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**NOISE CLASSIFICATION METHODS FOR URBAN
ROAD SURFACES:
“Backing Board” Method: LCPC Contribution**

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Summary

Reduction of traffic noise in urban areas is one of the main problem to be solved by local road authorities. Between several solutions, the modification of road pavement by installing low noise wearing courses is one of them. To prove the acoustical efficiency of such pavements, new measuring techniques have been developed and implemented before being standardized.

Among different procedures, the passing-by techniques (Statistical Pass-by and Controlled pass-by) are the most currently used. However, those methods have been developed to be performed in open sites, that is to say, without any reflecting objects in the close proximity of the receiver. Unfortunately, these site configurations are not often compatible with urban area situations where building façades are quite always present. In order to avoid this problem, a solution is proposed. This solution consists in positioning the microphone on a total reflecting panel which simulates a theoretical +6 dB reflection. This technique called “Backing Board” has been presented, implemented and tested by several institutes participating to SILENCE WPF4. This report concerns the LCPC contribution to the tests.

1 Introduction

Traffic noise being one of the main factor of annoyance in urban areas, several new pavements have been developed and implemented to contribute to its abatement. In order to qualify and quantify the acoustic characteristics of those low noise pavements, several measurement techniques have been developed and, for some of them standardized. The most used are:

- The Statistical Pass-By method – SPB (ISO Standard 11189-1 [1]),
- The Close ProXimity method – CPX (ISO work still in progress [2])
- The *in situ* sound absorption measurement (ISO Standard 13472-1 [3])

The first two methods permit to measure the sound pressure levels related to tyre-road contact emission. In terms of environmental impact, the SPB method which considers the various vehicle classes composing the flow and, which takes into account the propagation characteristics of the medium, seems to be the best adapted for the evaluation of LAeq or Lden indexes representative of the whole traffic. On the other hand, the CPX technique, interesting to identify the intrinsic rolling characteristic of a pavement over long distances cannot replace the SPB method, even if it is complementary. Finally, the third method, is only useful for porous pavements for which the absorption coefficient is one of the main parameters to introduce in the models in addition to the SPB or CPX sound pressure levels.

When those methods were developed, the measurements were mainly performed on roads in open space and particularly the SPB technique which has to be used with strict site conditions without any reflecting obstacles in the close vicinity of the measuring microphone. Unfortunately, those conditions cannot be obtained in urban areas where building façades, more or less close to the receivers, are very often present. In order to alleviate this difficulty, a new measuring technique called “Backing Board” has been developed in the framework of SILENCE - WPF4 and implemented by several institutes. The present report constitutes the LCPC contribution.

2 Principle of the "Backing Board" technique

The general principle of the method is identical to the classical SPB. The microphone is located 1.2 m high above the pavement and 7.5 m far from the vehicle axis (Figure 1). The only difference concerns the measuring microphone which is not located in free field. In fact, in urban areas, we have to simulate particular conditions to be representative of this semi-open environment. So, a method consisting to position a microphone flush to a hard and totally reflecting surface (Figure 2), has been developed by O. FÉGEANT [4] and experimentally implemented by L. GOUBERT [5]. This method allows to measure on any site with reflecting conditions similar to those produced by urban building façades. In our measurements, we used a hard wooden plate.



Figure 1 : Test vehicle passing-by the "Backing Board"

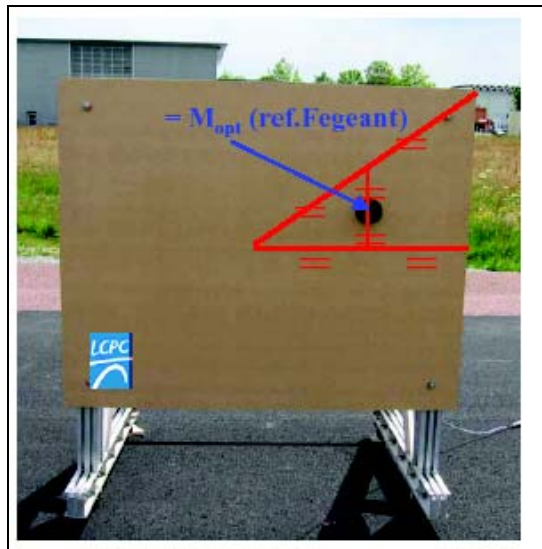


Figure 2 : Position of the microphone on the "Backing Board"

For a source located on the same side of the microphone, FÉGEANT determined the total sound pressure level at the microphone as the sum of the incident, reflected and diffracted fields. Assuming the wooden plate hardness, the incident and reflected fields can be considered as equal. In that case, the sound pressure level is doubled on the plate. This corresponds to a sound pressure increase of +6 dB. This theoretical value can fluctuate function of the diffracted effects on the board edges. From a theoretical diffraction model, FÉGEANT optimized the microphone position on the panel in order to minimize the diffraction effects on the final results. So, for a quasi-normal incidence, the centre, the diagonals and the central axis of the board are the worst positions where diffraction is maximum. On the other hand, the point noted $M_{opt} (x_{opt}, y_{opt})$, where the diffraction is minimum, is located at a particular point as shown on Figure 2. Consequently, we adopted this microphone position for all our measurements. The dimensions of the panel are: 1.44m x 1.22m x 0.022m.

Remark: In order to minimize the diffraction effects on the microphone itself, we decided to mount the microphone as flush as possible to the panel. A small hole with a diameter similar to the microphone has been drilled through the wooden panel and the microphone is located inside this adapted hole with the grid protection at the same level of the panel. The microphone is finally protected with a half windscreens attached to the panel with sticking strips (cf. Figure 3)

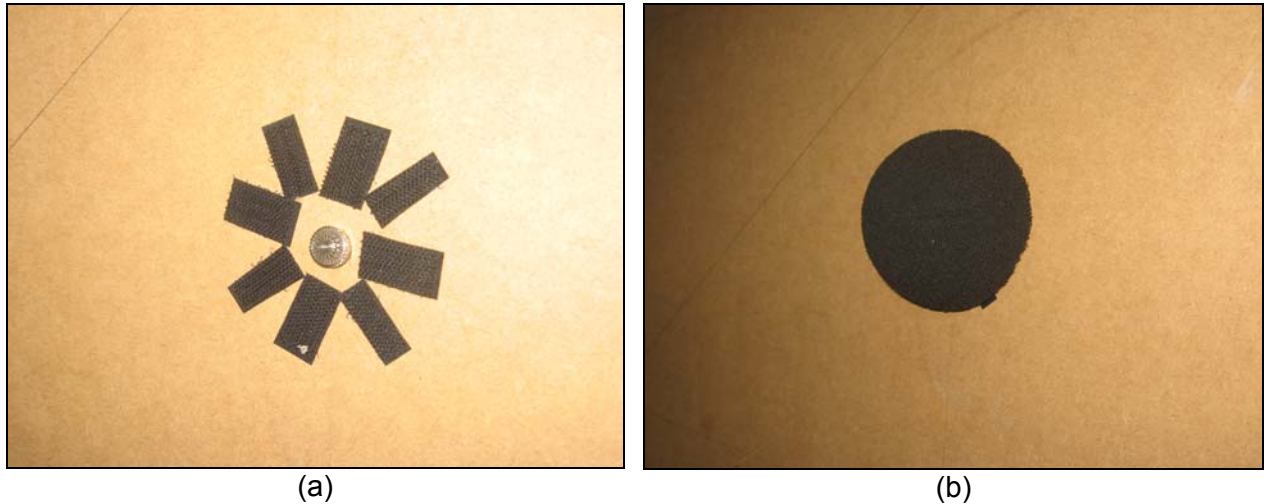


Figure 3 : Mounting of the microphone on the "Backing Board"
(a) without windscreen; (b) with windscreen

3 Validation of the method

Before using the "Backing Board" method directly *in situ*, its principle has been validated on the LCPC reference test track for controlled measurement conditions. The main goal of this experimental campaign was to verify, for various vehicle speeds and distances between the vehicle and the microphone the influence of the panel on the sound pressure level. That is to say:

- at 7.5m, can we verify the theoretical increase of +6 dB relative to free field?
- at a more realistic distance for urban conditions (for example: 3.5m), what can be the influence of the panel?

3.1 Measurement on the LCPC reference test track

During this experimental campaign, different kinds of measurements were successively carried out :

- Pass-by measurements at 7.5m and 3.5m in free field and with the "Backing Board". For these measurements we selected two different vehicle speed ranges:
 - between 30 and 70 km/h (every 5 km/h) in order to obtain a mean value at 50 km/h (regular urban speed) after a linear regression on the 9 measured values,
 - between 70 and 110 km/h (every 5 km/h) in order to obtain a mean value at 90 km/h (regular suburban speed) after a linear regression on the 9 measured values,

Remark 1: As the passing-by measurements were performed on a non trafficked road (LCPC reference test track), we only used passengers cars and the Controlled Pass-By technique (CPB) [6].

Remark 2: The various measurements have been performed twice in order to minimize the measurement discrepancies.

The regression equations and the main L_{Amax} results obtained after a linear regression are reported in Tables 1 and 2.

Table 1 : Regression equations (90 km/h) at 7.5m and 3.5m for two passing speed series

Regression equations - 90 km/h in free field		
	7.5m	3.5m
Series 1	$77.1 + 33.4 \cdot \log_{10}(V/90)$	$84.8 + 37.2 \cdot \log_{10}(V/90)$
Series 2	$77.9 + 37.4 \cdot \log_{10}(V/90)$	$83.9 + 31.7 \cdot \log_{10}(V/90)$
Regression equations - 90 km/h with "Backing Board"		
	7.5m	3.5m
Series 1	$83.5 + 35.4 \cdot \log_{10}(V/90)$	$90.3 + 36.4 \cdot \log_{10}(V/90)$
Series 2	$84.1 + 35.5 \cdot \log_{10}(V/90)$	$90.1 + 31.9 \cdot \log_{10}(V/90)$

Table 2 : L_{Amax} obtained after linear regression at 7.5m and 3.5m for two passing speed series

Speed in km/h	Free field conditions in dB(A)		With "Backing Board" in dB(A)		"Backing Board" effects in dB(A)	
	7.5m	3.5m	7.5m	3.5m	7.5m	3.5m
30	61.2	67.1	66.6	72.9	5.4	5.9
40	65.3	71.7	71.0	77.5	5.7	5.8
50	68.6	75.3	74.5	81.0	5.9	5.7
60	71.2	78.2	77.3	83.9	6.0	5.6
70	73.5	80.7	79.6	86.3	6.2	5.6
70	73.8	80.4	80.2	86.6	6.4	6.2
80	76.0	82.3	82.3	88.5	6.3	6.2
90	77.9	83.9	84.1	90.1	6.2	6.2
100	79.6	85.4	85.7	91.6	6.1	6.2
110	81.2	86.7	87.2	92.9	6.0	6.2

As a first conclusion, these experimental results demonstrate that the theory developed by O. FÉGEANT and the experimental process established by L. GOUBERT are quite well verified for a light vehicle. In fact, the differences between the free field and the "Backing Board" conditions are very close to the theoretical value of +6dB for all the tested speeds and distances.

The differences seem to be higher for the lower speeds, but with respect to the method accuracy (around ± 1 dB), we can consider that a difference lower than 0.5 dB is not significant.

3.2 Validation of the method on a discontinuity

In the previous section, we show that the “Backing Board” technique can be used with no particular problems when dealing with a light vehicle and regular road pavements. However, it could also be used to identify the effect of different modifications of the surface pavement. It is particularly the case in presence of pavement distresses or discontinuities investigated in the framework of SILENCE - WPF3.

In order to be sure that this method is relevant in presence of pavement discontinuities, we experimented, in a first time, one theoretical case on the LCPC reference test track: a cable put across the track as shown on Figure 4 and in a second time, on a real road discontinuity: a paved pedestrian crossing as shown on Figure 5.

3.2.1 Validation on a theoretical discontinuity: a cable across the track

The experimental set-up is shown on Figure 4.



Figure 4 : Validation of the "Backing Board" technique on the LCPC Reference test track
(a) the cable across the track; (b) the test vehicle passing on the cable

This new stage in the “Backing Board” validation is based on the same measurements carried out on a smooth pavement (without discontinuity). We also performed the measurements at various vehicle speeds and for two distances (7.5m and 3.5m).

In order to minimize the errors due to the positioning of the cable on the track, we tightly fixed the cable on the pavement. The results were the following:

Table 3 : *L*A_{max} obtained after linear regression at 7.5m and 3.5m on the theoretical discontinuity (cable across the track)

Speed in km/h	Free field conditions in dB(A)		With "Backing Board" in dB(A)		"Backing Board" effects in dB(A)	
	7.5m	3.5m	7.5m	3.5m	7.5m	3.5m
30	64.2	71.6	69.8	75.8	5.6	4.3
35	66.4	74.2	72.4	78.6	6.0	4.5
40	68.3	76.4	74.6	81.0	6.3	4.6
45	70.0	78.4	76.6	83.1	6.6	4.8
50	71.5	80.1	78.4	85.0	6.9	4.9
55	72.9	81.7	80.0	86.7	7.1	5.0

Even if the order of magnitude is respected and particularly at 7.5m, we observe on those results a less accuracy with respect to the expected +6 dB and particularly in the very near field (3.5m). One of the reasons could be the effect of a very short impact ("dirac" impulse) which can influence the accuracy of the signal processing technique not totally adapted to such a short impulse at the top of the time signature (rather smooth for a regular pavement) and another reason could be the effect of the distance between the source and the receiver. In fact, at a short distance, the equivalent source (including the impact of the discontinuity) cannot be considered as omni-directional, as it is assumed in the theoretical approach. When this hypothesis is not completely reached, the discrepancy on the results should increase. This has to be more investigated in the future.

3.2.2 Validation on a real discontinuity: a paved pedestrian crossing

To complement the study, we experimented a real discontinuity. A paved pedestrian crossing has been chosen (cf Figure 5). Considering the topography and the location of the site, it was unfortunately not possible to perform the measurement at a distance of 7.5m. So, the following results are given only for the distance of 3.5m and for a speed range between 30 and 60 km/h. They are reported in Table 4.



Figure 5 : Validation of the "Backing Board" technique a real discontinuity (pedestrian crossing)

Table 4 : L_{Amax} obtained after linear regression at 3.5m on a real discontinuity (paved pedestrian crossing)

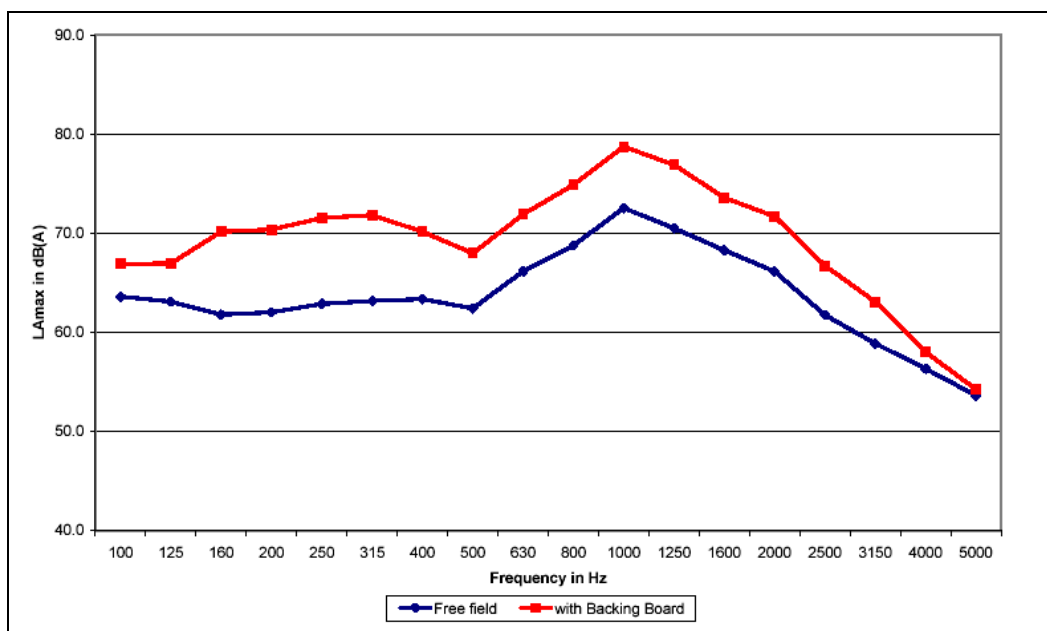
Speed in km/h	Free field conditions in dB(A)	With “Backing Board” in dB(A)	“Backing Board” effects in dB(A)
	3.5m	3.5m	3.5m
30	74.0	79.2	5.3
40	78.9	83.8	4.9
50	82.8	87.4	4.6
60	85.9	90.3	4.4

The values in Table 4 confirm those presented in Table 3 on a short discontinuity at the distance of 3.5m. Even if in that case, the impact of the discontinuity on the time signature of the vehicle passing-by is not so strong, the effect of the distance and the source directivity seems to be the most important in the result differences with respect to +6 dB.

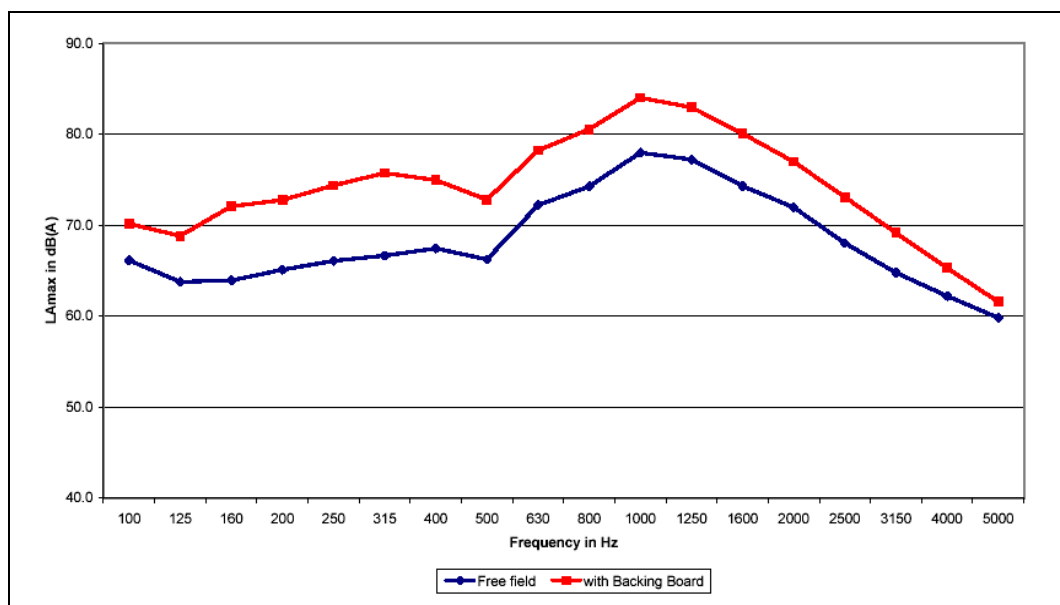
3.3 Spectral analysis

The previous experimental results were only expressed in terms of A-weighted L_{Amax} . However, in order to widely validate the « Backing Board » technique, we needed to verify that the noise amplification due to the presence of the panel was rather similar over the whole frequency range. The following results are presented on Figure 6.

They show that the reflection effect on the panel is rather similar over the whole frequency range and both for the measurement at 7.5m and 3.5m distance. This is an interesting result which allows to be confident in the future spectral measurements which will be performed in urban areas for various road configurations.



(a)



(b)

Figure 6 : Spectral evolution with and without “Backing Board”
at 90 km/h on the LCPC Reference test track
(a) distance: 7.5m; (b) distance: 3.5m

4 Conclusion

In urban areas, several solutions can be implemented to mitigate traffic noise: action on vehicle speed, modification of the pavement, action on the traffic planning and building of road barriers.

In complement to the work performed in the framework of SILENCE WPH1 and WPF3, this study largely emphasizes on the acoustic characteristics of pavements and particularly on the experimental methods developed or adapted to test them in urban areas.

The method developed and tested in this report deals with an adaptation of the standardized Statistical and Controlled Pass-By methods (SPB and CPB) to urban conditions by addition of a total reflecting surface around the measuring microphone. This method called “Backing Board” has been tested for various road configurations: on a homogeneous and a discontinuous road surface, with a light vehicle.

Theoretically, if we consider the vehicle as a point source, after optimization of the microphone position, the effect of the reflecting panel should be +6 dB with respect to a free field configuration (in accordance to the ISO standard [1]). Considering the measurement accuracy, we verified during this study, that this value is obtained on a regular road surface (without discontinuity) whatever the distance between the vehicle and the microphone (7.5m or 3.5m more adapted to urban conditions). On the other hand, when discontinuities are present on the pavement surface the impact of the “Backing Board” can be slightly different. Whatever the discontinuity width, the difference with and without “Backing Board” is around +6 dB when the measurement is carried out at the standard distance of 7.5 m. When, the distance between the source and the receiver is shorter (3.5m), the difference is lower (1 to 1.5 dB). This is certainly due to two main reasons: the impact of the discontinuity on the time history of the vehicle passing-by (addition of a “dirac” impulse) and the effect of the source directivity which cannot be considered as omni-directional at this distance. That has to be more investigated in the future and particularly for heavy vehicles.

5 References

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