inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 3.1

IN SITU METHODS FOR THE CHARACTERISATION OF ROAD NOISE BARRIERS EFFICIENCY

F. Anfosso-Lédée*, V. Steimer, P. Demizieux****

* LCPC, Route de Bouaye - BP 4129, 44341, Bouguenais Cedex, France

** LRPC Strasbourg, 11 rue Jean Mentelin - BP 9, 67035, Strasbourg Cedex, France

Tel.: +33 - (0)2 40 84 57 92 / Fax: +33 - (0)2 40 84 59 92 / Email: fabienne.anfosso@lcpc.fr

Keywords:
NOISE BARRIER, ROAD NOISE, EXPERIMENTAL METHOD, NOISE CONTROL

ABSTRACT
Different acoustic properties of road noise barriers can be measured on site: global characteristics of insertion loss, or intrinsic characteristics of sound absorption and sound transmission. For insertion loss measurement, the standardised method ISO 10847 was tested on a basic case of an existing road barrier. An experimentation implying three independent laboratories showed relatively poor reliability and a lack of operational applicability on real site. For intrinsic characteristics of sound absorption and transmission, an experimental comparison was made between two impulse methods: the French standardised method AFNOR 31089 using a gun shot, and "Adrienne" method developed by a European research group and suggested as a future European Standard. A rather good agreement was found between both methods and differences are discussed.

1 - INTRODUCTION

The development of methods for measuring acoustic performances of road noise device is demanded for different purposes: first, for the qualification of products in order to allow them to circulate on national or international market, second for research and development in order to improve the performance of devices, and finally for public authorities of road maintainers who wish to check these performances on site after construction. This paper presents the work done in France to evaluate the test methods available for this kind of measurements. In a first part, the standardised method ISO 10847 for the measurement of insertion loss of barriers is tested on a real site experimentation implying three independent laboratories. In the second part, a method for measuring the sound absorption and transmission developed in a European pre-normative research is experimented on real site and compared with an existing national standardised method.

2 - IN SITU MEASUREMENTS OF INSERTION LOSS: TEST OF THE ISO/DIS 10847

2.1 - The ISO/DIS 10847 method and its critical points

The main function of a noise barrier is to reduce sound pressure levels in inhabited areas near to the road. Thus the most relevant indicator of its efficiency is the insertion loss, i.e. the difference in sound pressure level between with and without the barrier. Sometimes, a value of insertion loss is specified in call for proposal official documents. Consequently, it seems important to be able to measure accurately the insertion loss of a barrier erected on a real road site to see if requirements are fulfilled. A measurement method exists in an international standard: ISO/DIS 10847 [1]. But some points in this method were severely discussed in France and the national standardisation committee asked for a research project in order to test the reliability and the applicability of the method on real site.
The principle of the method is simple: the sound pressure level is measured at the point where insertion loss need to be evaluated, before the construction of the barrier ($L_{R(before)}$). To ensure the equivalence of traffic noise emission, a reference point measurement is performed simultaneously where the barrier should have no influence ($L_{ref(before)}$). Sound pressure difference is actually calculated:

$$\Delta L_{(before)} = L_{ref(before)} - L_{R(before)}$$

The same measurement is repeated in all equivalent conditions after the construction of the barrier and Insertion Loss indicator is then calculated:

$$DIL = \Delta L_{(after)} - \Delta L_{(before)}$$

This is the ***"direct method"***. When the sound can not be measured before the barrier erection, the standard suggests an ***"indirect method"*** where the $\Delta L_{(before)}$ is replaced by a $\Delta L_{(equiv)}$ measured on a perfectly equivalent site.
The mains critical points expressed were dealing with:

- the reliability of the results (comparison of DIL measured several times or by several teams)
- equivalence of direct and indirect methods
- relevance of the meteorological classes defined in the standard
- applicability of the method in operational in situ situations?

Other technical points were also questioned, like time duration of measurements, validity of correction factor Cr for free field, reflection surface or façade measurement.

2.2 - The experimentation
An in situ experimentation was organised in order to test these critical points. Three laboratories were involved (LRPC of Lille and Strasbourg, CEBTP). Natural traffic source was considered. The test site was located along the A22 motorway. It was free from obstacle on more than 500 m distance and more than 100 m behind the barrier. An equivalent site was identified nearly 2 km away along the same motorway. On this equivalent site the sound source is identical, the site configuration and orientation are roughly identical.

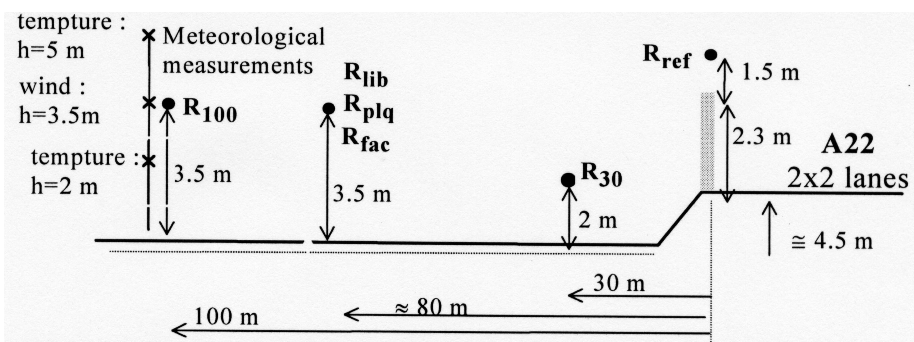

Figure 1: Site section and location of measurement points.

The acoustic measurements were performed on 4 hour long periods, in free field, 30 m and 100 m behind the barrier (or future barrier), and for several atmospheric conditions as defined in the standard. Short duration measurements have also been performed on the façade of a house.
Both direct and indirect methods were performed. The measurements BEFORE took place in 1996, the barrier was completed in June 1997, the measurements AFTER and on the EQUIVALENT SITE were implemented from June 1998 to August 1999.

2.3 - Comparison of the results
The first difficulty encountered is the poor applicability of the method as it is demonstrated by the time schedule. It took 3 years to complete the measurements, the main reason being the equivalence of weather conditions (especially wind direction and speed) and ground impedance. Furthermore, when selecting the test site, it was realised that an equivalent site does not exist (even an approximation) in many cases, especially in dense urban areas.
The first observation made was that 2 mn measurements as specified in the standard are too short for a stable and reliable evaluation of sound pressure levels. The optimal periods for observation are 15 mn to 30 mn, as longer periods would possibly introduce atmospheric changes.

The global results are presented in table 1 for the direct method and table 2 for the indirect method. For the direct method, the atmospheric class D1 corresponds to a cloudy day with no wind (<1 m/s) and short grass, and D2 corresponds to a sunny day with no wind and grass of 40 cm approximately. For the indirect method, the class I1 corresponds to a cloudy day and mild wind of direction opposite to the sound propagation. Class I2 corresponds to cloudy day with no wind and I3 to partially cloudy day with no wind.

	30 m receiver point			
Atmospheric class	**D1**			**D2**
Laboratory	Lab 1	Lab 2	Lab 3	Lab 1
DIL average [dB(A)]	**4.3**	**7.5**	**5.2**	**4.5**
Standard deviation [dB(A)]	*0.4*	*0.3*	*0.3*	*1.3*
	100 m receiver point			
Atmospheric class	**D1**			**D2**
Laboratory	Lab 1	Lab 2		Lab 1
DIL average [dB(A)]	**3.8**	**8.1**		**3.8**
Standard dev. [dB(A)]	*0.3*	*0.6*		*0.7*

Table 1: Global results of insertion loss: **direct method**.

	30 m receiver point			
Atmospheric class	**I1**	**I2**		**I3**
Laboratory	Lab 1	Lab 2	Lab 3	Lab 1
DIL average [dB(A)]	**6.1**	**5.0**	**4.5**	**5.2**
Standard dev. [dB(A)]	*0.0*	*0.4*	*0.8*	*0.5*
	100 m receiver point			
Atmospheric class	**I1**	**I2**		**I3**
Laboratory	Lab 1	Lab 2		Lab 1
DIL average [dB(A)]	**3.7**	**3.9**		**4.4**
Standard dev. [dB(A)]	*0.3*	*0.5*		*0.3*

Table 2: Global results of insertion loss: **indirect method**.

The results do not show a very good agreement. Roughly speaking, by direct method insertion loss values of the tested barrier range from 4 dB(A) to 8 dB(A) at distances of 100 m and 30 m from the road. By indirect method, insertion loss values are more coherent and range from 4 dB(A) to 6 dB(A) at 30 m distance and around 4 dB(A) at 100 m distance. Important deviations have also been observed between laboratories: 3 to 4 dB(A) for a maximum 8 dB(A) insertion loss. These deviations are supposed to be due to meteorological variations. The conditions for equivalence of wind, especially wind direction, although very difficult to fulfil in practice, seem essential, even at a 30 m distance. This can explain why indirect method results seem more reliable, as it is easier to meet the same atmospheric and ground conditions the same day than 3 years later. However, it is not proved whether the same physical quantity is measured with indirect method as with direct method.
In present state of the standard, direct and indirect methods are not equivalent. Differences ranging from -2 dB(A) to +4 dB(A) have been observed. In fact, in order to improve the direct method (the only one to be correct physically) the effect of wind speed, wind direction, temperature and wind speed vertical gradients, on noise levels measurements should be better known. Researches are still going on in this domain and may bring improvements in measurement methods.

3 - IN SITU MEASUREMENTS OF SOUND ABSORPTION AND INSULATION

3.1 - Existing and future methods

Because noise barriers need to circulate on national and international markets, their intrinsic acoustic performances need to be evaluated. In Europe, the current standardised method for qualifying road noise barriers is an indoor measurement of sound absorption and transmission in reverberant rooms, exactly like products for building construction [2]. Of course in the case of road noise barriers, an in situ qualification would be preferable, or at least, in more realistic conditions than in a reverberant field.
In France, a standardised method NFS 31089 [3] proposes a method for measuring in situ the sound absorption and airborne sound insulation of noise barriers in free field. However, this impulse method

presents some fundamental difficulties. It is based on the use of a gun shot, resulting in a poor repeatability of the test signal. Furthermore, the reflection loss of the device is measured for two directions of incident wave: normal incidence and 30° with normal incidence, and that is not sufficient to give a relevant absorption evaluation in case of strongly non flat barriers (more than 10 cm surface irregularities). And finally, the 3 ms long time window for impulse response processing is too short to provide a reliable information at low frequencies.
This is why the European Committee for Standardisation (CEN) decided to draft a new method, more extensive. A collective project supported by the European Union was in charge of the development and the test the new method, called temporarily "Adrienne" [4]. This method is also based on an impulse technique, but uses a Maximum Length Sequence (MLS) signal driven through a loudspeaker to get the impulse response. This type of signal provides a good immunity to background noise due to a periodic cross-correlation between the emission and the response. The measurements are repeated for different incidences, the number of which depends on the degree of unevenness of the barrier. Thanks to a subtraction technique applied in order to separate incident and reflected waves, the specific time window used for impulse response processing is long enough (7.4 ms) to get reliable information in low frequency range.

3.2 - The comparison tests

The LRPC of Strasbourg had a long-term practice of the AFNOR method on real road sites. But it was decided to acquire the proper equipment for practising Adrienne method in order to compare the results obtained with both methods. In a first step, the measuring equipment and signal processing procedures have been assessed by comparing the results of "Adrienne" measurements performed on test samples used previously by the European research group. These barrier samples are mounted on a 20 m long test wall in free field in Grenoble. For reflection loss measurements as well as for sound transmission loss, a fairly good agreement was found. The worst comparison is for an absorbing metallic barrier (mineral wool behind perforated sheets), but the discrepancies can be explained by the presence of humidity on the barrier, thus probably reducing the absorption by the mineral wool. These experiments confirm the good repeatability found out by the European research group, but this time with a commonly manufactured equipment (not a prototype one).
Additional measurements were performed on these same barrier samples, but with the AFNOR gun shot method. Note that the indicators specified in the two methods are different (see definitions in [2] and [3]). Actually, in the AFNOR method the averages are performed for two incidences whereas in the "Adrienne" method they are performed for 9 or more positions.
For sound reflection measurements, the comparisons of results obtained with both methods are fairly good. An example is given in Figure 2 for absorbing wood chip concrete sample. Small discrepancies can be noticed at low frequencies (below 250 Hz) and in the third octaves bands of centre frequencies 500 Hz and 630 Hz. Bigger discrepancies have been observed on absorbing metallic barrier, but they can be due to humidity problems as stated before.

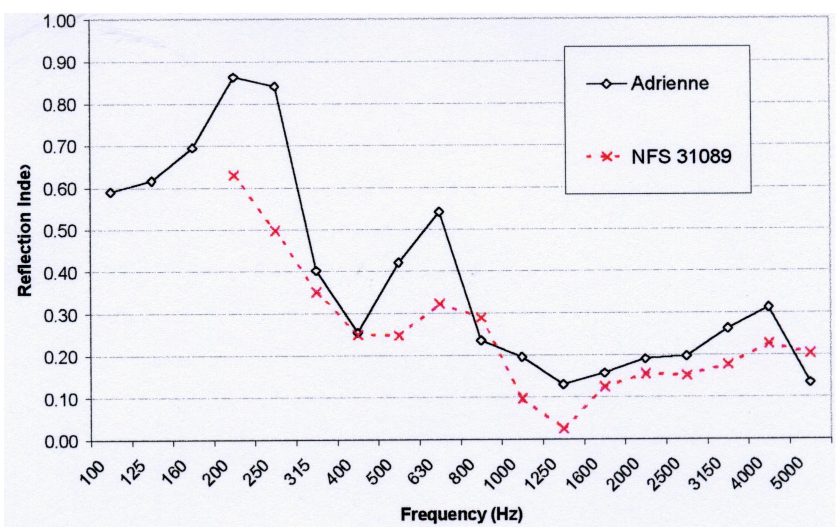

Figure 2: Comparison of reflection measurement – wood chip concrete barrier.

For airborne sound transmission loss measurements, the comparisons are also satisfying. For medium and high transmission samples (acrylic barrier or metallic one) the comparisons are good, as well in the centre of the samples as near joints. Discrepancies are small and limited to a few third octave bands, as shown in figure 3 for the metallic barrier near a joint. Big discrepancies have been observed for the very thick sample made of wood concrete + plain cement concrete + wooden zigzag. But in this case, especially at high frequencies (above 1250 Hz) the sound insulation is very high. Consequently the energy transmitted through the barrier is so small that the transmitted peak is hardly identified. In this case both method give incorrect results, but it does not really matter as the purpose of the measurement is to detect insulation weaknesses.

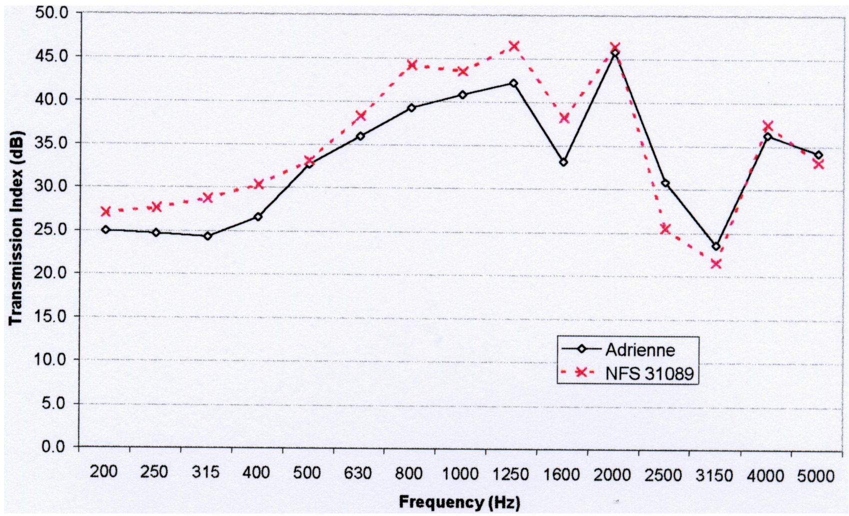

Figure 3: Transmission measurements for metallic absorbing barrier (near a joint).

4 - CONCLUSIONS

The experimental test of the standard ISO/DIS 10847 method for insertion loss measurement showed some difficulties for application on real site. Furthermore, as insertion loss tends to be very dependent on meteorological conditions (wind, clouds ...) which effects on noise measurements are not yet well mitigated, it is wise not to use this quantity as a fixed target in official pieces. For the in situ measurement of intrinsic characteristics of noise barrier (sound absorption and transmission), the comparison between a long-term existing French method and a possible future European method "Adrienne" showed rather good agreements in third octave band results. Further tests should be performed but so far, one can be optimistic as the classification of products according to their intrinsic performances should be preserved.

REFERENCES

1. **ISO/DIS 10847**, Acoustics - In-situ determination of insertion loss of outdoor noise barriers of all types, *ISO*, 1997

2. **EN 1793 part 1 to 3**, Road traffic noise reducing devices - Test method for determining the acoustic performance, *CEN*, 1997

3. **NFS 31089**, Code d'essai pour la détermination de caractéristiques acoustiques d'écrans installés en champ libre, *AFNOR*, 1990

4. **EU-Project MAT1-CT94049**, *Test methods for the acoustic performance of road traffic noise reducing devices - Final Report*, European Union, 1998