0,85
250	0,45	1,01
315	0,41	1,06
400	0,61	1,12
500	0,67	1,16
630	0,49	0,99
800	0,42	1,01
1000	0,38	1,04
1250	0,35	0,99
1600	0,31	0,94
2000	0,30	0,92
2500	0,31	0,85
3150	0,33	0,78
	DL_{α} =5, A_2 *category*	DL_{α} =18, A_4 *category*

5. Conclusions

The absorption capacity for those two considered constructive variants is characterized by absorption coefficients at significantly performing levels for whole frequency range considered. Also massivity effect, expressed by mass of acoustic elements made from concrete coated with wood fiber bonded with cement, lead to a better absorption and isolation capacity for frequencies less than 1250 Hz (for 46 mm thickness) and less than 2500 Hz (for 25 mm thickness).

a) Acoustic element made from concrete coated with wood fiber bonded with cement (for 46 mm thickness) has high insulation capacity in low frequencies ranges comparative with acoustic elements with 25 mm thickness which has sound insulation characteristics under performance of item with 46 mm thickness in low frequencies range.
b) Sound absorption is higher for acoustic element made from aluminum alloy with insertion of mineral wool layer comparative with acoustic element made from concrete coated with wood fiber bonded with cement, for the whole frequency range considered.
c) Air noise insulation index falling within B_3 performance class, for both constructive variants considered.
d) Index of sound absorption performance evaluation falling within A_2 performance class for acoustic element made from aluminum alloy with insertion of mineral wool layer comparative with A_4 performance class for acoustic element made from concrete coated with wood fiber bonded with cement.
e) Constructive solutions of acoustic elements considered demonstrate that the aluminum tire is characterized by high performance of insulation and noise absorption to higher values than in the case of item made of concrete.

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6. References

[1] Guide du Bruit des Transports Terrestres, *Recommandations techniques pour les ouvrages de protection contre la bruit*, mai 1978.
[2] Specificaţie tehnică „*Bariere de izolare fonică pentru protecţia mediului - Alufon*" emisă de Societatea ALUBEL EXPO SRL, Timişoara.

[3] SR EN 1793-1:1998: *Dispozitive pentru reducerea zgomotului din traficul rutier. Metoda de incercare pentru determinarea performantei acustice. Partea 1: Caracteristici intrinseci ale absorbtiei acustice*
[4] CHRISLER V.L., *Sound absorption coefficients,* The Journal of the Acoustical Society of America, vol. 6.2, pp. 115, 1934.
[5] SR EN 1793-2:1998: *Dispozitive pentru reducerea zgomotului din traficul rutier. Metoda de încercare pentru determinarea performanţei acustice. Partea 2: Caracteristici intrinseci ale izolaţiei la zgomote aeriene.*
[6] SR EN 1793-3:1998: *Dispozitive pentru reducerea zgomotului din traficul rutier. Metoda de incercare pentru determinarea performantei acustice. Partea 3: Spectrul sonor standardizat al circulatiei*
[7] SR EN ISO 10140-2:2011: *Acustică. Măsurarea în laborator a izolării acustice a elementelor de construcţii. Partea 2: Măsurarea izolării acustice la zgomot aerian*
[8] Mohamed, N., *The study of Normal Incidence Sound Absorption Coefficience (Sound Absorption) of Wood Circular Perfora Panel (CPP) Using Numerical Modelling Technique*, Universiti Teknologi, Malaysia, 2006.

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