TECHNICAL UNIVERSITY OF CLUJ-NAPOCA
ACTA TECHNICA NAPOCENSIS
Series: Applied Mathematics, Mechanics, and Engineering
Vol. 63, Issue I, March, 2020

PARAMETERS AFFECTING THE OUTDOOR NOISE BARRIERS EFFECTIVENESS - SIMULATION WITH SOUNDPLAN

Marius JOLDEA, Iulian LUPEA

***Abstract**: The article presents design principles of sound barriers and an assessment of the acoustic parameters that can influence their efficiency. It was studied how the acoustic absorption coefficients of the noise barriers coupled with the noise emission characteristics of the noise sources influence the values of the noise level at the receiver. For this, with the help of the SoundPlan software package, it has been shown that for noise sources with the same acoustic power values and sound barriers of the same size, the values of the sound pressure level at the receiver location differ significantly depending on the spectral characteristics of the acoustic emission and by the sound absorption coefficients of the sound barriers. It has been shown that the sound absorption evaluation index - DLα - of sound barriers does not always reflect the actual performance of the sound barriers, there being situations where, for industrial noise sources, a sound barrier having DLα = 8 dB will lead, at the receiver point, to lower values of the sound pressure level than a barrier with a higher value of this index - DLα = 10 dB. As soon as the DL_{α} index is given for the normalized traffic noise spectrum, not for industrial noise spectra, it's obvious that for industrial noise sources, a different approach must be used, which takes into account the sound absorption coefficients of the barrier, in the 1/1 or 1/3 octave band instead of DL_{α} index.*

***Keywords:** noise barrier, insertion loss, transmission loss, sound absorption spectrum, barrier simulation, sound source emission spectrum.*

1. INTRODUCTION

The attenuation of the noise generated by the industrial noise sources, mechanical & HVAC equipment, the road and railways traffic noise, is provided by various sound barriers. A noise source can be often linear like the traffic road or the railway, volume source, area source or point source like in the present approach. Homes, apartments, schools, hospitals, office buildings or public parks and so on, are potential receivers. The barrier is inserted between the source and the receiver in order to block the sound rays traveling to the receiver, hence to protect them.

The barrier effectiveness is evaluated by the insertion loss (1):

$$IL = 10\log_{10}\left(P_0 / P\right)^2 \qquad (1)$$

where P_0 is the initial effective (rms) pressure at the receiver without the barrier and P is the sound pressure (rms value) at the receiver after the barrier insertion. The sound waves follow two paths, one is the diffracted path and the second (a small part) is transmitted through the barrier material.

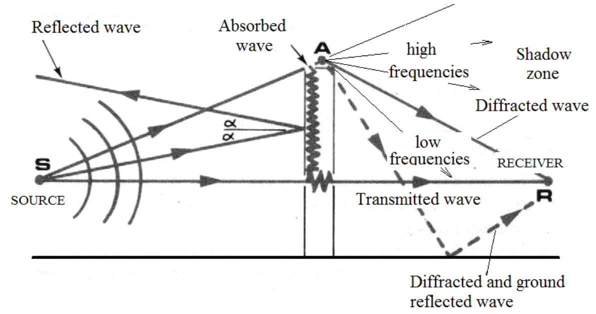

Fig. 1. Sound barrier and diffraction [9]

Sound rays bend when passing over the top of the barrier because of the wave diffraction (Fig.1) and the phenomenon is depending on the sound source frequency. High frequencies can be stopped easier while low frequencies turn more downward around the barrier top because of the diffraction [1-7], [9]. Sound barriers are most effective at mid and high frequencies.

Sound barriers are made of various materials like brick and masonry, concrete, steel, plastics, wood, composites or earth (berm) and should be sufficiently dense to efficient diminish sound waves from traveling through them. Reflective barriers are low cost like those made of concrete or bricks. Absorptive barriers are more expensive being reflective and as well absorptive on one side or both sides [4-6].

When a noise barrier is tall up to the line of sight from the road to the receiver, the reduction in sound level is of about 5 dB(A). For each one meter of barrier height increase, a 1.5dB additional noise reduction level is obtained. The barrier should be located as close as possible to either the source or the receiver in order to have maximum efficiency [9].

Two important noise related quantities of a barrier material are: 1. the ability to absorb acoustic energy (α) valid for porous and lightweight materials and 2. the ability to reflect sound energy (STL) valid for dense and nonporous materials of minimum density of 15-20 kg/m^2. Both abilities are not findable in a unique material, therefore is common to see an absorbing layer on the source side placed in parallel and contact with a barrier structure. Common values for insertion loss are between 5 to 12 dB. In practice a noise reduction of 5dbA is easy to be obtained, 10dBA is often obtained, 15dBA is very difficult to reach and a reduction of 20dBA is almost impossible [5,8].

2. SOUND SOURCES AND NOISE BARRIERS

For a known sound source power (L_W), the sound pressure (L_P) at the receiver is calculated as follows [10],[15]:

$$L_p = L_W + D_C - A \qquad (2)$$

where Dc – Directivity correction; A- Attenuation of sound on propagation path, in dB.

In determining the attenuation of sound during propagation in outdoor environment, geometrical divergence, noise barrier insertion loss, ground and air absorption, wind and meteorological effects have to be taken into account.

A point sound source is often described as single value by it’s sound power (Lw) but also it’s sound power frequency spectrum is important to be defined.

Two (or more) sound sources with same sound power level can have different sound power spectrum - as shown in the following figures where are figured two industrial sound sources (a steam valve and a granulating machine) with same sound power Lw = 84 dB, but with different sound power spectrum :

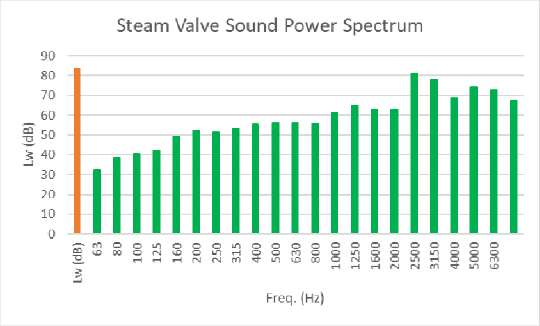

Fig. 2. Steam Valve Sound Power Spectrum

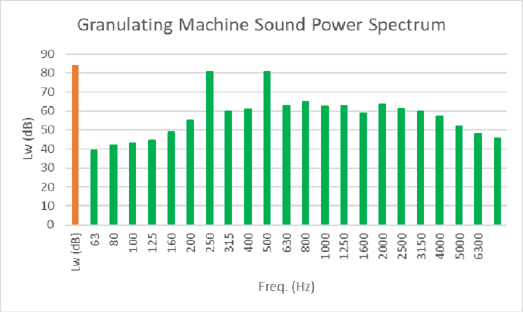

Fig. 3. Granulating Machine Sound Power

The numerical values of the sound powers of the sources, in the 1/3 octave band, are shown in Table 1:

Table 1

Sound power Spectrums – 1/3 octave

Freq. (Hz)	**Steam Valve (dB)**	**Granulatig Machine (dB)**
Lw	***84***	***84***
63	32.12	39.22
80	38.62	41.92
100	40.22	43.12
125	42.32	44.62
160	49.42	48.82
200	52.42	54.92
250	51.52	80.52
315	53.22	59.82
400	55.32	60.92
500	56.12	80.82
630	55.92	62.92
800	55.52	65.12
1000	61.32	62.42
1250	64.72	62.72
1600	62.92	58.62
2000	63.12	63.42
2500	80.82	61.32
3150	77.92	59.72
4000	68.92	57.32
5000	74.42	52.32
6300	72.62	48.22
8000	67.32	45.72

The sound spectra of noise sources described above were measured under real operating conditions, on site, during an Noise Study conducted for AZOMURES SA in 2017.

As mentioned before, the noise barriers effectiveness is often described by the Insertion Loss (IL) but also the ability to absorb sound waves can be of particular interest.

The noise barriers sound absorption functional efficiency can be described with an one digit nominal value of sound absorption index (determined by laboratory measurements) - **DLα**, dB (EN 1793-1). The **DLα** value is given by following equation:

$$DL_{\alpha} = -10\log\left|1-\frac{\sum_{i=1}^{n}\alpha_{S_i}10^{0,1L_i}}{\sum_{i=1}^{n}10^{0,1L_i}}\right|, n=18 \quad (3)$$

where:

α_{Si} are sound absorption coefficients for each 1/3 octave wide frequency band in the frequency range from 100 Hz to 5 kHz (central frequencies). L_i is the normalized A-weighted sound pressure level of traffic noise in the i-th one-third octave band [dB], as defined in EN 1793-3 (frequency range 100 Hz to 5 kHz). The normalized traffic noise spectrum comes from the average of road traffic noise spectra taken in Europe. The additional surfaces and the effects of sound diffraction on the barrier edges are not considered in **DLα** calculation.

Depending on **DLα** value, a noise barrier can be in one of the following performance categories (Table 2):

Table 2

Category	***DLα* [dB]**
A_0	undetermined
A_1	<4
A_2	4…7
A_3	8…11
A_4	12...15
A_5	>15

Another parameter that describes a noise barrier is the single number rating of airborne sound insulation power (measured in laboratory) giving an overall indication of the performance, is the reduction index DL_R (EN 1793-2):

$$DL_R = -10\log\left|1-\frac{\sum_{i=1}^{n}10^{(0,1L_i-0,1R_i)}}{\sum_{i=1}^{n}10^{0,1L_i}}\right|, n=18. \quad (4)$$

That value can be different than the value observed in outdoor conditions [6]. The measurement conditions in the laboratory (scattered field in classical reverberation test chamber) and in situ (outdoor direct incident field) are not fully comparable.

3. BARRIERS DESIGN WITH SOUNDPLAN

Commercial software for outdoor sound simulation like SoundPlan from Braunstein, CadnaA developed by Datakustik, LimA developed by Stapelfeldt Ingenieure, Odeon and many others are offered nowadays.

In our current activity we often use SoundPLan [14] and we found it to be very accurate - the calculated values of noise pressure level at receiver point is near identical with the measured values (difference between calculated an measured values is often between +/- 1,5 dB).

In order to evaluate the factors that influence the acoustic performance of noise barriers in reducing noise level at receiver point, the following scenario depicted in Figure 4, was used.

In the evaluated situation, it was considered that the receivers (residential buildings) are located on three sides of an industrial building, the noise source being represented by an equipment (point source) located outside the industrial hall.

Receiver points were located outside of nearby houses, at 1.5 m from soil level and 3 m from houses facades – according to ISO 1996-2:2017 ”Acoustics - Description, measurement and assessment of environmental noise - Part 2.

For a correct evaluation of ground attenuation, the ground type (concrete) between noise source and receivers was defined in the model.

Two sound sources (a steam valve and a granulating machine) were used, both having a sound power level Lw = 84 dB, but different sound power spectrum, as presented previously. In that scenario, a noise barrier of 2,50 m height was considered in the simulation to be placed as shown in Figure 4.

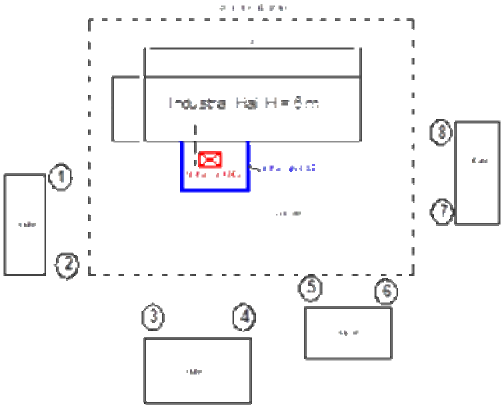

Fig. 4. Scenario used in simulations

Three variants of noise barrier were used in simulations: a reflective noise barrier and two absorbing noise barriers.

The two types of sound absorbing barriers were made of FORSTER B14 (producer Forster Gesellschaft GmbH) and LWK120 H (producer: Katz & Klumpp Gesellschaft GmbH) prefabricated elements. In the simulations the sound absorbing spectrum used for each barrier variant was that included into SoundPlan library. In Figure 5 a comparison of the two barrier absorption spectrum is presented.

According to data available in absorption library of SoundPlan software package, the nominal values of sound absorption index for the two variants of sound barriers used are as follows:

Forster B14: $DL_\alpha = 10$ dB;

LWK120 H: $DL_\alpha = 8$ dB;

Scenarios for all combinations of sound sources types and noise barriers were evaluated using SoundPlan package and the results are presented. Figure 6 shows graphically how the noise level at the receiver point is influenced by the type of material used in the construction of the sound barrier for a ”granulating machine” noise source.

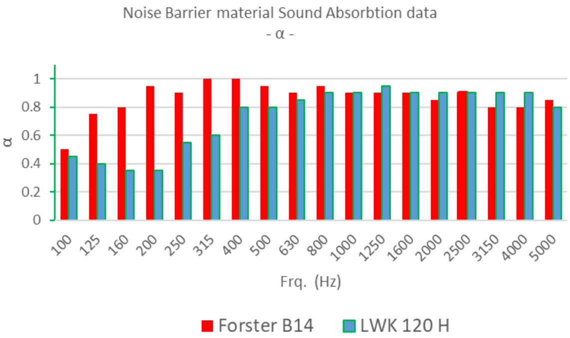

Fig. 5. Comparison of the absorption spectrum of Forster B14 (red) and LWK120H (blue)

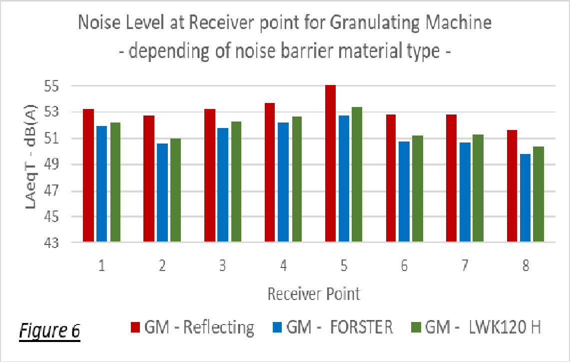

Fig. 6. Noise level at receiver points for the 'granulating machine” noise source

As illustrated in this figure, if the noise source is of the "granulating machine" type, the highest noise level is predicted in the case of a reflective sound barrier, and the lowest noise level in the case of a barrier made of FORSTER B14 elements.

Figure 7 shows the noise level at the receiver point, depending on the type of sound barrier used, for a "steam valve" type noise source. As shown in figure 7, if the noise source is of the "steam valve" type, the highest noise level is calculated in the case of a reflective sound barrier, but the lowest noise level in the case of a barrier made of LWK120 H elements.

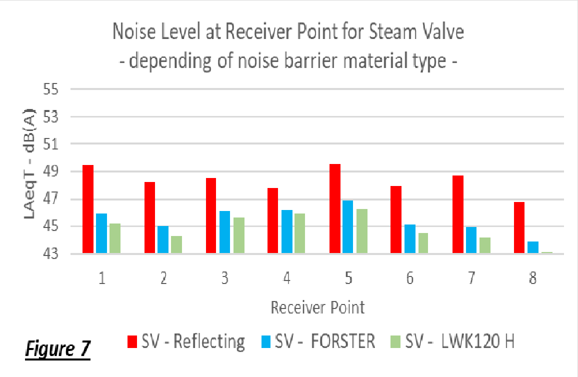

Fig. 7. Noise level at receiver points for the 'steam valve" type noise source

A comparison of the resulted noise levels for all noise sources and noise barrier types are presented in the Figure 8 and Table 3.

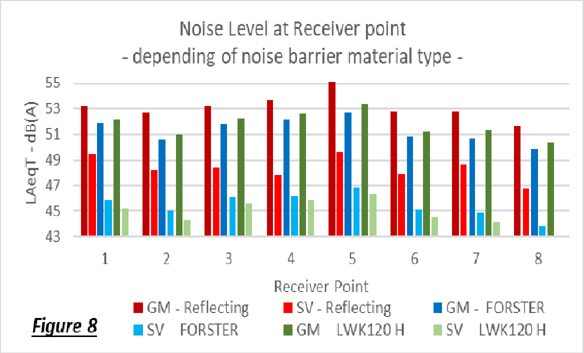

Fig. 8. Comparative results at the receiver points for two sources and three barriers

Table 3

Reception Point	**Steam Valve**			**Granulating Machine**		
	Reflecting Barrier	*FORSTER B14*	*LWK120 H*	*Reflecting Barrier*	*FORSTER B14*	*LWK120 H*
	Receiver sound pressure level – dB(A) -					
1	49.5	45.9	45.2	53.3	51.9	52.2
2	48.2	45	44.3	52.7	50.6	51
3	48.5	46.1	45.6	53.3	51.8	52.3
4	47.8	46.2	45.9	53.7	52.2	52.6
5	49.6	46.9	46.3	55.1	52.7	53.4
6	47.9	45.1	44.5	52.8	50.8	51.2
7	48.7	44.9	44.2	52.8	50.7	51.3
8	46.8	43.9	43.1	51.6	49.8	50.4

4. CONCLUSIONS

The basic principles of reflective and absorptive sound barrier design are mentioned, and examples of proper barrier materials are employed. For the outdoor sound field simulation with absorbing barriers the source sound spectrum, the source histogram and the barrier absorption spectrum are considered.

From the analysis of the data obtained from the simulations performed and presented in the present paper, an aspect is worth mentioning, namely the influence of the acoustic emission characteristics of the noise sources, corroborated with the sound absorption parameters of the noise barriers on the noise level at the receiver.

From the analysis of the data presented in Table 3, it is observed that, in the same scenario, for the same height of the noise barrier and for the same sound power of the noise sources, the noise level at the receiver point may vary by more than 7 dB depending on the characteristics of the sound power spectrum of the noise sources and of the sound absorption parameters of the material from which the sound barrier is made.

It should also be noted that, as the above data shows, in certain situations, the DL_{α} index does not correctly illustrate the actual performance of sound barriers in reducing noise levels generated by industrial sources. This fact is demonstrated by comparing the results obtained for the two types of sound-absorbing barriers used, depending on the acoustic emission characteristics of the noise sources.

For the "steam valve" noise source, the noise level at the reception points is lower in the case of the noise barrier made of LWK120H elements than of the Forster B14 elements, although the DLα index of the Forster elements is higher than that of the LWK elements.120 H.

SV power spectrum source is larger then GM from 2500Hz to 6300Hz, interval for which LWK120H is more efficient then Forster B14.

The DL_{α} index of noise barriers is given for the normalized traffic noise spectrum, not for industrial noise spectra, and the latest ones may differ significantly from traffic ones, but the above consideration are still important because in most situations, the noise barriers materials are chosen taking into account the DL_{α} value not the type of sound sources. So, for industrial sound sources, in the process of designing noise barriers should be taken into account both the sound power spectra of the sources and the noise absorption spectra of the noise barrier.

5. REFERENCES

[1] Barron R., *Industrial noise control and acoustics*, 2003

[2] Bratu, P., *Acustică interioară pentru construcţii de maşini*, Editura Impuls, 2002.

[3] Clairbois,J-P., Garai, M., *Noise barriers and standards for mitigating noise*, CEDR Conf., Hamburg, Sept. 2015

[4] Garai,M., Guidorzi,P., *European methodology for testing the airborne sound insulation characteristics of noise barriers in situ*: *experimental.*, 2000.

[5] Kotzen, B., English, C., *Environmental Noise Barriers - A guide to their acoustic and visual design*, Spon Press, 2009.

[6] Kurze, U.J, Anderson, G.S., '*Sound attenuation by barriers*', App.Ac., 4, 1971.

[7] Lupea, I., Stremţan, Florina-Anca, *Considerations on the acoustic panel absorber*, ATN, AMM, Vol.56, Issue II, 2013

[8] Lupea,I., Vibration and noise measurement by using Labview programming, Casa Cărţii de Ştiinţă, Cluj-Napoca, 2005,

[9] Lupea, I., *Considerations on the outdoors noise barriers design and simulation*, Acta Technica Napocensis, Series: AMM, Vol.59, Issue III, 2017

[10] Maekawa, Z. 1968. *Noise reduction by screens*. Appl. Acoust. 1: 157–173.

[11] Stremtan, Florina-Anca, Garai, M., Lupea, I., *Micro-perforated panels and sound absorption*, Acta Technica Napocensis, Series: AMM, Issue. III, Vol. 55, 2012.

[12] Tatge, R., *Barrier wall atenuation with a finite sized source*, Journal of Acoustical Soc. of America, vol.53, p1317, 1973.

[13] ** https://www.fhwa. dot. gov/ Environment/ noise/ noise_barriers/

[14] ** SoundPlan, User's Manual, 2018

[15] **ISO 9613 /1,/2 – 2008 Acoustics - Attenuation of sound during propagation outdoors.

[16] **ISO 1996 1/2 – 2017 Acoustics - Description, measurement and assessment of environmental noise.

Parametri acustici ce influenţează eficienţa barierelor fonice - simulări utilizând pachetul software SoundPlan

Rezumat: *In articol sunt prezentate principii de proiectare a barierelor fonice şi o evaluare a parametrilor acustici ce pot influenţa eficienţa acestora. A fost studiat modul în care parametrii de absorbţie acustică ai barierelor fonice coroboraţi cu caracteristicile de emisie acustică a surselor de zgomot influenţează valorile nivelului de zgomot la receptor. Pentru aceasta, cu ajutorul pachetului software SoundPlan s-a demonstrat faptul că, pentru surse de zgomot cu aceleaşi valori de putere acustică şi bariere fonice de aceleaşi dimensiuni, valorile nivelului de presiune acustică în punctele de recepţie diferă semnificativ în funcţie de caracteristicile spectrale ale emisiei acustice şi de coeficienţii de absorbţie acustică ai barierelor fonice. S-a arătat ca indicele de evaluare al absorbţiei acustice a barierelor fonice* DL_{α} *nu reflectă întotdeauna performanţele reale ale barierelor fonice, existând situaţii în care, pentru surse de zgomot industrial, o barieră fonică având* $DL_{\alpha} = 8$ *dB va conduce la valori mai mici ale nivelului presiunii acustice la receptor decât o barieră cu o valoare mai mare a acestui indice -* $DL_{\alpha} = 10$ *dB. Dat fiind faptul că indicele* $DL\alpha$ *este dat pentru spectrul de zgomot normalizat din traficul rutier, nu pentru spectrul de zgomot industrial, este evident că pentru sursele de zgomot industrial, trebuie utilizată o abordare diferită, care ţine cont de coeficienţii de absorbţie acustică ai barierei, în bandă de 1/1 sau 1/3 octavă în locul indicelui* $DL\alpha$.

Marius JOLDEA, SC ACUSTIC EXPERT SRL, 16 Gheorghe Titeica Str., Selimbar, Sibiu, Tel. +40-744-506649; e-mail: info@acousticexpert.ro ; www.acousticexpert.ro

Iulian LUPEA, Professor Ph.D., Technical University of Cluj-Napoca, Department of Mechanical Systems Engineering, 103-105 Muncii Blvd., 400641 Cluj-Napoca, ☎+40-264-401691, e-mail: iulian.lupea@mep.utcluj.ro ; www.viaclab.utcluj.ro