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Determination of Equal Sound Level Curves Behind the Noise Barriers

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Abstract: The paper presents a study of the acoustics phenomenon in the noise barriers shadow zone. The authors calculate the curves of equal sound level received behind a noise barrier, considering different frequencies of emitted sound and different heights of the barrier.

Keywords: sound level, noise barrier, Fresnel's number, frequencies

1. INTRODUCTION

The highways construction is at the incipient phase in Romania, compared to other countries. For this reason, the heavy traffic is usually directed on routes which pass through urban areas, generating high levels of noise and thus annoyance. In the given situation, the construction of nooise barriers along these roads or at least on some segments becomes a necessity [1], [3].

The first step is to study the sound field along the highways and noisy roads in order to assess the existing situation and then to choose the best ways to protect the environment, using sound barriers and others possibility to reduce the noise. These solutions should meet the requirements of the Romanian legislation regarding limits for the noise indicators L_{den} and L_{night} as defined in Directive 2002/49/EC.

In order to design a barrier the following aspects are essential [6], [7], [10]:

1. The height and the length should be large enough to achieve the desired levels of sound attenuation.
2. The position of the sound barrier related to the source and the location of the possible "receivers" (offices, homes, etc.);
3. Environmental impact – to fit into landscape and do not cause visual discomfort to those who live in that area.
4. The construction materials need to ensure a good reliability of the barriers in order to resist to rain, wind, snow and also the recycling.
5. Barrier should be made so that certain components, boards – jointing elements – can not be stolen.

The financial problems are extremely important, generally for reasons of economy, the construction of the barrier is preferred to be simple. In the case of noise barriers in the villages, they have not only to fit into the landscape but also they must not hinder the visibility of landscape.

2. THEORETICAL CONSIDERATIONS

In the presence of an obstacle (a sound barrier) between the sound source and receiver, a sound wave will suffer the following changes [8], [9]:

• Changes due to the barrier surface reflection and diffuse reflection (dispersion). When the streets are bordered by two parallel barriers, to decrease the effect of multiple reflections on the two barriers, the distance between them must be at least 10 times greater than their height.
• Absorption due to the barrier occurs when it contains materials that absorb sound and resonators to cancel certain frequencies of sound.
• Sound waves pass through barrier (transmission)
• Diffraction sound waves above the top of barrier represents a process that depends on the sound wave length.

Recent studies have shown the importance of sound diffraction. In Fig. 1 are presented the types of barriers commonly used. It is known that barriers having the top of the special forms, like letters T or Y, reduce sound diffraction [2].

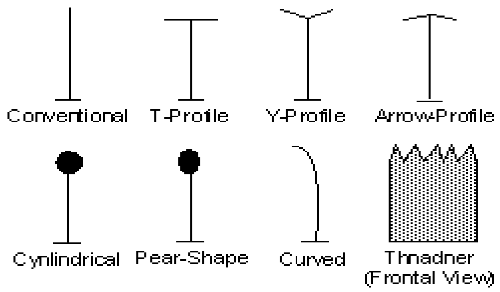

Fig. 1 Different noise barrier types

In order to study the effect of noise barriers one should compare the sound pressure level (SPL) in the absence of barrier and the SPL_{barr} in the presence of the barrier, for a specific frequency of sound.

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Sound attenuation (insertion loss = IL) is defined as follows:

$$IL = -20\log\left(\frac{SPL_{barr}}{SPL}\right) = 20\log\left(\frac{SPL}{SPL_{barr}}\right) \qquad (1)$$

Based on experimental research (different sound barriers, different sound frequencies, positions of sound source and receiver), the attenuation of sound may be calculated with the following equation:

$$IL = 10\log(3 + 20\,N) \quad [dB(A)]$$
$$IL = 5 + 20\log\left(\frac{\sqrt{2\,\pi\,N}}{\tanh\sqrt{2\,\pi\,N}}\right) \; [dB(A)] \qquad (2)$$

where: N – Fresnel's number $\left(N = \frac{2\delta}{\lambda}\right)$, λ is the sound wavelength $\left(\lambda = \frac{v}{f}\right)$, v – sound velocity, f – sound frequency and δ = a + b - c (Figure 2).

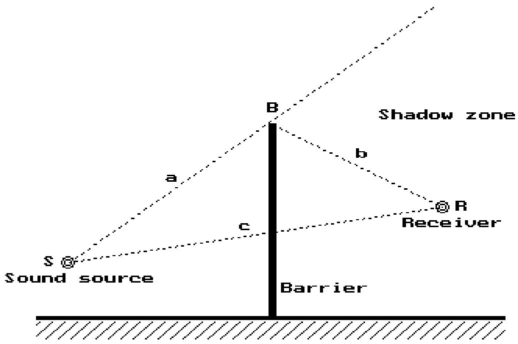

Fig. 2 Noise barrier, noise source S and receiver R

where: a is the distance between the sound source and the top B of the barrier; b is the distance from the top of the barrier to the receiver R; and c is the distance in a straight line between the source S and receiver R.

In Fig. 3 and 4 are presented the variations of noise attenuation, depending on the value of Fresnel number, using the formulas of Maekawa [5] and Kurze-Anderson [4]:

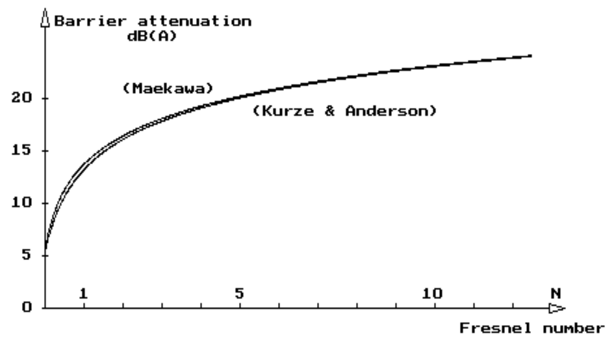

Fig. 3 The barrier noise attenuation depending of the Fresnel number for N≤10

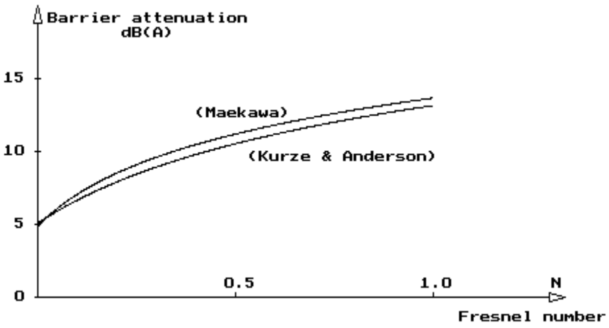

Fig. 4 The barrier noise attenuation depending of the Fresnel number for N≤1

There are small differences between the values of noise attenuation, obtained using the two formulas.

It is shown, based on experimental results, that, in the presence of noise, sound barrier attenuation is between 5 and 24 dB in the shadow zone. In this study, a more accurate formula was used to calculate the attenuation of the sound pressure level:

$$IL_k = \begin{cases} 0\,[\mathrm{dB}], & N_k \le -0.2 \\ 20\log\left(\frac{\sqrt{2\pi\,|N_k|}}{\tanh\sqrt{2\pi\,|N_k|}}\right) + 5, & -0.2 < N_k < 0 \\ 5\,[\mathrm{dB}], & N_k = 0 \\ 15\log\left(\frac{\sqrt{2\pi N_k}}{\tanh\sqrt{2\pi N_k}}\right) + 5, & N_k > 0 \end{cases} \qquad (3)$$

In formula (3), acoustic attenuation of noise barrier depends on the length of the way covered by a sound wave, from the source to the receiver, directly through barrier or by refractions.

There are four variants of calculation for the distance δ_k that intervenes in the Fresnel number formula (Fig. 5):

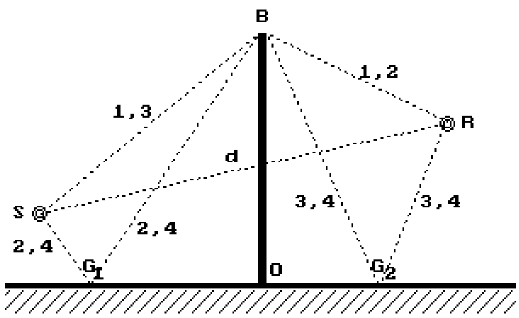

Fig. 5 Noise barrier, source, receiver and possible sound waves paths

$$\delta_k = \begin{cases} \overline{SB} + \overline{BR} - d, & k=1 \\ \overline{SG_1} + \overline{G_1B} + \overline{BR} - d, & k=2 \\ \overline{SB} + \overline{BG_2} + \overline{G_2R} - d, & k=3 \\ \overline{SG_1} + \overline{G_1B} + \overline{BG_2} + \overline{G_2R} - d, & k=4 \end{cases} \qquad (4)$$

where:

$$\overline{SB} = \sqrt{d_S^2 + (h_B - h_S)^2}$$
$$\overline{BR} = \sqrt{d_R^2 + (h_B - h_R)^2} \qquad (5)$$
$$\overline{SG_1} + \overline{G_1B} = \sqrt{d_s^2 + (h_B + h_S)^2}$$
$$\overline{BG_2} + \overline{G_2R} = \sqrt{d_R^2 + (h_B + h_R)^2}$$

3. NUMERICAL RESULTS

The results were obtained using a C program wich containes the described algorithm. The distances d_s = 8 [m] and h_s = 1 [m] defines the sources position with respect of sound barrier and the ground.

Both distances remain the same during all numerical calculations. In this paper are considered two variable parameters, the emitted sound frequency and barrier height.

There are four values for sound frequencies and three values for barrier heights: 250, 500, 750 and 1000 [Hz] respectively 4, 5 and 6 [m]. Considering the first case of wave sound transmission, regarding to the figure 5 and k=1 in equation (4), the obtained results are shown in the following figures:

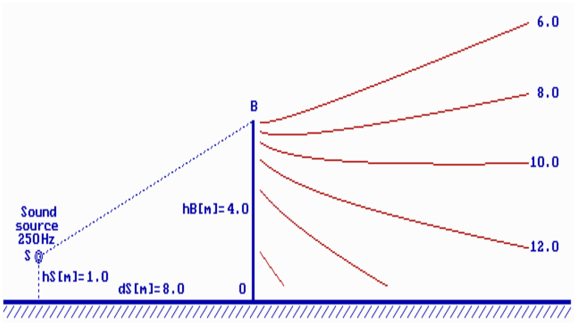

Fig. 6 The equal insertion loss curves when barrier height is 4.0 [m] and the sound frequency is 250 [Hz]

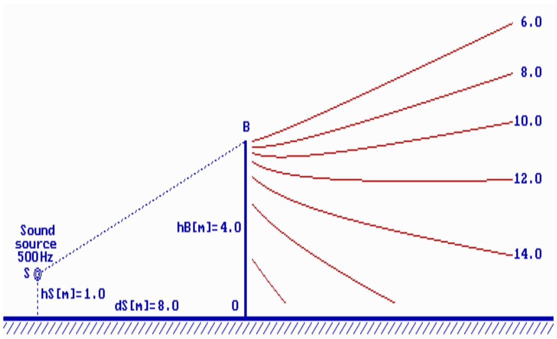

Fig. 7 The equal insertion loss curves when barrier height is 4.0 [m] and the sound frequency is 500 [Hz]

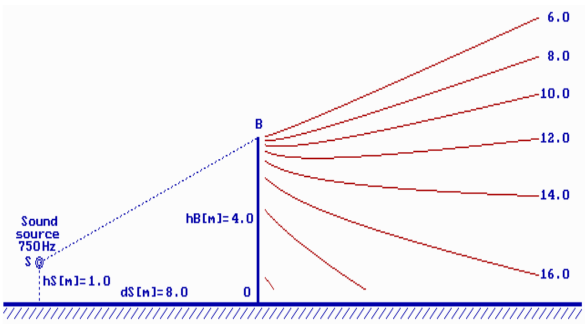

Fig. 8 The equal insertion loss curves when barrier height is 4.0 [m] and the sound frequency is 750 [Hz]

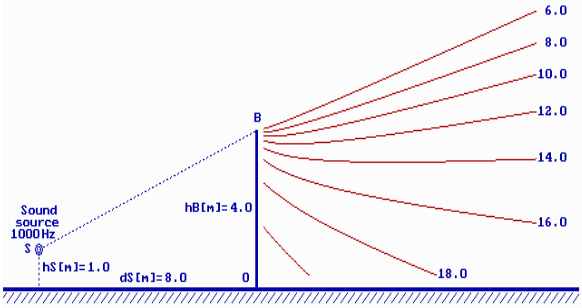

Fig. 9 The equal insertion loss curves when barrier height is 4.0 [m] and the sound frequency is 1000[Hz]

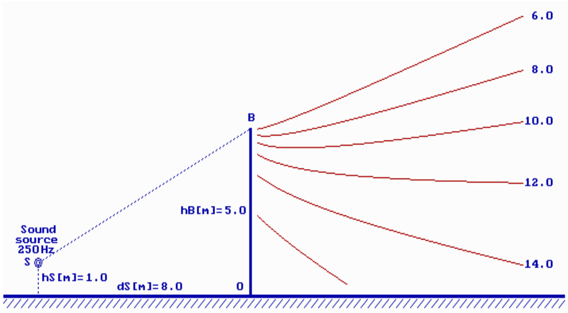

Fig. 10 The equal insertion loss curves when barrier height is 5.0 [m] and the sound frequency is 250 [Hz]

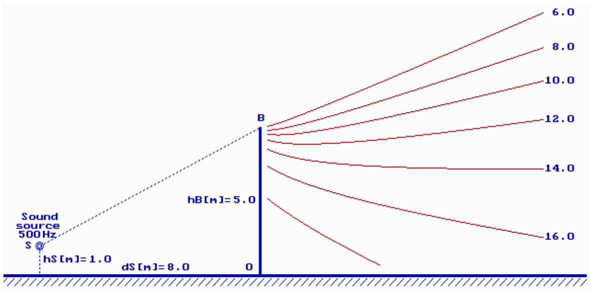

Fig. 11 The equal insertion loss curves when barrier height is 5.0 [m] and the sound frequency is 500 [Hz]

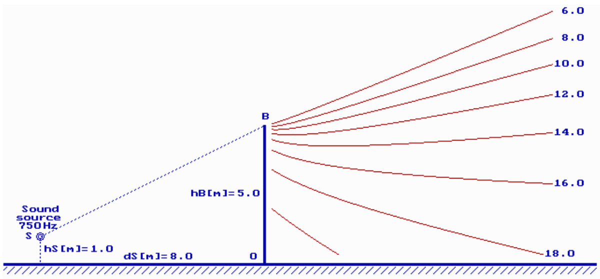

Fig. 12 The equal insertion loss curves when barrier height is 5.0 [m] and the sound frequency is 750 [Hz]

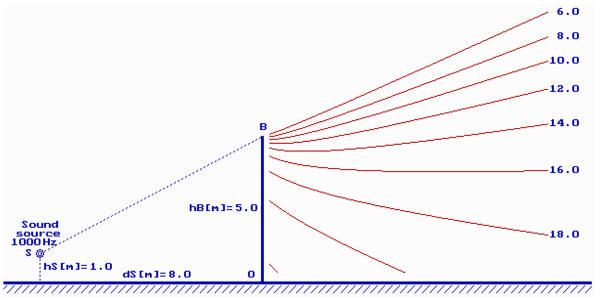

Fig. 13 The equal insertion loss curves when barrier height is 5.0 [m] and the sound frequency is 1000[Hz]

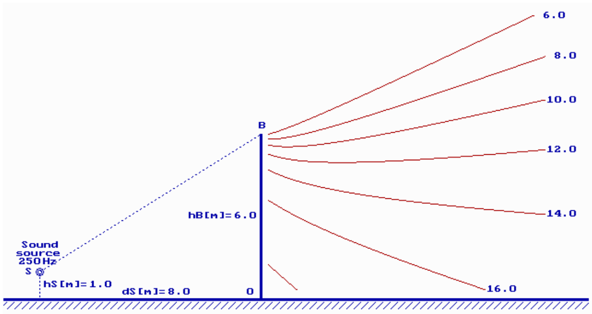

Fig. 14 The equal insertion loss curves when barrier height is 6.0 [m] and the sound frequency is 250[Hz]

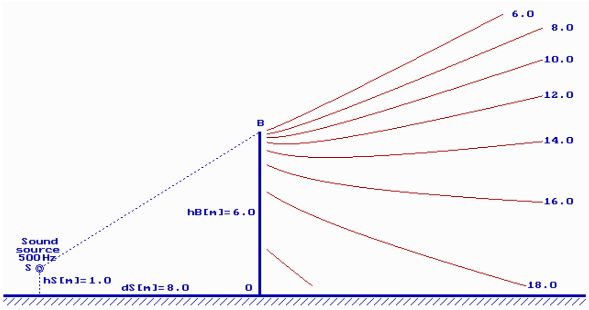

Fig. 15 The equal insertion loss curves when barrier height is 6.0 [m] and the sound frequency is 500[Hz]

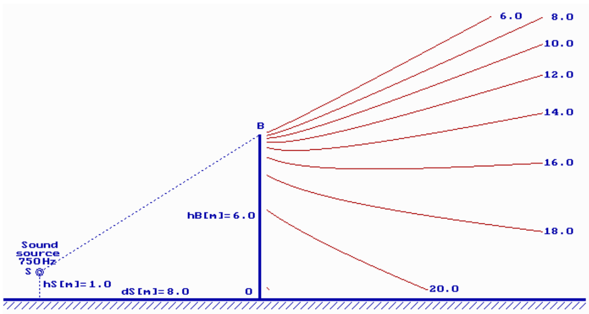

Fig. 16 The equal insertion loss curves when barrier height is 6.0 [m] and the sound frequency is 750[Hz]

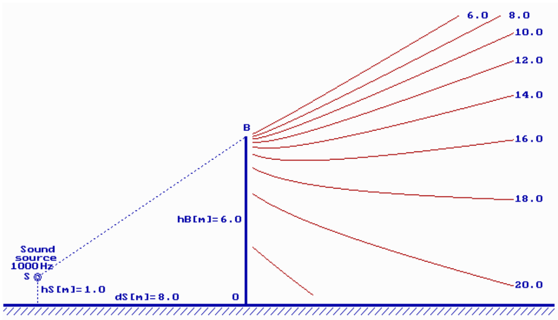

Fig. 17 The equal insertion loss curves when barrier height is 6.0 [m] and the sound frequency is 1000[Hz]

The plots in the Fig. 6 to 17 presents the insertion loss in the shadow zone of the noise barrier. They were obtained based on the computer procedure developed by the autors.

4. CONCLUSIONS

Using a C program that contains the algorithm developed by the autors, a study was made on the influence of different heights of the noise barriers and different emitted sound frequencies on the attenuation of noise induced by the barrier. The program may be used to study any real situation on the location of noise barriers.

Authors consider that the study presented in this paper contributed to the better understanding of acoustics phenomenon in the noise barrier shadow zone. The obtained results are valid for straight noise barriers.

5. ACKNOWLEDGEMENTS

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