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Influence of Spectral Emission on the Dimension of Acoustical Barriers

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Abstract Acoustical barriers are wide implemented and the way to estimate its attenuation is well known. However, the spectral emission of sources such as road traffic is not well established. So, the intent of this communication is to define the influence of spectral emission on the dimensions of acoustical barriers and the level of uncertainty occurring when we do not know the characteristics of the spectrum. We have calculated the difference between the dimensions of barriers to give the same attenuation, for three types of spectral emission with the same overall level: low frequency, median frequency and high frequency. We will define the relations of these spectra with real characteristics of traffic.

1. INTRODUCTION

The assessment of the environmental impact caused by any noise sources should be performed before the implementation of any construction or activity that may cause any form of damage to the environment. In Brazil, for example, the Constitution, in its chapter VI, referring to the environment, establishes that "*All have the right to an ecological balanced environment, a well-being for the common use of the people and essential to the healthy quality of life…*" (Nagen, 2004). In Portugal, according to Rosão (2001), the Constitution of the Portuguese Republic, April 2, 1976, in its article 66, unaltered during the last constitutional revision of 2001, states the following: "*All have the right to a humane, healthy and ecologically balanced environment of life and duty to protect it*". The concern with the acoustic comfort and the quality of life is common to any citizen, but the State must be active and promote, guide and inform the civil society about the necessity to control the noise production with the subsequent goal of reducing noise pollution and verify the construction works and activities that generate or may produce noise and acoustic discomfort.

In relation to the noise in cities, the road traffic is one of the most significant sources of acoustic discomfort, when compared to other sources such as the industry, airports and even that produced by people in their daily activities (Gündoğdu, 2005). In the study presented by Ali and Tamura (2003) the authors report a close relation between traffic noise and the sensation of great discomfort and irritability in the population. The road traffic is of utmost economic importance to the society; however the reduction of the noise it makes are necessary and urgent.

The automobile is complex source of noise. The main sources are the engine, the exhaust, the gears, the tyres and the car structure (Jonasson and Storeheier, 2000). The reduction of the noise produced by road traffic can be achieved, amongst other options, by introducing mechanic improvements or by improving the quality of the pavement. However, the most usual process to reduce the impact of this noise source is to introduce acoustical barriers.

The acoustical barriers have been extensively studied. Neto (2002) has presented a report about the performance of acoustical barriers composed by different materials, regarding efficiency and sound quality. Several other studies (Aylor, 1976; Watts, 1999) have addressed this subject, while others focused on the barrier geometry (Ishizuka, 2004).

There are several software programs developed to predict noise production and impact of road traffic (Steele, 2001). The forecast of the environmental impact in relation to road traffic and the design of acoustical barriers predicted by this software usually take in consideration a standardized spectrum of noise caused by automotive vehicles. However, the urban road traffic presents components in the low frequencies range while the noise produced by the traffic in highways is characterized by high frequencies (Coelho, 1995), thus the road traffic noise should not be evaluated based on a single standard spectrum.

The road traffic is composed by passenger cars, trucks, motorcycles, etc, all producing characteristic spectra. Versfed and Vos (2002) indicated that the discomfort caused by light weight vehicles, such as passenger automobiles, is different from that caused by trucks and lorries. Our objective in this paper is to show the importance of knowing the different spectra produced by the road traffic and the interaction with the acoustical barriers, since the changes in spectrum will determine the dimensions of the acoustical barriers (height and length) to obtain similar and effective noise attenuation.

1. NOISE ATTENUATION PRODUCED BY AN ACOUSTICAL BARRIER

Any common noise source can be decomposed in a set, more or less complex, of single point sources, and it is relevant to ascertain the reduction produced by an acoustical barrier relatively to that point source.

According to ISO 9613-2, from 1996, to a given acoustical barrier fixed in the ground, 3 different diffracted paths can be considered: one at the top of the barrier, another at its left side and one at its right side. For each diffracted path, the attenuation of acoustical barrier, A, is given by:

$$\begin{cases} A = 10\log_{10}\left(3 + \frac{40f}{c}\Delta\right) & \text{if} \quad \frac{40f}{c}\Delta \geq -2 \\ A = 0 \quad \text{if} \quad \frac{40f}{c}\Delta < -2 \end{cases} \tag{1}$$

Where f is the frequency in study, c is the velocity of sound, and Δ is the difference of length between the diffracted path in study and the direct path. In Figure 1 $\Delta = b+c-a$.

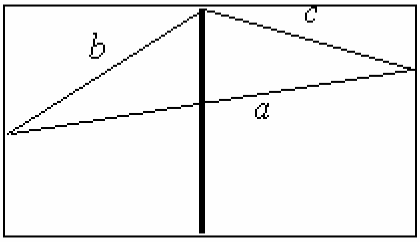

Figure 1: Difference of path.

Considering the central frequencies of the Octave Bands between 63 Hz and 4000 Hz, the Figure 2 presents the attenuation of an acoustical barrier for those different frequency bands and to values of Δ between 0 and 4 metres.

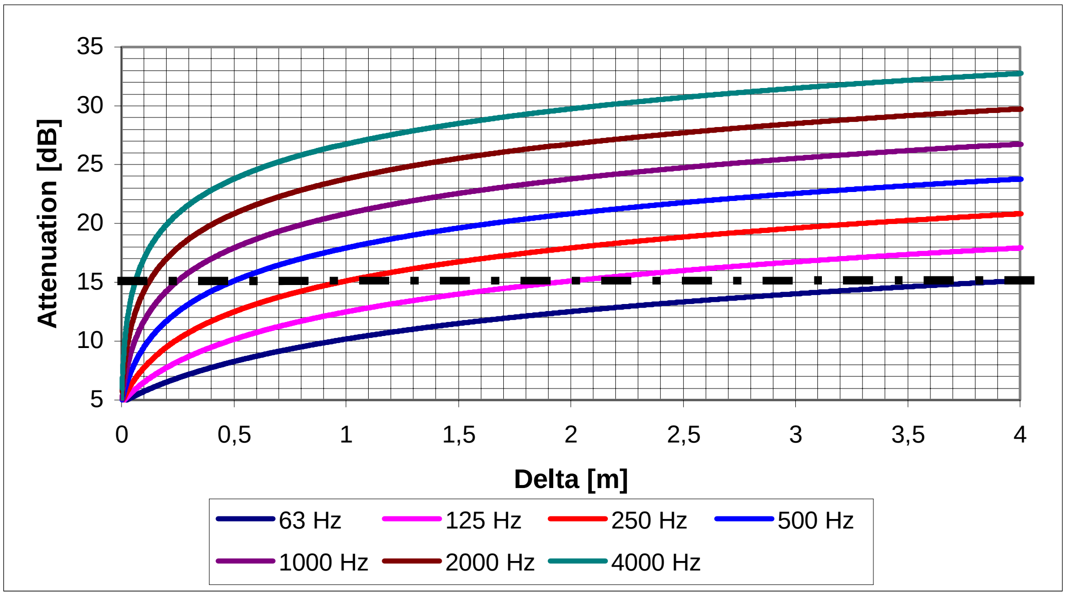

Figure 2: Attenuation of an acoustical barrier in function of the frequency and the difference of path Δ

The analysis of Figure 2 shows that for a reduction of 10 dB for the central octave band of 63 Hz, it is necessary to create a value of Δ of approximately 4 metres, for 125 Hz a value of Δ of approximately 2 metres, for 250 Hz a value of Δ of approximately 1 metre, for 500 Hz a value of Δ of approximately 50 centimetres, for 1000 Hz a value of Δ of approximately 25 centimetres, for 2000 Hz a value of Δ of approximately 12.5 centimetres and for 4000 Hz a value of Δ of approximately 6.75 centimetres. Such observation is a consequence of the known principle that acoustical barriers are more efficient in reducing the impact of high frequency noise.

2. INFLUENCE OF THE SPECTRUM

According to the French standard XP S31-133 of 2001, which corresponds to the EU regulation (2002/49/EC), it is established a single, normalized spectrum for the road traffic. This normalized spectrum [values in Octave Band normalized in relation to the global value of Broad Band (A-weighted)] is shown in Figure 3.

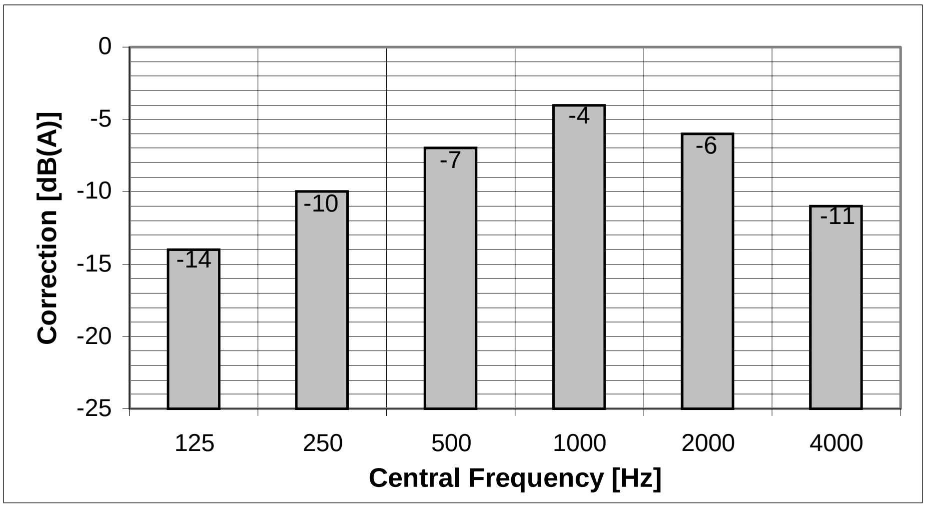

Figure 3: Normalized spectrum of road traffic noise.

Figure 4 presents the spectra obtained *in situ* for normal road traffic in a smooth and in a rough pavement. It can be observed the overall profile similarity with the normalized standard spectrum shown in Figure 3, but important differences can be pointed out.

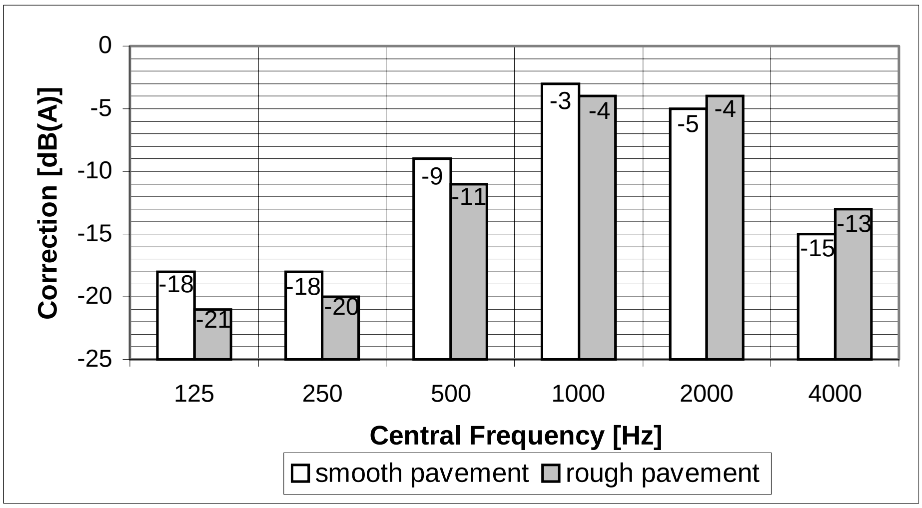

Figure 4: Spectra of two pavements.

However in specific cases the actual spectrum may be significantly different from the normalized spectrum. For example, in situations in which exist the predominance of a particular type of vehicle (e.g. more heavy vehicles usually involves more low-frequency noise), or when the traffic speed is very high (in which the low-frequencies prevail due to aerodynamic noise), or very low (the low-frequency component prevail due to engine noise). However the standard normalized spectrum used to predict and design the acoustical barriers does not contemplate such situations, which may have important consequences on its efficiency.

In such circumstances, in addition to the normalized spectrum we propose two more types of theoretical spectra, denominated *Low frequency spectrum* (prevalence of low-frequency, with a decrease of 3 dB per octave) and *High frequency spectrum* (prevalence of high-frequency, increase of 3 dB per octave), as shown in Figure 5.

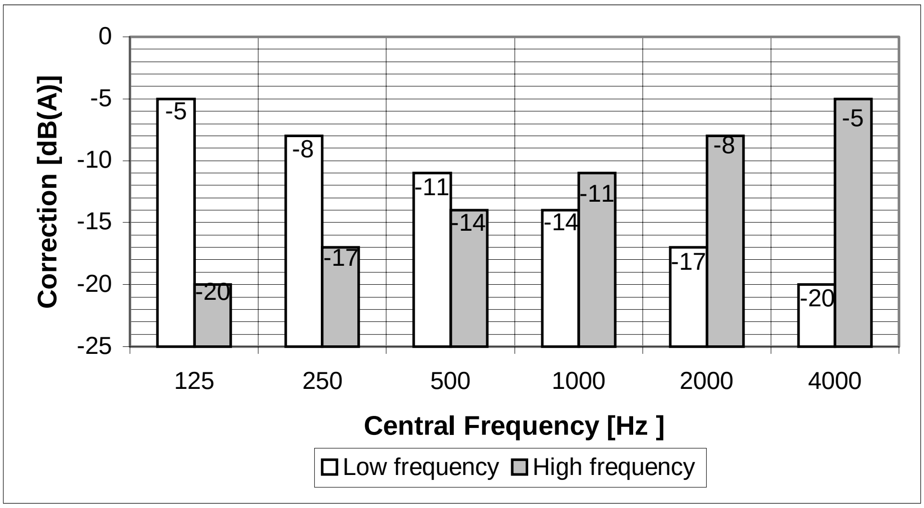

Figure 5: Theoretical spectra of Low and High frequency.

The data in table 1 represents the resulting attenuations of Broad Band using the 5 types of spectra previously described, using different values of Δ.

Table 1: Attenuation in dB of acoustical barriers in function of the spectrum and the difference of path Δ.

Path difference Δ [m] / Spectra	0.125	0.25	0.5	1	2	4
High frequency	14	16	19	21	24	27
Rough Pavement	11	13	16	19	21	24
Smooth Pavement	10	13	15	18	20	23
Normalized	9	11	14	16	19	22
Low Frequency	9	10	12	14	16	19

It is observed that for the same overall noise emission, maximal variations in attenuation of up to 8 dB can be obtained just by modifying the model spectrum.

Although the maximal value will correspond to a difference in the two spectra (*Low frequency spectrum* and *High frequency spectrum*) that in reality has little chance of occurring, it can, nevertheless, be used as an indication for extreme situations.

If we consider the difference between the spectra recorded *in situ* (Figure 4) and the normalized spectrum (Figure 3), we would obtain a maximal difference of attenuation of 2 dB.

3. DIMENSIONS AND COSTS OF THE ACOUSTICAL BARRIERS

As a first approach, we may consider that a given acoustical barrier fixed in the ground is sufficiently long (the resulting lateral diffractions are neglectable in relation to the top diffractions), if the angle (in degrees) of the lateral noise paths, in relation to a given receptor, is identical or larger than (CETUR, 1980):

$$\varphi \geq \frac{180 \cdot 10^{\frac{A}{10}}}{1 + 10^{\frac{A}{10}}} \tag{2}$$

where A is the Attenuation of broad band of the acoustical barrier, and should be higher than 0dB.

In this case, considering a straight road of infinite length, an acoustical barrier parallel to the road, and a receptor located in a perpendicular line to those and that crosses the barrier in its middle point, the barrier is sufficiently long if:

$$l \geq 2 \cdot d \cdot \mathrm{Tan}(\varphi) \tag{3}$$

In table 2 are presented indicative values of l in relation to possible A and d.

Table 2: Length of acoustical barriers sufficiently long.

Path difference Δ [m] / Attenuation of acoustical barrier [dB]	5	10	15	20	25	50	100
5	25 m	50 m	76 m	101 m	126 m	252 m	505 m
8	45 m	92 m	137 m	183 m	229 m	458 m	916 m
12	106 m	214 m	321 m	428 m	535 m	1071 m	2139 m
13	133 m	266 m	399 m	533 m	666 m	1331 m	2663 m
14	166 m	332 m	498 m	664 m	830 m	1661 m	3322 m

In agreement to the reasoning in the previous chapter, we verify that variations in noise levels of 1 dB can occur due to slight variations of the spectrum, and of up to 8 dB if important variations in the spectrum variations are considered.

From the data in table 2, to obtain a change of 1 dB in the attenuation provided by the barrier (due to a slight variation in the spectrum) it would be necessary to significantly change the length of the barrier. In the case of a change from an effective attenuation of 14 dB or 12 dB to 13 dB, to compensate for the variation in predicted values between the model and the actual spectrum, one would need to either shorten the barrier in approximately 650 m or enlarged it in almost 525 m respectively, considering a receptor located at a distance of 100 m in perpendicular to the middle point of the barrier.

In Portugal, the most common height of the acoustical barriers is 4 meters, and assuming an overall cost (structure and labour) of 150 €/m^2, a modification in length of 600 metres will alter the costs in 360000 €, a significant value, especially if considers that we are altering the attenuation of the barrier by 1 dB, and due to a slight change in the spectrum.

4. CONCLUSIONS

Considering the data and reasoning described, it is necessary that the available software and the one to be developed take in account the spectral characteristics of the noise sources, which does not happen modeling of road traffic noise, mostly due to the lack of spectral databases, which are at present being developed by the EU projects *Harmonoise* (http://www.harmonoise.nl/) and Imagine (http://www.imagine-project.org/).

Nonetheless it would be of great interest that the software would include, in addition to the default spectrum, the possibility for the user to define one or more custom spectra, according to noise emission, specially when the characteristics of the of road traffic are known and the spectrum can be obtained *in situ*.

Such possibility would allow to better predict and adjust the barrier to specific cases, and ultimately result in great economically and environmental benefits. According to this study, reductions in costs of 360000 €, and differences in attenuation of up to 8 dB could be achieved.

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