TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 65, Issue I, March, 2022

ANALYSIS OF NOISE REDUCTION AND THE INFLUENCE OF WAVE'S DIFFRACTION ANGLE USING NOISE BARRIERS

Mihai BUGARU, Ovidiu VASILE, Marian NEAGOE

Abstract: *The paper reveals the experimental research carried out, in the anechoic chamber at the department of mechanics of University POLITEHNICA of Bucharest, to high-lite the noise reduction (the acoustic attenuation) from the source (S) to the receiver (R), using different material layers for the noise barrier. The tests were performed on an experimental model having the dimensions 2mx1.5m, considering an incident wave angle of the source with respect to the receiver, having initially a diffraction angle of* 0^0 *(in the shadow field, orthogonal on the plane of the barrier), subsequently with a diffraction angle of* $\pm 45^0$ *(angle of the receiver with respect to the direct straight angle of the source). The experimental results are presented as a function of the internal layers of the barrier's structure as well as a function of the incident diffraction angle of the sound wave. The conclusion of the paper reveals the basic differences obtained by this experimental research.*

Key words: *Noise Barriers, Noise Reduction, Acoustic experiments.*

1. INTRODUCTION

People in the urban area have problems with the noise produced by the railway traffic, the vehicle traffic as well as the industrial plants. Excepting the solutions of reducing the noise at the source and the receptor, one of the most common solution in practice is to „block" the way of noise propagation by using acoustical barriers or noise barriers. Usually, these noise barriers must fulfill some aspects like noise attenuation, resistance at long exposure at high temperature variation of air as well as air humidity, resistance at wind[1] and snow exposure[2]. In their grand majority the noise barriers for road traffic must accomplish specific acoustical and mechanical performance to achieve a high rate of use during a period of two decades[3]. As a part of the sustainable industrial development in the last decade a particular field is the environmental protection, a special attention being given to noise pollution in urban areas, noise pollution induced by the road traffic and the activities in the industrial areas[4,5]. The noise is a risk factor for the human body, that affect not only the hearing but also other organs inducing low labor productivity as well as a low state of human health[6,7].

In the area of study for the diffraction phenomena as well as the studies for the „mask field" for the noise barriers some works could be mentioned for the previous research[8-14].

This work reveals the experiments realized on three constructive options of a noise barriers; the data being obtained in the anechoic chamber at the University POLITEHNICA of Bucharest. For the experimental model, the measurements were performed for three incident directions, the position of the receiver (R) being modified with respect to the noise propagation direction S(source)-R(receiver).

2. EXPERIMENTAL DATA

2.1 Model of noise barrier

The noise barrier is made as a sandwich panel with a profiled steel sheet at the exterior having the width of 0.8 mm, with perforations towards the noise source and the global 2000 mm x 1500 mm, while the steel sheet towards the receiver is

Received: 02.11.21; **Similaritie**s: 28.02.22: **Reviewed**: 11.02/21.02.22: **Accepted**:18.03.22.

plane and without perforations. This structure is fixed into a frame compose of two steel U profile columns with perforations, as can be seen in figure 1. Inside, this sandwich structure contains one central OSB plate having the dimensions 2000 mm x 1500 mm x 15 mm as core and two sheets of phono-absorbent material, one on every sides of the OSB core, having the dimensions 2000 mm x 1500 mm x 40 mm, as can be seen in figure 1.

Fig. 1. Structure detail of the noise barrier model

To establish the noise attenuation efficiency as function of the structure of the noise barrier it were used three kind of different materials having the same width of 40 mm as in figure 2:

a. case 1 – expanded polyethylene,
b. case 2 – recycled polyurethane foam, having the density of 90 Kg/m^3 (with60% flakes of flexible polyurethane foam, 30% textile materials and 10 % binder glue),
c. case 3 – basaltic wool.

a. b. c.

Fig. 2. Types of materials used for phono absorption: a. case 1-expanded polyethylene, b. case 2-recycled polyurethane foam, c. case 3 – basaltic wool.

2.2 Measuring procedure

For acoustical data it was used: as acoustic source (S) a loudspeaker connected to an amplifier and a generator of white noise. The noise level was measured in the nearby vicinity of the source in the opposite side of the barrier, in different points of receiving (R_i), using a sonometer Model 2270 Brüel & Kjær. All the data were transferred to a computer to processed.

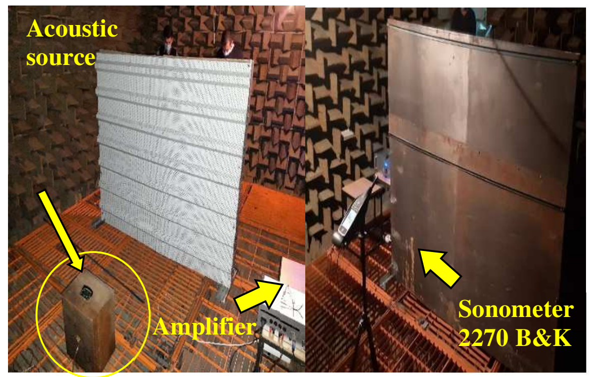


Fig. 3. Photos during the tests.

The sonometer used for data recording was placed nearby noise source (S) and then in different positions of the receiver (Ri) at distances of 0.5 m; 1 m; 2 m with respect to the barrier at a variable height of 0.5 m; 1 m; 1.5 m from the ground , on the orthogonal direction to the barrier and inclined with ± 45^0 to this direction, being done 21 recordings for each case 1 to 3. All the elements were placed on a steel lattice at 0,5 m height above the phono-absorbing surface of the anechoic chamber. The scheme of all measuring positions is presented in figure 4.

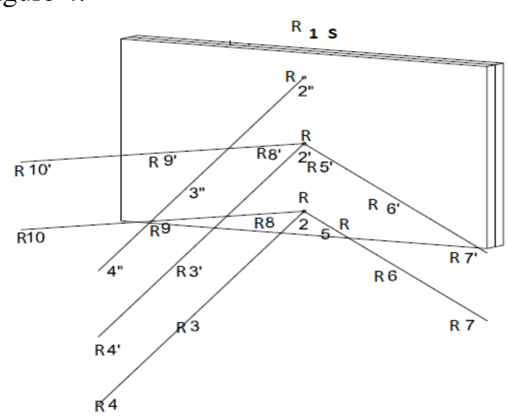


Fig.4. Scheme of measuring positions.

For a better understanding all the notations as well as the geometric disposal of measuring points in figures 5 to 7 are presented the details, for the incident directions with respect to the source position at 0^0 and respectively at $\pm45^0$. The positions of measuring points presented in figure 5, at an incident angle of 0^0, are:

- R1 is placed at la 0,5 m with respect to the noise source (S) at a height of 0,5 m above the lattice,
- R2, R2', R2" are the measuring positions placed at a distance of 0,5 m with respect to the barrier and at a variable height of 0,5 m, 1 m and 1,5 m above the lattice,
- R3, R3', R3" are the measuring positions at 1 m with respect to the noise barrier and at variable height of 0,5 m, 1 m and 1,5 m above the lattice,
- R4, R4', R4" are the measuring positions at 2 m with respect to the noise barrier and at variable height of 0,5 m, 1 m and 1,5 m above the lattice.

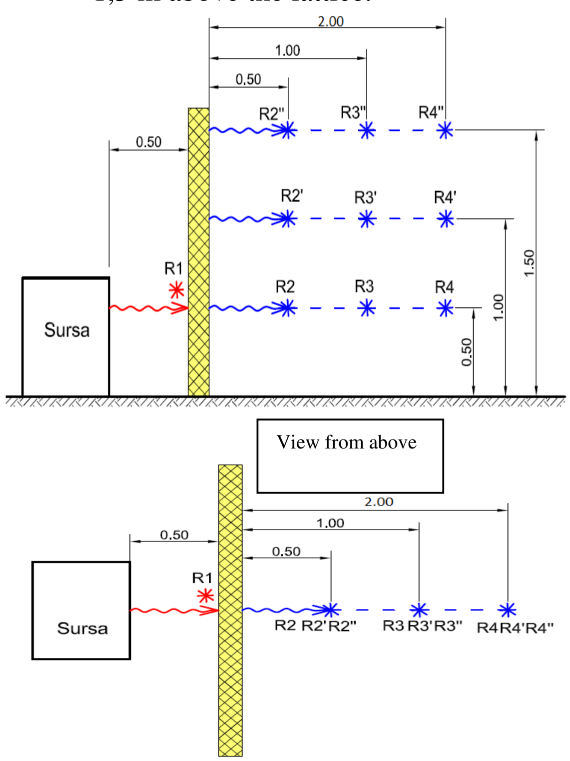


Fig. 5. Positions of the measuring points for an incident angle of 0^0 (lateral view; view from above).

The positions of measuring points presented in figure 6, at an incident angle of $+45^0$, are:

- R1 is placed at la 0,5 m with respect to the noise source (S) at a height of 0,5 m above the lattice,
- R5, R5' are the measuring positions placed at 0,5 m with respect to the barrier and at a variable height of 0,5 m and 1 m above the lattice,
- R6, R6' are the measuring positions placed at 1 m with respect to the barrier and at a variable height of 0,5 m and 1 m above the lattice,
- R7, R7' are the measuring positions placed at 2 m with respect to the barrier and at a variable height of 0,5 m and 1 m above the lattice.

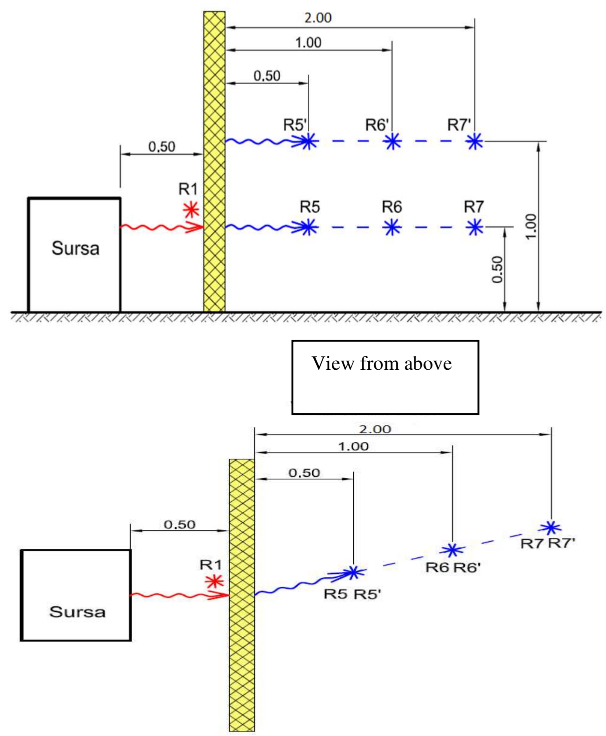


Fig. 6. Positions of the measuring points for an incident angle of $+45^0$ (lateral view; view from above).

The positions of measuring points presented in figure 7, at an incident angle of -45^0, are:

- R1 is placed at la 0,5 m with respect to the noise source (S) at a height of 0,5 m above the lattice,
- R8, R8' are the measuring positions placed at 0,5 m with respect to the barrier and at a variable height of 0,5 m and 1 m above the lattice,
- R9, R9' are the measuring positions placed at 1 m with respect to the barrier and at a variable height of 0,5 m and 1 m above the lattice,

- R10, R10' are the measuring positions placed at 2 m with respect to the barrier and at a variable height of 0,5 m and 1 m above the lattice.

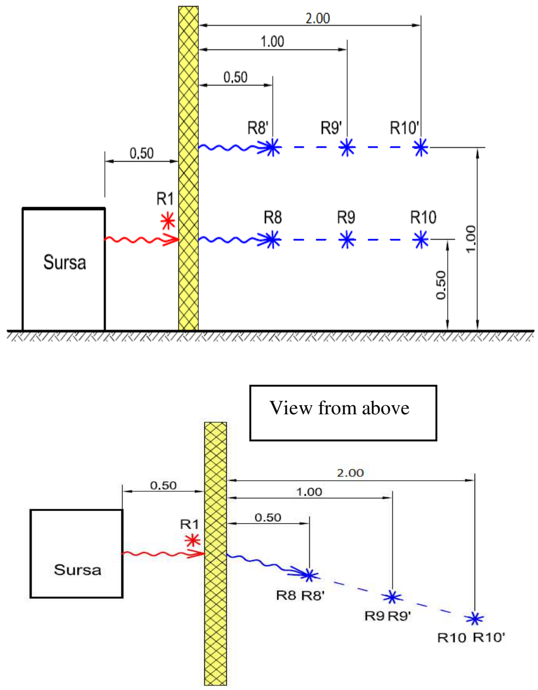


Fig. 7. Positions of the measuring points for an incident angle of -45^0 (lateral view; view from above).

3. EXPERIMENTAL DATA

Function of constructive considered solutions, cases 1 to 3, presented in figures 4 to 7, are presented the experimental data.

3.1 Experimental data for case 1

In the case 1 for which it was used as acoustic phono absorbent material the expanded polyethylene, see figure 2. a., with an angle of incidence of 0^0 with respect to the orthogonal direction on the surface of noise barrier, see figure 5, the experimental data are presented in figure 8. To high-lite the position of noise source (S), denoted R1, it is considered on horizontal direction, at -0,5 m (in front of the barrier) on the left-hand side. The other measuring positions R2, R2' … R4", are in the backside of the, at distances mentioned above on the right-hand side of the barrier (positive values for the distances). The experimental data, to high-lite the variation of acoustic level for the case 1, at inclined incidence angle of ±45^0 , see figures 6 to 7, are presented in figure 9.

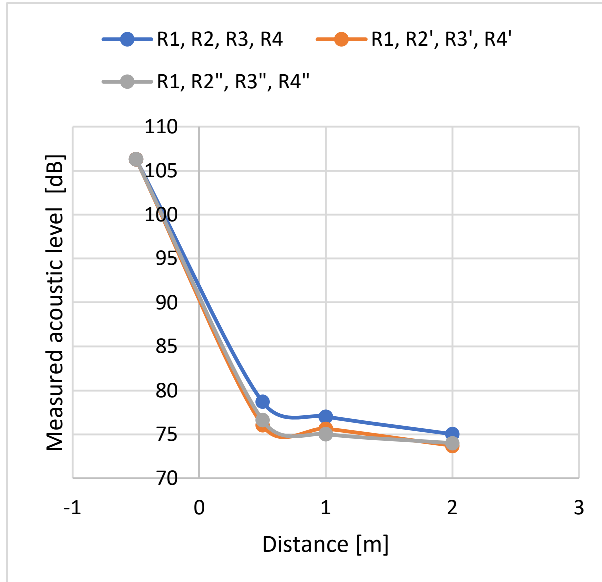
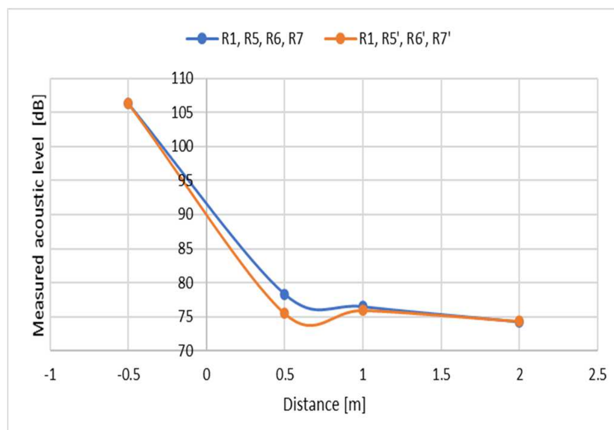
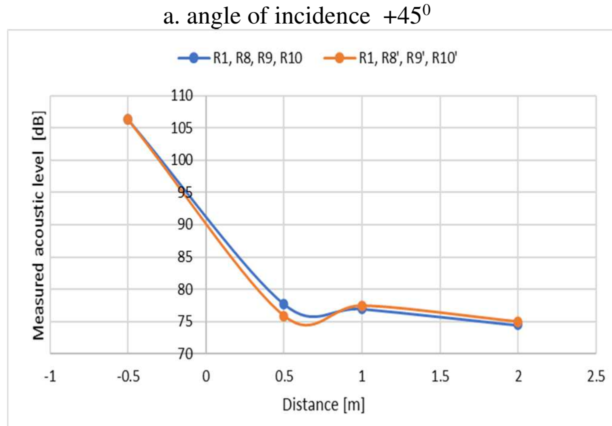


Fig. 8. Variation of acoustic level, case 1, angle of incidence of 0^0.



a. angle of incidence +45^0



b. angle of incidence -45^0

Fig. 9. Variation of acoustic level for the case 1, at incidence angles ±45^0

Due to the geometric form of the acoustic barrier, with respect to the position of the noise source (S), in figure 9 the variations of acoustic level at incident angles of $\pm 45^0$ are similar.

3.2 Experimental data for case 2

In the case 2, when the structure of the noise barrier is using as acoustic phono absorbent material recycled polyurethane foam, case 2, see figure 2. b., for the incident angle of 0^0, as in figure 5, the experimental data are presented in figure 10.

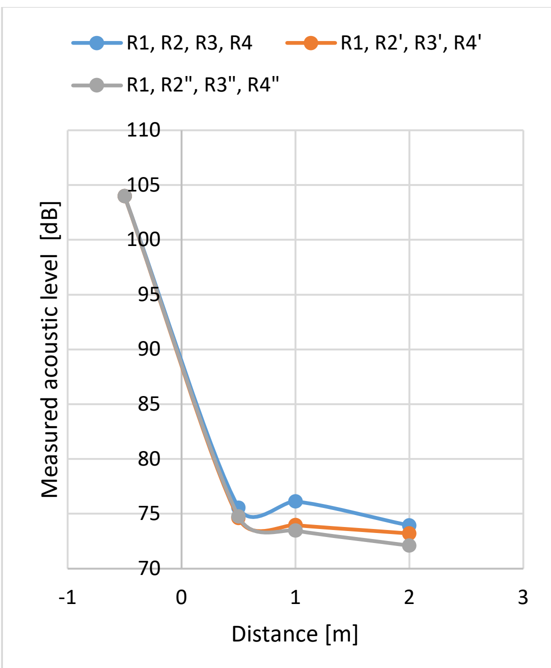
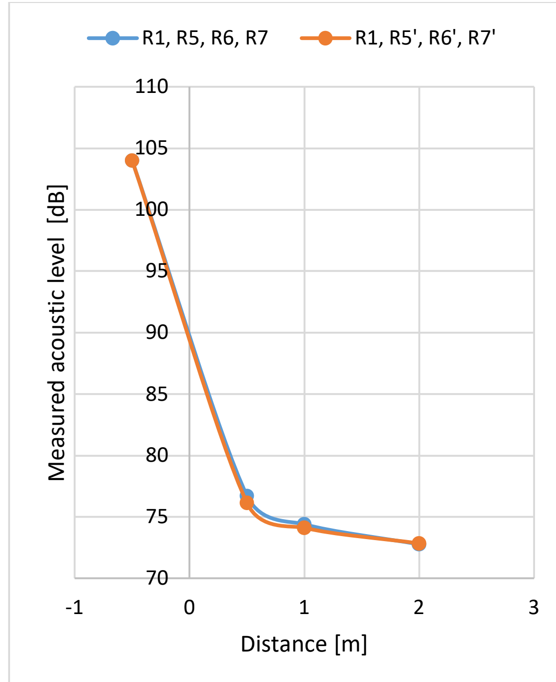
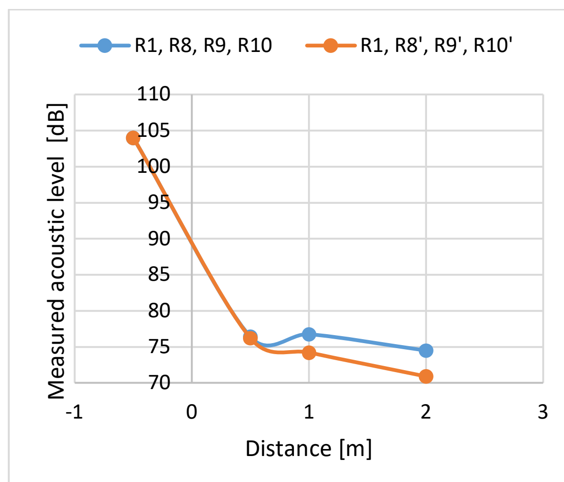


Fig. 10. Variation of acoustic level, case 2, angle of incidence of 0^0.

The experimental data, to high-lite the variation of acoustic level for the case 2, at inclined incidence angle of $\pm 45^0$, see figures 6 to 7, are presented in figure 11. Due to the geometric form of the acoustic barrier, with respect to the position of the noise source (S), in figure 11 the variations of acoustic level at incident angles of $\pm 45^0$ are similar.



a) angle of incidence $+45^0$



b) angle of incidence -45^0

Fig. 11. Variation of acoustic level for the case 2, at incidence angles $\pm 45^0$

3.3 Experimental data for case 3

In the case 3, when the structure of the noise barrier is using as acoustic phono absorbent material recycled polyurethane foam, case 3, see figure 2. c., for the incident angle of 0^0, as in figure 5, the experimental data are presented in figure 12. The experimental data, to high-lite the variation of acoustic level for the case 3, at inclined incidence angle of $\pm 45^0$, see figures 6 to 7, are presented in figure 13.

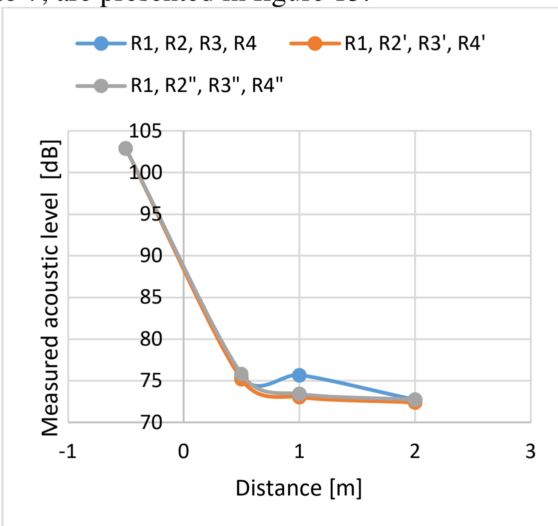
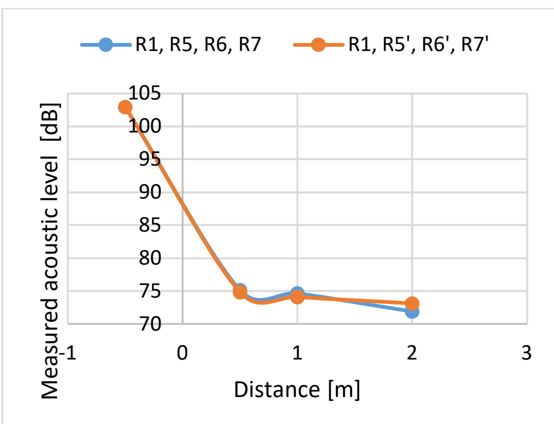
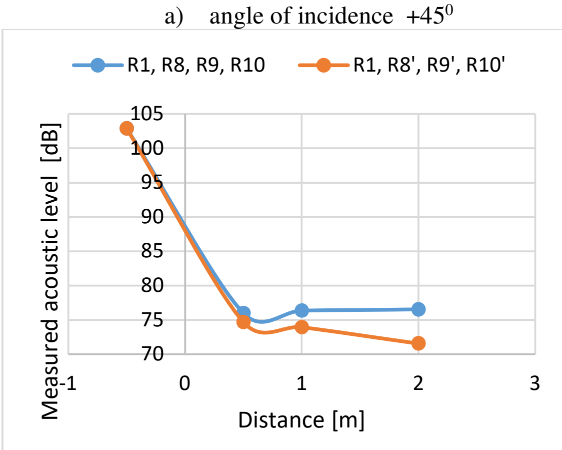


Fig. 12. Variation of acoustic level, case 3, angle of incidence of 0^0.



a) angle of incidence $+45^0$



b) angle of incidence -45^0

Fig. 13. Variation of acoustic level for the case 3, at incidence angles $\pm 45^0$

Due to the geometric form of the acoustic barrier, with respect to the position of the noise source (S), in figure 13 the variations of acoustic level at incident angles of $\pm 45^0$ are similar.

4. CONCLUSION

The experimental data were not altered by the adjacent noise and by using the anechoic chamber were avoided the multiple reflections. The recordings, done on short period of time, in the range of one third of octave, pondered on the reference level A[16], were presented only as global equivalent acoustic levels L_{Aeq}, as a variation between the level of measured acoustic data at source (S, R1) and the level of measured acoustic data at different receiving points (R2, R3, …, R10').

To define the acoustic parameters, it was considered the next terms [14]:

$$L_{Aeq} = 10\log\left[\frac{1}{T_0}\int_{t_1}^{t_2}\frac{p_A^2(t)}{p_0^2}dt\right] \quad [\text{dB(A)}] \qquad (1)$$

where: $p_A(t)$ is the pondered instantaneously acoustic pressure, p_0 is the reference pressure, having the value 20, $(t_2 - t_1)$ is the period of time measuring, the selected value being 15 s, T_0 is the reference time, having the value of 1 s. In correlation with the indirect measuring method[13], when the data of acoustic pressure are collected before and after the presence of noise barrier, because the distances are relative short, it can be approximated the noise attenuation of the barrier or the loss of insertion as:

$$\Delta L_i = L_S - L_{Ri} \quad [\text{dB(A)}] \qquad (2)$$

where L_S is the sound pressure level nearby acoustic source (S, R1) and L_{Ri} is the sound pressure level measured in the receiving positions R2, R3, …, R10'.

In tables 1 to 3 is presented the computation of acoustic attenuation for the cases considered being split for variable heights at 0.5 m, 1 m and 1.5 m above the lattice.

Table 1. Acoustic attenuation at the height of 0,5 m

ΔL_i	ΔL_2	ΔL_3	ΔL_4	ΔL_5	ΔL_6	ΔL_7
Case1	27.58	29.27	31.26	28	29.8	**32.04**
Case 2	28.44	27.88	30.06	27.28	29.59	**31.22**
Case 3	27.4	27.22	30.16	27.78	28.26	**31.02**

Table 2. Acoustic attenuation at the height of 1 m

ΔL_i	$\Delta L_{5'}$	$\Delta L_{6'}$	$\Delta L_{7'}$	$\Delta L_{8'}$	$\Delta L_{9'}$	$\Delta L_{10'}$
Case1	30.82	30.33	31.92	30.45	28.84	31.32
Case 2	27.86	29.89	31.16	27.79	29.79	**33.09**
Case 3	28.09	28.82	29.79	28.22	28.96	**31.35**

Table 3. Acoustic attenuation at the height of 1,5 m

ΔL_i **[dB(A)]**	ΔL_2	ΔL_3	ΔL_4
Case1	29.67	31.27	**32.29**
Case 2	29.25	30.53	**31.9**
Case 3	27.07	29.46	**30.14**

The maximum values in this tables are bolded to high-lite its. In table 1, can be remarked that in all the cases for the height of 0.5 m, the maximum values of attenuation are ΔL_7 that correspond to the point R7, that is at 2 m distance from the barrier at an inclined incidence angle of $+45^0$. Also, in table 2 can be remarked that the maximum values are for a height of 1 m, above the lattice, for the case 1 at $\Delta L_{4'}$, that corresponds to the point R4' and at $\Delta L_{10'}$, for the cases 2 to 3, see point R10', in figure 7, at inclined incidence angle of -45^0.

For the height of 1.5 m above the lattice, the recordings were performed only in the plane of symmetry of the noise barrier, due to possible alteration given by the geometric dimensions of the barrier. In this case can be remarked that the maximum value for the acoustic attenuation is $\Delta L_{4''}$ that corresponds to point R4".

In conclusion, based on the obtained data, can be remarked a strong efficiency of the acoustic barrier at inclined incidence angle of $\pm 45^0$, this being justified not by numerical modelling. Maximum values of acoustic attenuation are not sensitive to the composition of the layers of the sandwich structure of the noise barrier.

8. REFERENCES

[1] CR 1-1-4:2012 - Design code. *Evaluation of the wind action on constructions.*

[2] CR 1-1-3:2012 - Design code. *Evaluation of the action of snow on constructions.*

[3] EN 14388:2016 – Specifications. *Road traffic noise reducing devices.*

[4] Bratu, M., Bucur, E., Danciulescu, V., Petrescu, M., Gheorghita, T., Vasile, O. (2020), *Assessment of the level of noise and chemical air pollution in two distinct urban areas*, http://Doi.Org/10.21698/Rjeec.2020.216

[5] Karakitsios, S.P., Papaloukas, C.L., Kassomenos, P.A., Pilidis, G., *Assessment and prediction of benzene concentrations in a street canyon using artificial neural networks and deterministic models: their response to "what if" scenarios*, http://Doi.Org/10.1016/J.Ecolmodel.2005.07.024.

[6] Sygna, K., Aasvang, G.M., Aamodt, G., Oftedal, B., Krog, N.H., Road traffic noise, sleep and mental health, http://Doi.Org/10.1016/J.Envres.2014.02.010.

[7] Begou, P., Kassomenos, P., Kelessis, A., *Effects of road traffic noise on the prevalence of cardiovascular diseases: the case of Thessaloniki, Greece*, http://Doi.Org/10.1016/J.Scitotenv.2019.134477.

[8] Tămaş-Gavrea, D.-R.; Dénes, T.-O.; Iştoan, R.; Tiuc, A.E.; Manea, D.L. Vasile, O., A novel acoustic sandwich panel based on sheep wool, Coatings, http://Doi.Org/10.3390/ Coatings10020148.

[9] Jin, Y., Fang, X., Li, Y, Torrent, D., *Engineered diffraction gratings for acoustic cloaking*, http://Doi.Org/10.1103/Physrevapplied.11.011004.

[10] Pirinchieva, R.K., T*he influence of barrier size on its sound diffraction*, http://Doi.Org/10.1016/0022-60x(91)90570-A

[11] Bugaru M., Enescu N., Stanila R., Vasile O., *Reflection and absorption properties of the acoustical barriers of finite length*, 12th International Congress On Sound And Vibration 2005, Lisbon, Portugal, ICSV 2005, Volume 3, Pages 2143-2149, ISBN 978-162748149-6,2005, Publisher: International Institute of Acoustics and Vibration, Lisbon.

[12] Bugaru M., Dale R., Acoustic Properties Of Sound Barriers, Proceedings of The14th International Congress On Sound And Vibration 2007, ICSV 2007, Volume 5, Pages 4244 - 4250, ISBN 978-162748000-0, Cairns, Australia Qld, 9 July 2007 - 12 July 2007, Publisher: International Institute of Acoustics and Vibration, Cairns.

[13] Piechowicz, J., *Sound wave diffraction at the edge of a sound barrier*, http://Doi:10.12693/Aphyspola.119.1040

[14] Vasile, O., *Insertion loss analysis of the acoustic panels with composite construction*, Analele Universităţii "Eftimie Murgu" Reşiţa: Fascicola I, Inginerie, Anul Xx, No. 2, Pp. 85-91, ISSN 1453-7397, Resita, 2013.

Analiza reducerii zgomotului si a influentei unghiului de propagare a undelor acustice utilizand bariere acustice

Rezumat. Lucrarea abordeaza cercetarile experimentale realizate in camera anecoica din cadrul departamentului de mecanica al Universitatii POLITEHNICA din Bucuresti, cercetari realizate cu scopul de a determina reducerea zgomotului (determinarea atenuarii acustice) de la sursa (S) la receptor (R), utilizand diferite straturi de materiale pentru barierele acustice. Testele au fost realizate pe un model de panou acustic avand dimensiunea de 2m x1.5m, luand in considerare un unghi de incidenta variabil al directiei sursa-receptor pentru trei situatii ale unghiului de difractie : 0^0 (in zona de "umbra" perpendicular pe planul barierei acustice) si respectiv ± 45^0 (unghi dintre directia sursa-receptor si directia de propagare a zgomotului). Rezultatele experimentale sunt prezentate ca functii de compozitia interna al structurii straturilor fono-absorbante ale barierei acustice cat si in functie de unghiul de incidenta al propagarii zgomotului. Concluziile prezentei cercetari aduc lumina cu privire la diferentele de baza ale mecanismului de atenuare acustica relevat de experimente.

Mihai BUGARU, Prof. Dr. Ing., Universitatea POLITEHNICA din Bucuresti, Departamentul de MECANICA, E-mail: skmbugaru@yahoo.com, +40-21-402-9250, 62 Tony Bulandra, S2, Bucharest, Home Phone: +40-749-222333.

Ovidiu VASILE, Conf. Dr. Ing., Universitatea POLITEHNICA din Bucuresti, Departamentul de MECANICA, E-mail: ovidiu_vasile2002@yahoo.co.uk, +40-21-402-9250, Home Phone: +40-722-172700.

Marian NEAGOE, Drd. Ing., Universitatea POLITEHNICA din Bucuresti, Departamentul de MECANICA, E-mail: neagoe_florin_marian@yahoo.com, +40-21-402-9250, Home Phone: +40-747-543054.