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Experimental Study Of Acoustic Barriers In Urban Environment*

Tiberiu Catalina, Vlad Iordache, George Craciunescu

Research Center CAMBI, Faculty of Building Services Engineering, Technical University of Civil Engineering
Pache Protopopescu street no. 66, District 2, Bucharest, Romania
E-mail: tiberiu.cattalina@gmail.com, viordach@yahoo.com, geo_mvp_2nite@yahoo.com

Rezumat. *Acest articol prezintă un studiu experimental detaliat al unei bariere acustice proiectate pentru protecția la zgomot a ocupanților unui imobil de locuit. Studiul este bazat pe o situație de mediu urban reală în care măsurările nivelului de zgomot au fost realizate înainte și după implementarea acestei bariere acustice. Sursele de zgomot au fost unitățile exterioare ale unei pompe de caldură aer-apă. Începând cu protocolul de măsură până la concluzii, în acest articol sunt prezentate aspecte interesante privind protecția la zgomot a unei bariere acustice instalate în mediul urban. Atenuarea acustică maximă obtinută în cadrul acestui studiu a avut valoarea de 18.96 dB pentru o frecvență de 125 Hz iar media a fost în jurul valorii de 15 dB. În cele din urmă, s-a putut constata că această barieră a fost o soluție bună iar confortul acustic a fost asigurat.*

Cuvinte cheie: barieră acustică, studiu experimental, mediu urban.

Abstract. *This article presents a detailed experimental study of the design and analysis of an acoustic barrier used to protect the occupants of a building from the noise produced by a HVAC system installed outdoors. The study is based on a real urban situation in which noise measurements were conducted before and after implementation of the noise barrier. In this case the noise sources are the four fans of an air-water heat pump. From measurement protocol to conclusions in this article are present interesting insights about a noise barrier installed in urban areas. The highest acoustic attenuation obtained in this study had a value of 18.96 dB at a frequency of 125 Hz and the average was around 15 dB. At the end, the use of the noise barrier was found a good solution and the acoustic comfort was achieved.*

Key words: acoustic barrier, experimental study, urban environment.

1. Introduction

Nowadays, the general noise level has reached an alarmingly high level, as we are exposed to noise pollution not only by day but also at night time. Noise is among the most significant pollutants in the world and it can be generated by almost any sound source like road traffic, jet planes, loud music, construction equipment, manufacturing processes etc. The negative effects of noise pollution include hearing loss, high levels of stress, work inefficiency, sleep disorders, life quality alteration. As you can see, these unwanted sounds can affect human health and well-being and it is

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mandatory according to the current European noise pollution norms [1] and to the Romanian ones to try and rule them out from our daily routine in order to achieve acoustic comfort indoor [2] and outdoors [3]. Noise can derive from many sound sources and in this study we will focus on HVAC noise generating equipment's. The emergence of modern comfort systems like heat-pumps, chillers, etc., assumes that the noise generating equipment would be mounted outdoors, which decreases the indoor noise level and increases the outdoor one. HVAC (heating, ventilation, and air conditioning) systems represent the technology of which main purpose is to help maintain good indoor air quality through adequate ventilation with filtration and provide thermal comfort. The main problem with these HVAC systems is noise pollution that affects urban environments and indoor life quality [2] [4] [5]. Currently, there are only a few experimental studies on acoustic barriers in Romania, and even fewer projects based on the preliminary calculations of these acoustic barriers. The experimental study consists of measurements of the sound pressure levels of noise generating HVAC type equipment. The aim of this study is to demonstrate the practical aspect of implementing a professional acoustic barrier as a sound insulation solution for the urban environment and the nearby apartment buildings. Therefore, the main objective of the study will be the experimental comparison of sound pressure level before and after the installation of the acoustic barrier.

2. Experimental Study

The experimental study consists of acoustical sound pressure level measurements performed in order to establish the validity of the urban environment noise pollution norms. The measurement protocol has been accomplished before and after the implementation of the acoustic barrier solution. Noise is the main cause of this study, as its levels outweighed the legal outdoor noise pollution norm. In this case, noise is generated by four HVAC type equipment's (heat pump system) of which we will refer to as noise sources (NS). These sources are producing an important amount of noise pollution that affects an apartment building located near them. The noise generating sources as well as the noise polluted apartment building are presented in the following figure.

The sound pressure level measuring took place at night time to prevent high traffic noise levels and outdoor work-related unwanted sounds that could have interfered with the precision of the measurements. A professional Bruel & Kjaer class 1 sound level meter was used to perform the measurements. Background noise was measured in all the established measuring points before measuring the sound pressure levels of the operating noise sources. The upper limits of accepted sound levels for outdoor and indoor environments are shown in the next table according to the present European and Romanian noise pollution standards (NC=noise curve) [3].

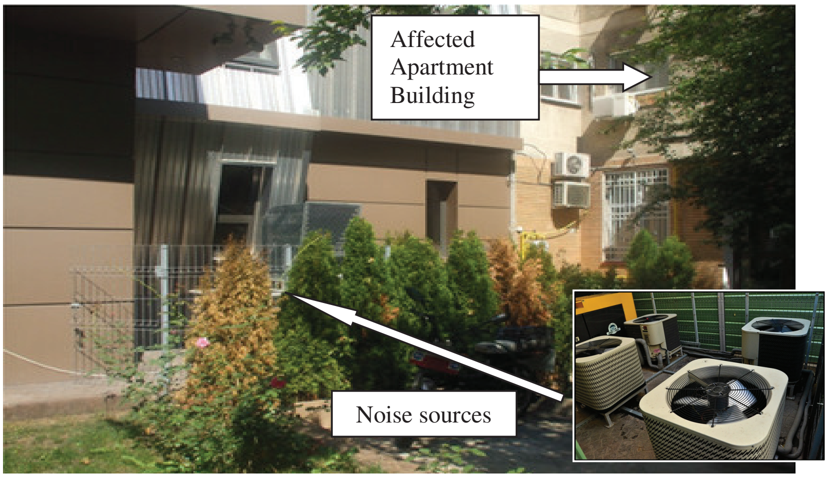

Fig.1 Noise sources and affected environment

Table 1 **Outdoor Noise Pollution Norm for Urban Environments**

Frequency [Hz]	31.5	63	125	250	500	1000	2000	4000	8000
NC30 [dB] indoor	75.8	59.2	48.1	39.9	34	30	26.9	24.7	22.9
NC45 [dB] outdoor	86	71	61.1	53.6	48.6	45	42.2	40	38.3

Measuring points were established before actually starting the measurements, resulting in a total of 6 measuring points located outdoors and indoors. The outdoors measuring points are located: in the center of the noise sources (**P1**), 0.5 m away from the noise source (**P2,P3**), 2 m away from the apartment building facade (**P4, P5**). The indoor measuring point is located inside the first floor apartment at 1 m away from the exterior window (**P6**) and were measured with the apartment windows closed. The measurements began after the heat-pumps started functioning in a nominal regime, to avoid any unwanted launching noise.

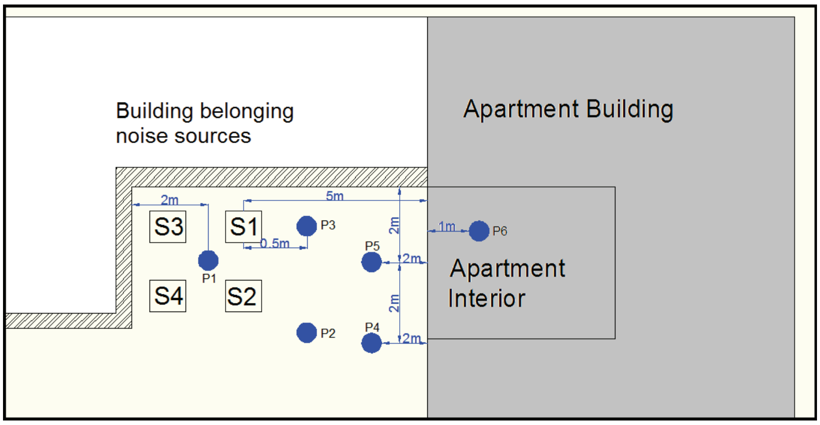

Fig.2 Outdoor and indoor measuring points;
S1, S2, S3, S4 are the four noise sources (outdoor units of the heat pump)

3. Initial noise measurements

The results of the both outdoor and indoor sound pressure level measurements have been obtained with the "BZ 5503" software, associated with the sound level meter and are selected and shown in the figures below and interpreted. The measured noise level for the outdoor points (P1,P2,P3,P4,P5) is compared with the outdoor nouse curve CZ45 (NC45 - urban environment between apartment buildings), while the one measured indoor (P6) is compared with the indoor noise curve CZ30 (NC30 – indoor sleeping room). All comparisons were carried out for the spectra between 31.5 Hz and 8000 Hz. .

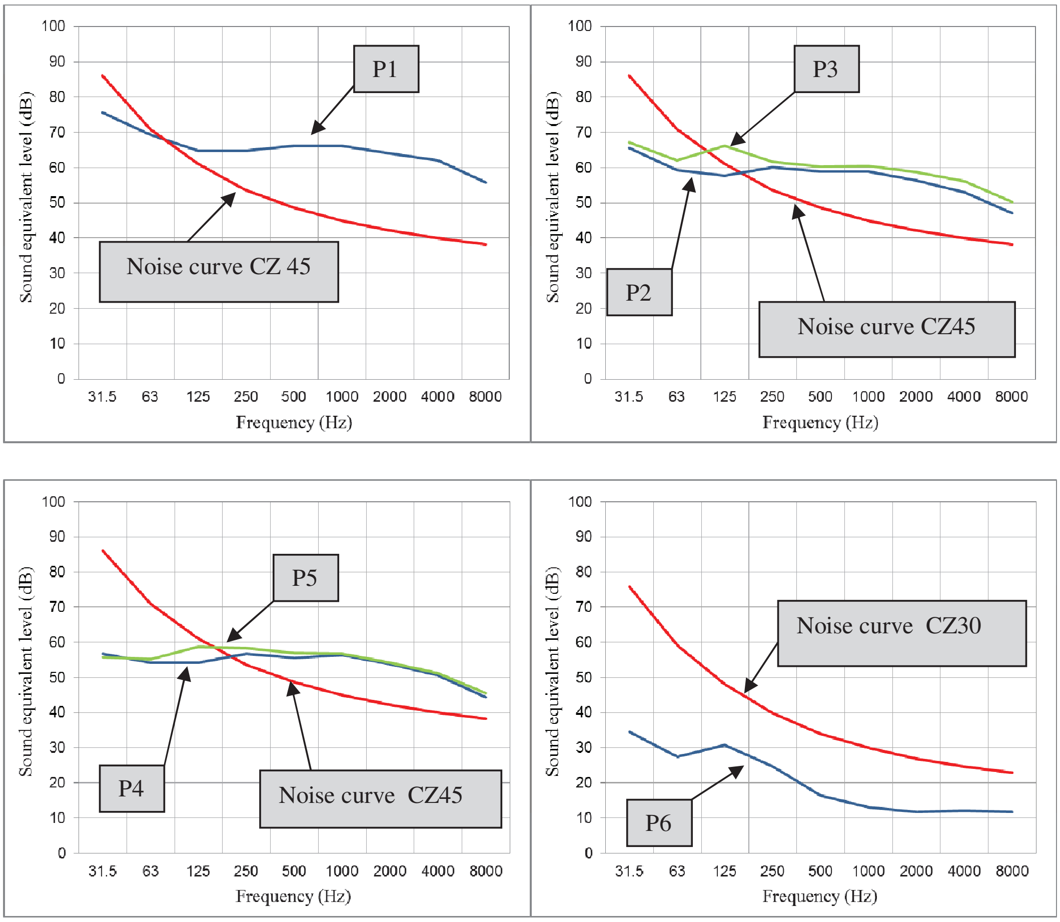

Fig.3 Sound equivalent levels for indoor and outdoor measured points (P1,P2,P3,P4,P5,P6) and comparison with the noise curves CZ45 and CZ30

As it can be noticed from Fig.3, the outdoor sound pressure levels are higher than the noise pollution norms from frequencies beginning with 125 Hz. The sound pressure level measured inside the apartment corresponds to the present noise pollution norms, as the P6 curve has a lower value than the reference indoor NC30, but with the apartment windows open (ventilation purposes) we can notice that the exterior noise affects the acoustic comfort inside.

Thus, a sound insulation solution must be applied in order to obtain acceptable noise levels.

4. Noise protection solution

In most cases, the most adopted solution is represented by a simple acoustic barrier made from a sheet of metal which has near-zero noise absorption coefficients. This type of solution is cheap and quick, but in the end the results are not sufficient and the only key to this problem is adopting a high quality acoustic barrier. Another solution for keeping noise levels down is represented by placing the equipment on the building's roof. This solution is very expensive and can often be impossible to achieve due to architectural restraints. In conclusion, for this situation, the best sound insulating solution in this case is the installation of a quality acoustic barrier with a perforated metal sheet for best acoustic performances [6]. The acoustic barrier used in this experimental study is a high-performance acoustic multi-panel (Fig. 4), made out of two main materials:

Fig.4 Acoustic barrier shape and model

- **Exterior**: 1mm thick perforated pre-painted zinked steel metal sheet on the front side of the barrier, that allows sound to be absorbed by the insulating material and 1mm thick Pre-painted zinked steel metal sheet on the back side of the barrier, that does not allow the sound to pass-through the acoustic barrier
- **Interior**: 60mm thick humidity-proof mineral wool with a density of 100 [kg/m^2]. [9]

The barrier construction was designed to have a slight angular curvature at the top of its height, of which purpose is to stop and attenuate the sound propagation by diffraction phenomena [7,8]. The selected barrier represents a professional sound insulating solution that can reduce noise levels up to 25 dB, according to the manufacturer. The geometrical measures of the acoustic barrier are: height H = 3.7 m; length L = 3.2 m; width W ~ 0.15 m.

a) b)

Fig.5 a) Photos of the acoustic barrier ; b) 3D model of the scene, recreated in 3Ds Studio Max

The next part of the paper presents the measured noise levels after the noise protection solution was installed between the outdoor units of the heat pumps and the nearby apartment building.

5. Noise measurements after the protection solution was mounted

The noise protection solution represented by the acoustic barrier has been installed between the noise sources (the heat pumps) and the receiver (the apartment building). Thus, it is important that a new series of measurements to be executed, in order cu obtain the sound attenuation caused by the implementation of the acoustic barrier. The results of the both outdoor and indoor sound pressure level measurements **after implementing the acoustic barrier** have been obtained, as it was previously mentioned, with the software associated with the usage of the sound level meter and then imported in excel format. Results have afterwards been selected and compared to the initial measurement results along with the noise curves NC45 and NC30 that must be respected.

The comparison was done between the sound pressure levels before and after the installation of the acoustic barrier, only for the following measurement points:

A) 0.5 meters away from the noise source (P2, P3)

B) 2 meters away from the apartment building facade (P4, P5)

The results for the other measuring points were not taken into consideration due to their inconclusive character. At the end of the comparison, the **global sound pressure levels** will be shown for all sound frequencies and the results will appear in tabular form. The sound pressure levels before the installation of the acoustic barrier were higher than the noise curves NC45 from the frequency of 125 Hz. The sound level after the implementation of the acoustic barrier was estimated to correspond with the current noise pollution norms, as it can be seen in the following figure.

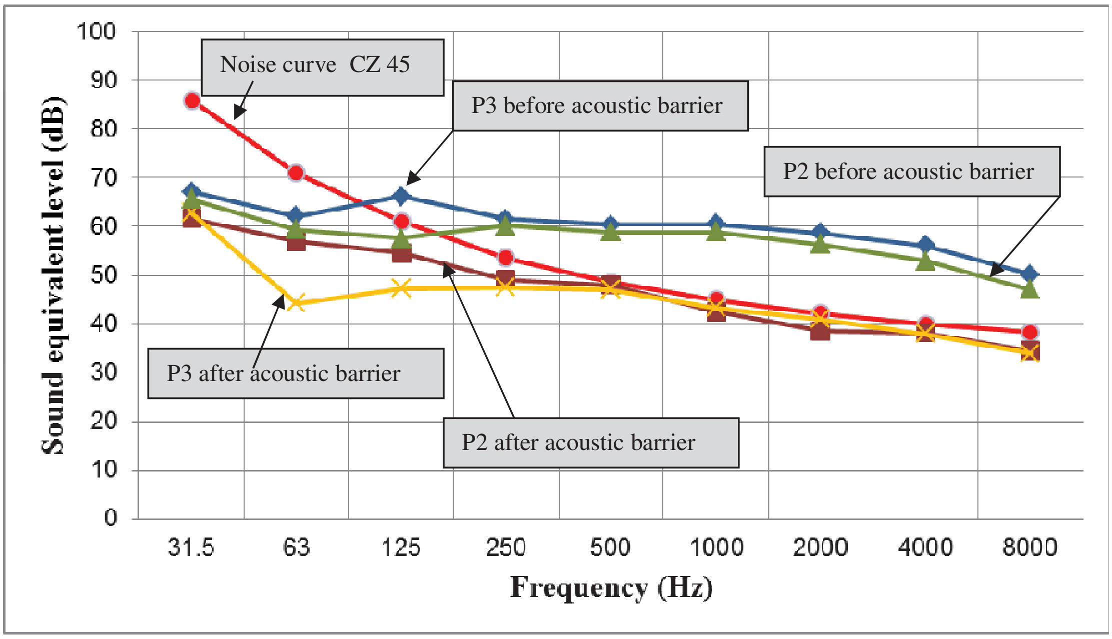

Fig.6 Comparison of the sound pressure levels of P2,P3 before and after the implementation of the acoustic barrier

As it can be observed from Fig.6 there is a visible sound attenuation after the installation of the acoustic barrier, and looking at the noise curves chart, the noise pollution norms are respected even if for some frequencies (500 to 4000 Hz) the results were on the edge. The following table is a numeric representation and shows the sound attenuation of the P2 and P3 measured points before and after the installation of the acoustic barrier.

Table 2 **Noise attenuation in P2 and P3 due to implementation of the acoustic barrier**

Frequency (Hz)	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
P2 before (dB)	65.64	59.37	57.63	60.13	58.92	58.87	56.36	52.99	46.99
P2 after (dB)	61.64	56.93	54.59	49.18	47.91	42.52	38.59	38.21	34.45
Attenuation ΔLp (dB)	**4.00**	**2.44**	**3.04**	**10.95**	**11.01**	**16.35**	**17.77**	**14.78**	**12.54**
P3 before (dB)	67.13	62.09	66.23	61.56	60.37	60.48	58.63	56.11	50.21
P3 after (dB)	62.79	44.27	47.27	47.53	47.03	43.35	40.94	37.95	33.88
Attenuation ΔLp (dB)	**4.34**	**17.82**	**18.96**	**14.03**	**13.34**	**17.13**	**17.69**	**18.16**	**16.33**

The maximum sound attenuation (18.96 dB) was obtained for the 125 Hz frequency in the case of the P3 measuring point. The minimum sound attenuation was obtained for the P2 measuring point (2.44 dB) at the frequency of 63 Hz. The same comparison was carried out for the measuring points P4 and P5 where the sound pressure levels before and after the mounting of the acoustic barrier (Fig 7). The sound level after the implementation of the acoustic barrier was estimated to correspond with the current noise pollution norms, as it can be seen in the following figure. As it can be observed from Fig.7 there is a visible sound attenuation after the installation of the acoustic barrier, and looking at the noise curves chart, the noise pollution norms are respected exactly like in the previous case. For the 1000 to 4000 Hz frequencies the sound attenuation, corresponding to the P4 and P5 measuring points, barely corresponds to the present noise pollution norms.

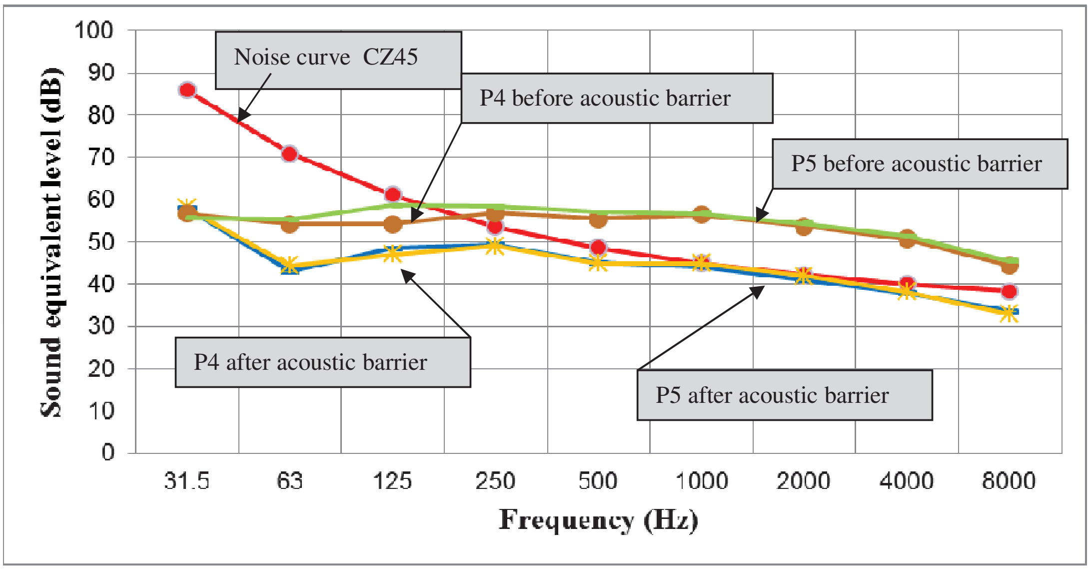

Fig.7 Comparison of the sound pressure levels of P4, P5 before and after the implementation of the acoustic barrier

The following table is a numeric representation and shows the sound attenuation of the P4 and P5 measured points before and after the installation of the acoustic barrier.

Table 2 **Noise attenuation in P4 and P5 due to implementation of the acoustic barrier**

Frequency (Hz)	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
P4 before (dB)	56.76	54.19	54.25	56.81	55.58	56.47	53.76	50.66	44.4
P4 after (dB)	58	44.5	47	49	45	45	42	38.2	33
Attenuation ΔLp (dB)	**-1.24**	**9.69**	**7.25**	**7.81**	**10.58**	**11.47**	**11.76**	**12.46**	**11.40**
P5 before (dB)	55.69	55.27	58.64	58.35	57.05	56.69	54.3	51.33	45.49
P5 after (dB)	58.06	43.06	48.49	49.43	45.14	44.24	40.91	37.87	33.57
Attenuation ΔLp (dB)	**-2.37**	**12.21**	**10.15**	**8.92**	**11.91**	**12.45**	**13.39**	**13.46**	**11.92**

The maximum sound attenuation (13.46 dB) was obtained for the 4000 Hz frequency in the case of the P5 measuring point. The minimum sound attenuation was obtained for the P4 measuring point (7.25 dB) at the frequency of 125 Hz. The sound attenuation for the P2 and P3 measuring points was greater than that of the P4 and P5 points because the P2, P3 points were located behind and in the proximity of the acoustic barrier, while the P4 and P5 points were located further away from the barrier thus resulting in the possibility of sound waves reflection to occur and amplify the sound pressure level. Using the measured data we were able to show the global sound pressure level for all the frequencies of each measured point before and after the implementation of the acoustic barrier as well as the sound attenuation regarding each measured point. The results are listed below in Table 4.

Table 4 **Effect of the acoustic barrier with respect to the global sound pressure levels**

Sound pressure level [dB(A)]				
	Before	After	Sound attenuation ΔL_p (dB)	LIMIT according to [2,3]
P1	**71**	**71.8**	-0.8	50
P2	**63.4**	**49.2**	14.2	50
P3	**65.4**	**48.92**	16.48	50
P4	**60.7**	**49.53**	11.17	50
P5	**61.4**	**49.14**	12.26	50
P6	**21.6**	**15.22**	6.38	35

As it can be seen from the previous table, the noise levels diminished considerable. For the case of the P1 measuring point, the sound pressure level was amplified by 0.8 dB(A) because of the resulting reflections after the installation of the acoustic barrier.

6. Conclusion

The present study set out to determine the effect of an acoustical barrier installed between a noise source - the four fans of the heat pump system) and a receiver - the apartment).

The necessity of installing an acoustic barrier came from the excessive noise level in relation to present noise pollution norms [1, 2]. The noise levels at 2 m away from the building's facade were above the noise curve NC45 before the installation of the acoustic barrier. After the implementation of the barrier, the noise levels dropped considerably and the noise pollution norms were respected. The noise levels at 0.5 m away from the sound source also diminished after the installation of the acoustic barrier and the noise pollution norms were also respected.

The maximum sound attenuation obtained during the measurements was 18.96 dB and it was obtained for the P3 measuring point (0.5 meters away from the sound source) on the frequency of 125 Hz.

The maximum global sound attenuation was also obtained for the P3 point (0.5 meters away from the sound source) with a value of 16.48 dB(A).

This study has gone some way towards enhancing our understanding of how noise insulation solutions work and makes several noteworthy contributions to the apprehension of acoustic barriers.

In conclusion, this study has found that in general, a quality acoustic barrier is an almost flawless solution when it comes to diminishing noise pollution.

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References

[1] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise - Declaration by the Commission in the Conciliation Committee on the Directive relating to the assessment and management of environmental noise (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:189:0012:0025:EN:PDF)

[2] STAS 6156-86 Protecţia împotriva zgomotului în constructii civile şi social-culturale. Limite admisibile şi parametrii de izolare acustică. (in Romanian)

[3] STAS 10009-88 Acustica urbană. Limite admisibile ale nivelului de zgomot urban (in Romanian)

[4] Vlad Iordache, Tiberiu Catalina, Acustica cladrii si a instalatiilor: Aplicatii Proiectare, ISBN: 978-973-755-909-8, Seria Complemente Ingineresti, Editura MATRIX Rom, 2013

[5] Vlad Iordache, Protectie la Zgomot. Acustica cladirilor si a instalatiilor, Editura MATRIX ROM, Bucuresti , 2007, ISBN 978-973-755-224-2

[6] M. Naderzadeh, M. R. Monazzam. „Application of perforated sheets to improve the efficiency of reactive profiled noise barriers”. Applied Acoustics, vol. 72, Issue 6, May 2011, Pages 393-398.

[7] T. Okubo, K. Yamamoto. „Procedures for determining the acoustic efficiency of edge-modified noise barriers”. Applied Acoustics, vol. 68, Issue 7, July 2007, Pages 797-819.

[8] Ishizuka T, Fujiwara K. “Performance of noise barriers with various edge shapes and acoustical conditions” Applied Acoustics 2004;65:125–41.

[9] G.R. Watts, N.S. Godfrey. „Effects on roadside noise levels of sound absorptive materials in noise barriers”. Applied Acoustics, vol. 58, Issue 4, December 1999, Pages 385-402