20 YEARS OF IN SITU MEASUREMENTS ON NOISE BARRIERS IN RETROSPECT

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1 INTRODUCTION

In order to protect exposed population from noise generated by roads or railways, noise barriers represent an efficient and long term solution. These devices are quite expensive and the control of their quality and efficiency is a necessity.

A test method has been published in France as a standard (NFS 31089) in 1986. This was the first standard to allow for the in situ evaluation of the intrinsic acoustic performances of noise barriers. With this new method (at the time) designed to be used along road, it became possible to compare the acoustic characteristics of these devices before their construction with the manufacturer tests report and after the construction with this in situ test.

This paper deals with the control of the acoustic performances after construction.

2 PRESENTATION OF THE TEST METHOD AND TECHNICAL RULES TO CONTROL ACOUSTIC NOISE BARRIERS

2.1 Test method

2.1.1 General

The test method is described in the French standard NFS 31089. It allows for the determination of the acoustic energy losses by reflection and transmission introduced by noise barriers installed in a free field. It is applicable in situ and is intended to be used for monitoring the acoustic characteristics of sound barriers installed along roads or railways.

Since the first publication as a provisional text in 1986, the standard has been revised two times: in July 1990 and in October 2000.

Before the publication of the European standards EN 1793 parts 12 and 23 in 1997, the French method was used both for product tests and in situ tests. After 1997, the EN standards replaced NFS 31089 for tests done by the manufacturer. The use of the French method is restricted to the survey after construction.

In France, this method is still used and will be replaced by European standard (1793 parts 5 and 6 when published as EN) when these parts will be published as a full Europen standard.

2.1.2 General principles of the method NFS 31089

The method is based on the use of a transient acoustic signal, which may be produced by a signal pistol. The impulsive noise source is placed in front of the barrier (level: 120 dB at 1.5 m and duration of 1 ms).
A microphone M1 is placed 0.5 m behind the screen, on the same side as the source and a microphone M2 is placed at 0.4 m behind the screen (see Figure 1).

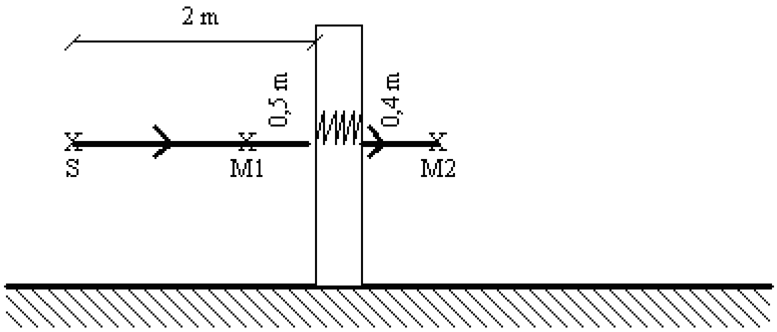

Figure 1 : Principle of the method

When the impulse is generated (minimum five repetitions), the signal is recorded on both microphones M1 (in front of the barrier) and M2 (behind the barrier). One part of the signal measured by the microphone M1 corresponds to the direct signal. One other part corresponds to the signal reflected from the barrier. For the microphone M2, one part of the signal corresponds to the transmitted signal.

In order to separate these useful signals used for the measurements, from unwanted signals (reflection from the ground for M1 or diffraction for M2 for example), a time-domain filter is applied through a rectangular time window (the width of this window is defined in the standard: 3 ms for perpendicular measurements).

2.1.3 Measurement of local loss of acoustic energy by transmission

For each repetition, the transient signal of the incident wave, $p_i(t)$, from microphone M1 and the transmitted wave, $p_t(t)$, from microphone M2 are isolated in a transient signal analyzer by means of these time windows.

In the Formula 1, the transmission factor τ_j for the jth repetition, is given by the square of the modulus of the ratio of the Fourier transforms of the transmitted signal $P_t(\nu)$, in M2 and the incident signal $P_i(\nu)$, in M1, corrected by the spherical divergence factor K_t between M1 and M2.

$$\tau_j = \left| \frac{P_t(\nu)_j}{P_i(\nu)_j} \right|^2 . K_t^2 \text{ Where } K_t = \frac{SM2}{SM1} \qquad \text{Formula 1}$$

The local energy loss due to transmission, TL_T, is calculated following Formula 2

$$TL_T = 10\lg \frac{1}{\frac{1}{n}\sum_{j=1}^{n}\tau_j} \qquad \text{Formula 2}$$

Where:
τ_j is the transmission factor calculated for the jth repetition
n is the number of repetitions (minimum 5)

The measurement is achieved for only one direction, perpendicular to the barrier

2.1.4 Measurement of local loss of acoustic energy by reflection

For this measurement, only the microphone M1, placed in front of the barrier is used.

For each repetition, the transient signal of the incident wave, $p_i(t)$, and the reflected wave, $p_r(t)$, f are isolated in a transient signal analyzer by means of temporal windows.

In the Formula 3, the modulus of the reflection factor r_j for the jth repetition, is obtained from the ratio of the moduli of the Fourier transforms of the reflected signal $P_r(\nu)$ and the incident signal $P_i(\nu)$. As the incident and reflected signals are picked up by a single microphone M1, the modulus of the reflection factor r_j must be corrected by Kr, the spherical divergence between M1 and M1' (see Figure 2 and Figure 3).

$$\left|r_j\right| = \frac{P_r(\nu)_j}{P_i(\nu)_j} K_r \quad \text{Where} \quad Kr = \frac{SM1'}{SM1} \qquad \text{Formula 3}$$

The local energy loss due to reflection, TL_R, is calculated with the Formula 4

$$TL_T = 10\lg \frac{1}{\frac{1}{n}\sum_{j=1}^{n}\left|r_j\right|^2} \qquad \text{Formula 4}$$

Where:
$\left|r_j\right|$ is the modulus of the reflection factor calculated for the jth repetition
n is the number of repetitions (minimum 5)

The measurement is carried out for 4 incidences: 0°, 10°, 20° and 30° compared to the perpendicular direction. These variations for the incident direction are done in a vertical or horizontal plane according the shape of the barrier (see Figure 2 and Figure 3).

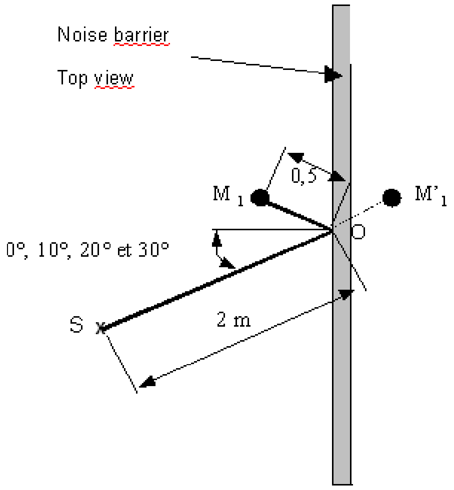

Figure 2 : Variation of the incidence for the measurements in a horizontal plane (top view)

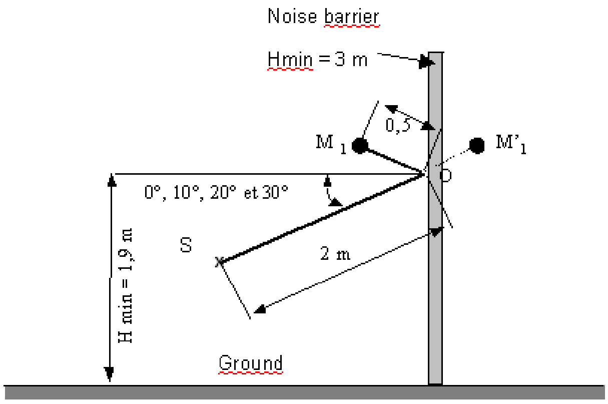

Figure 3 : Variation of the incidence for the measurements in a vertical plane (sectional view)

2.1.5 Limits of the method

In order to be able to separate the different signals, the tested noise barrier must have a 3 meters height.

A temporal window of 3 milliseconds is used. This short duration limits the frequency range of the measurement: from 200 to 5000 Hz for insulation and from 400 to 5000 Hz for absorption.

2.2 The recommended rules to check the acoustic performances of noise barriers in France

2.2.1 General

The rules are described in a document published by CERTU : "LES ÉCRANS ACOUSTIQUES Guide de conception et de réalisation"[1].

2.2.2 Organization of the controls

Two levels of control are recommended:

- Control of the products proposed by the manufacturer. This control is based on the test results according the two European standards: 1793 part 1 for absorption and 1793 part 2 for insulation;
- Control of the acoustic performances of the barrier after the construction with the in situ method NFS 31089.

As the methods are different for these two steps of control, the minimum values requested for the barrier are different: the aim of the control is to check the quality of the product (conform to the proposed product) and the quality of the installation and not to have non-conformities due to the different methods. Hereafter are gviven some examples of requirements according the different method:

- For insulation, when 27 dB(A) is requested for DL_R according EN 1793-2, 27 dB(A) is requested for TL_T according NFS 31089;
- For absorption, when 8 dB(A) is requested for DL_α according EN 1793-1, 5 dB(A) is requested for TL_R according NFS 31089;

3 20 YEARS OF CONTROLS AFTER THE CONSTRUCTION OF NOISE BARRIERS - SYNTHESIS

3.1 General

This section addresses only the measurements done on site after the construction of the barrier. The objective of these tests is to verify the conformity of the barrier to the contract established with the contracting authority and the installer.

For this check, two types of intrinsic performances are evaluated:

- The insulation performance on all noise barriers.
- The absorption performance for only the noise barriers where this characteristic is requested.

For insulation performance, in general, the contract for the construction requests that the noise barrier respects the prescribed minimum value in any point. During the measurements, we therefore attach to test the a priori weakest areas at random places when no leakage is visible (which constitutes the majority of cases). In case of visible problems, a measurement is made at this point.

These insulation measurements are undertaken mainly in front of assembly (posts, superposition of panels ...).

For absorption measurements, reflective posts, when not masked by absorbent material are excluded from the measurement area (as provided in the standard) and measurements are made in current section of panels.

3.2 Synthésis

For more than 20 years, LRPC Strasbourg has been carrying out tests on noise barriers after their construction. All these results of tests are gathered in a database with the following information for each receipt of noise reducing device after the construction:

- A tracking number to make anonymous the site;
- The date of the measurements
- The type of noise barrier. In this column, the dominant material is indicated. When on the same site, the barrier has several sections with different materials, they are recorded into the database as different barriers;

- The type of post, usually metal or concrete. In some types of work, there is no post and in this case, the cell is left empty;
- The absorbent nature of the barrier;
- The acoustic performance for absorption when the barrier is absorbing. This series of columns indicate the requirement and the measured results;
- The acoustic performance for insulation. This series of columns indicate the requirement and the results measured in front of post and in a current section;
- A summary of absorption measurements indicating the number of measurements and the number of non-conformity;
- A summary of insulation measures indicating the number of measurements (section posts and current) and the number of non-conformity;
- A summary of the receipt indicating compliance with the contract;
- A comment to explain the origin of problems

Référence number	date of meas.	Type of NRD	Type of post		Absorption		Insulation				Absorption receipts		Insulation receipts		Comments
		matérial		Absorbent	number of meas.	non conformities	number of post meas.	post non conformities	number of current meas.	current non conformities	number	non conformity	Number	non conformity	
84	23/10/2008	Transparent	Métal		0	0	1	0	0	0	0	0	1	0	
83	22/10/2008	wood concrete	Métal	x	0	0	4	1	0	0	0	0	1	1	bad design of the junction
82	22/10/2008	wood concrete	Métal	x	2	0	2	0	2	0	1	0	1	0	
81	22/10/2008	Transparent	béton		0	0	1	1	3	0	0	0	1	1	Sealing
80	02/10/2008	wood	Métal		0	0	3	0	0	0	0	0	1	0	
79	20/06/2008	Metal	Béton	x	2	0	4	0	0	0	1	0	1	0	Height < 3m
78	20/06/2008	Metal	Métal	x	1	0	3	1	0	0	1	0	1	1	leakage beetween barrier and concrete restrain system
77	19/06/2008	wood concrete	Métal	x	2	0	3	0	1	0	1	0	1	0	
76	06/05/2008	wood concrete	Métal	x	2	0	4	0	0	0	1	0	1	0	
75	06/05/2008	Transparent	Métal		0	0	2	0	0	0	0	0	1	0	Height < 3m
74	01/02/2008	wood	Métal	x	2	0	3	0	0	0	1	0	1	0	
Totals					**107**	**3**	**218**	**44**	**53**	**5**	**58**	**3**	**93**	**26**	
non conformity rate												**5,2%**		**28,0%**	

Figure 4 : part of the database

3.2.1 Analysis of absorption results

In the database, a total of 58 receipts concern the control of the intrinsic characteristics of sound absorption. For this acoustic characteristic, only three non-compliance were identified representing a rate of non-conformity of 5%.

This relatively low rate is explained by the fact that this characteristic of the noise barrier is essentially related to the panels provided and, in most cases, not related to the construction. If the acoustic performance was correctly checked when selecting products, the risk is low that the final performances are not consistent.

The three cases of non-compliance in the database concern barriers type "gabion" (stone baskets) assembled on site, where the filler material used for the construction is different of the material used for the qualification tests.

3.2.2 Analysis of insulation results

In the database, a total of 93 receipts concern the control of the intrinsic characteristics of sound insulation. These 93 receipts are the results of 218 measurements in front of posts and 53 measurements in front of current section.

For this acoustic characteristic, 26 non-compliance were identified representing a rate of non-compliance of 28%. This rate is relatively high.

Looking in more detail in these results, we find that only 4 cases of non-compliance concern measurements in front of current section of panels. These weaknesses in the acoustic panels can have several origins:

- They may be due to a design problem of acoustic panel, which should have been detected when choosing the product before the construction. In the database, it concerns an aluminum noise barrier.
- They may be due to a design problem of the acoustic panel difficult to detect when selecting the product. In the database, it concerns two wood noise barrier whose performance can be depending on the moisture content of wood
- They may be due to changes between the proposed product and the product installed. In the database, it concerns a gabion assembled on site, which the filler material used for the construction is different from the material used for the qualification tests.

These weaknesses in the panels represent a low proportion of non-compliance. For all other problems, the assembly is responsible with an insufficient acoustic seal. The leakages may themselves have several origins:

- The design for mounting the noise barrier is complex and it is difficult to get a good seal. In the database, this includes various projects with several cases of curved barriers (see examples on pictures in Figure 5 and Figure 6), barriers on concrete restraint system (see examples on pictures in Figure 7and Figure 8),...
- The seal chosen is not suitable for the barrier: not thick enough, not dense enough...
- The installation is not performed correctly: too short seals, seals in several pieces on the same post, seals torn when mounting the panels in the posts, seals insufficiently compressed.

Figure 5 : example of leakage on a curved barrier

Figure 6 : example of leakage on a curved barrier (top view)

Figure 7 : example of leakage near a post for a barriers fixed on a concrete restraint system

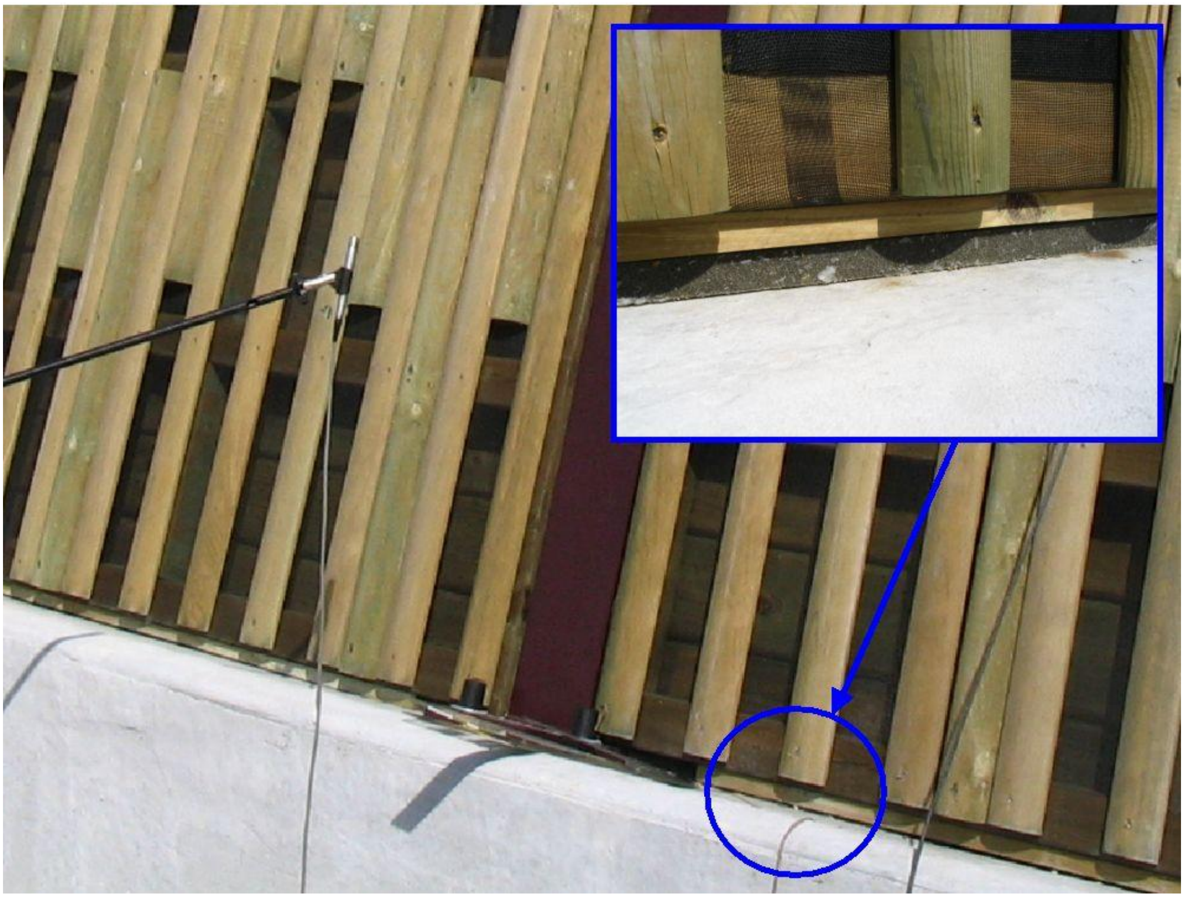

Figure 8 : example of leakage through a foam gasket for a barriers fixed on a restraint system

4 CONCLUSIONS

The organization for checking the acoustic performance of noise barriers after their construction is not followed for all projects. In many cases, only a visual control is performed.

This analysis of our measurements reveals that it is very important to evaluate the acoustic performance of the noise barriers after their construction, in particular for the insulation characteristics and to promote this approach among builders and contractors.

5 REFERENCES

[1] "LES ÉCRANS ACOUSTIQUES - Guide de conception et de realization" – published by CERTU - ISBN : 978-2-11-097152-4- http://www.certu.fr/catalogue/product_info.php?products_id=1823&language=fr

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