Monitoring the acoustic performance of low-noise pavements

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MONITORING THE ACOUSTIC PERFORMANCE OF LOW-NOISE PAVEMENTS

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ABSTRACT

In 2012, the City of Paris began an experiment on a 200 m section of the Paris ring road to test the use of low-noise pavement surfaces and their acoustic and mechanical durability over time, in a context of heavy road traffic. Bruitparif maintained a permanent noise measurement station in order to monitor the acoustic efficiency of the pavement over several years.

Similar follow-ups have recently been implemented by Bruitparif in the vicinity of dwellings near major road infrastructures crossing Ile-de-France territory, such as the A4 and A6 motorways. The operation of the permanent measurement stations will allow the acoustic performance of the new pavements to be monitored over time.

As part of the European LIFE "COOL AND LOW NOISE ASPHALT" project led by the city of Paris, in which Bruitparif is a partner, three innovative asphalt pavement formulas are being tested to fight against noise pollution and global warming at three sites in Paris that are heavily exposed to road noise. Asphalt mixes combine sound, thermal and mechanical properties, in particular durability.

It is interesting to study the contribution of low-noise pavements for these three different urban situations: downtown with traffic speed limits of 50 km/h or less, ring road with traffic speed limit of 70 km/h and motorway with traffic speed limit of 90 km/h.

1. INTRODUCTION

Reducing noise generated by road traffic in urban areas involves a combination of several actions. Among the possible actions, the laying of low-noise pavements appears to be a promising solution to solve the problem at source. Various evaluations on the subject are carried out in the Ile-de-France, on the Paris ring road, on the A4 and A6 motorways. More recent experimental projects combining acoustic and thermal properties in Paris are also underway.

An article on this subject was published in 2018 [1]. This document provides new elements concerning the monitoring of acoustic performance two years later.

2. TEST ON THE PARIS RING ROAD

Over the 2010-2011 period, several factors led the City of Paris to test the use of low noise road surfaces on the Paris ring road, in a context of strong constraints liked to the large number of vehicles using this road infrastructure daily (more than 1.2 million vehicles with up to 270,000 vehicles per day in some places):

- the publication of Bruitparif of the results of the noise measurement campaign conducted around the ring road in January 2010 [2],
- the development of the maintenance market and opening to "alternative products with improved noise characteristics" in February 2011.
- The renewal of the maintenance market and opening to "alternative products with noise characteristics" in June 2011.

2.1 Experimental section

As early as 2012, the City of Paris and Bruiparif tested this type of solution on part of the Paris ring road in order to assess its relevance and durability over time from an acoustic and mechanical point of view.

The portion chosen for the experiment is a 200 m section located at the Porte de Vincennes. This sector benefited from ADEME funding as part of the treatment of noise hot points.

From 25 to 29 June 2012, the City of Paris and the Colas Company applied BBTM 0/6 and BBTM 0/4 type asphalt on the interior and exterior lanes of ring road respectively instead of the old pavements aged 3 to 30 years.

2.2 Noise source evaluation method

Continuous measurements of tyre/road contact noise according to LCPC method n°63 M1 (CPX) have been regulary programmed by the City of paris in order to monitor the evaluation of the acoustic perfirmance of each traffic lane.

2.3 Noise evaluation method at residential facades

As part of the HARMONICA [3] project supported by the European LIFE program, Bruitparif deployed five noise measurement stations to monitor the acoustic efficiency of the products tested (cf. figure 1).

Figure 1. Noise monitoring stations at the Porte de Vincennes of the Paris ring road.

At first station was installed between the lanes (in close proximity to traffic), three others were installed on the facades of the nearest residential buildings. The fifth station was positioned outside the experimental perimeter for operations as a control station.

Real-time access to the results of the noise monitoring system at the Porte de Vincennes is available on the Bruitparif data consultation platform via the Bruitparif website: http://rumeur.bruitparif.fr. The results of this experiment have also been published and shared with other examples of good practice on the noise abatement actions database available on the HARMONICA [3] project internet portal online from the end of 2013: http://www.noiseineu.eu.

2.4 Initial performance: tyre/road contact noise

The CPX approach allows to characterize the 8 lanes independently for a differentiated follow-up according to the supported traffic (fast lane 1 and slow lane 4). The sound levels were measured at 70 km/h and corrected to a reference temperature of 20°C.

To evaluate the gains obtained between the initial situation and the situation after the laying of acoustic pavements, two measurements campaigns were carried out, before (in March 2012) and after in August 2012). Table 1 presents the gains achieved for each lane.

The decrease in sound levels is very important since its varies for BBTM 0/6 from 5 dB(A) to 78 dB(A) and for BBTM 0/4 from 7.0 dB(A) to 10.1 dB(A). These performances depend to a large extent on the initial conditions of the road surfaces. Also, for substantially identical initial sound levels, the BBTM 0/4 offers a better performance.

Lane	Inner ring	Outer ring
1	-7,8	-8,3
2	-5,1	-7,0
3	-6,8	-10,1
4	-7,8	-9,5

Table 1. Sound levels in dB(A) measured at 70 km/h (Ref. 20°C).

2.5 Initial performance: noise at residential facades

The fist evaluation was carried out three months after the pavement was changed [4]. The noise reduction at the source was on average 7.5 dB(A) for the central location results (cf. figure 2). Such a reduction in noise is quite significant and corresponds to what could be obtained by dividing traffic by six (all other conditions being equal).

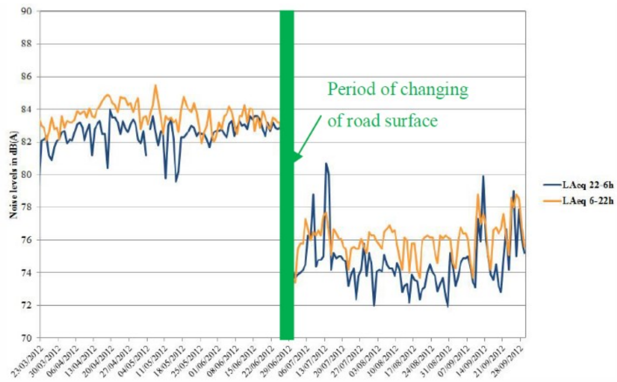

Figure 2. Reduction of day and night noise levels near the source (median) after the pavement change.

On the facades of residential buildings, noise levels have decreased by an average of 2.2 to 4.3 dB(A), depending on the location (cf. figure 3). The gains obtained correspond to what could be obtained by reducing traffic by 30 to 70%. The buildings that have seen the greatest improvement are those exposed mainly to noise generated by the ring road and located closest to the experimental section.

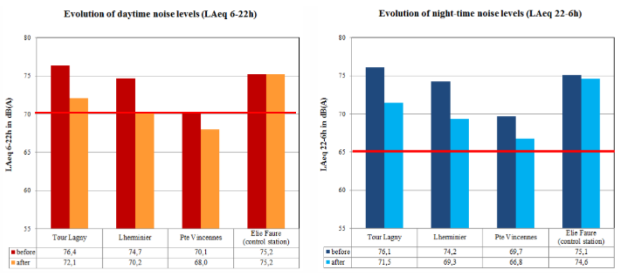

Figure 3. Change in day and night noise levels in the residential areas.

Despite this significant improvement, the situation in terms of noise exposure for residents closest to the ring road remains unsatisfactory. The regular threshold values are still exceeded by 2 to 6 dB(A) for the regulatory night indicators (the French regulatory threshold is 65 dB(A)). The situation is less critical for day time levels since two out of three stations on the front of buildings now record LAeq levels 6h-22h below or very close to the French regulatory threshold of 70 dB(A).

2.6 Performance monitoring: tyre/road contact noise

Table 2 presents the results of evaluations conducted in 2012, 2014 and 2017.

	Inner ring BBTM 0/6			Outer ring BBTM 0/4		
Lane	2012	2014	2017	2012	2014	2017
1	-7,8	-6,7	-5,0	-8,3	-7,5	-5,7
2	-5,1	-1,6	-1,6	-7,0	-4,6	-4,3
3	-6,8	-2,2	-1,2	-10,1	-4,3	-4,6
4	-7,8	-3,5	-3,5	-9,5	-4,6	-4,0

Table 2. Sound levels of side microphones in dB(A) measured at 70 km/h (Ref. 20°C) since 2012.

The evolution of the two products is comparable, however there is a differentiated evolution according to the traffic lanes and thus according to the supported traffic.

For the periods 2012 and 2014:

- the gains are still significant and vary between 1.6 and 7.5 dB(A);
- for the fast lane, the loss in acoustic performance is in the order of + 0.8 to + 1.1 dB(A) (lane 1), i.e. a loss in the order of + 0.4 to + 0.5 dB(A) per year. For the other lanes (2, 3 and 4), the loss is in the order of +4.1 to +4.3 dB(A) on average, i.e. a degradation in the order of +2.0 to +2.2 dB per year. Similar experiments carried out in Belgium [4] on other types of pavement surfaces show changes in rolling noise of the order of +0.5 to +2.5 dB per year;
- for an evolution identical to BBTM 0/6, the gains remain nevertheless more important for BBTM 0/4. However, a problem of durability for BBTM 0/4 was quickly noticed with the start of gravel on the surface.

For the periods 2014 and 2017:

- the loss of performance on the fast lane remains of the same order of magnitude with + 1.7 to + 1.8 dB(A) or + 0.6 dB(A) per year. For the other lanes (2, 3 and 4), we note a stabilization of performances with a loss of about + 0.3 to + 0.5 dB(A) on average;
- the gains on BBTM 0/4 remain significant with more than 4 dB(A). Deterioration has become widespread throughout the area.

2.7 Performance monitoring: noise at the central median

Figure 4 shows the evolution of the average LAeq 22h-22h noise level calculated per year since 2012. This annual approach makes it possible to avoid variations linked to traffic and weather conditions.

On 1 January 2014, the maximum speed limit on the Paris ring road was decreased from 80 km/h to 70 km/h. This led to a small decrease in average noise levels (around -0.5 dB(A) during day time and -1 dB(A) during night time). To overcome this confounding factor, the assessment of the acoustic performance of pavements was based on data available since 1 January 2014. The linear regression results correspond to a degradation of + 0.66 dB(A) per year.

Experiments conducted in Belgium [5], based on a different measurement method (measurement in passing SPB) and covering other types of pavement, show changes in rolling noise of the order of + 0.4 to + 1.7 dB per year.

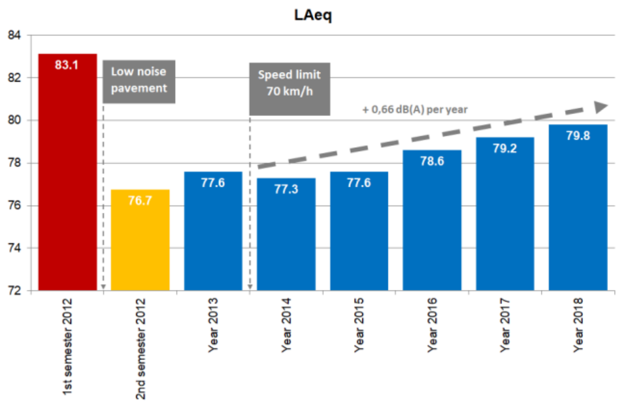

Figure 4. Evolution of the average noise level LAeq calculated per year since 2012.

In June 2019, the BBTM 0/4 placed on the outer ring, mechanically damaged, was replaced by a BBTM 0/6. Today, 50% of pavement used in the Paris ring road is a BBTM 0/6.

3. MOTORWAYS A4 AND A6

Class 1 noise measurement stations were deployed by Bruitparif on sections of the A4 and A6 motorways where low-noise road surfaces were laid in 2017. Thus, on the A4 motorway, two stations have been installed near the traffic lanes at Charenton-le-Pont (94), one in each direction of traffic, and one has been set up also in Joinville-le-Pont (94) (cf. figure 5). On the A6 motorway, two stations have also been set up, in each direction at L'Haÿ-les-Roses (94).

Figure 5. Location of a noise monitoring station (A4) at Joinville-le-Pont (94).

Figure 6 shows the decreases observed as of January 31, 2018 for pavements aged 3 to 6 months. On the LAeq 24h indicator, the gains are in the order of 5 to 8.5 dB(A). The deployed stations are intended to be maintained for many years in order to document the evolution of the acoustic performance of road surfaces.

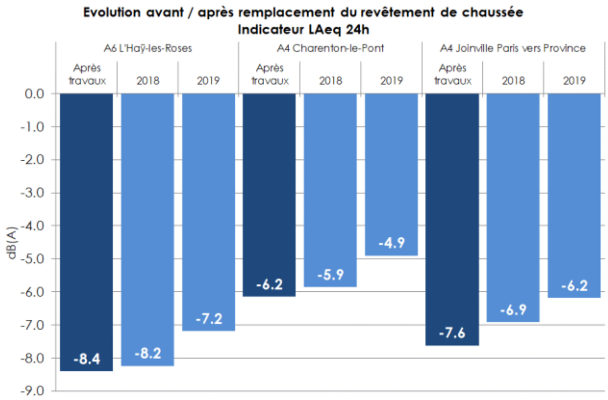

Figure 6. Evolution before / after road surface replacement; LAeq indicator 24h.

Two years after installing the low noise pavements, the results are still very positive in terms of the noise reduction efficiency provided by such solutions, with average noise levels reduced from 4.9 to 7.2 dB(A) on average over 24 hours, a reduction equivalent to what could be obtained by reducing the number of vehicles by a factor of 3 to 5.

A comparison of the reductions obtained in 2018 and in 2019, one year and two years respectively after the installation of the low noise pavements, however indicates a deterioration in their acoustic performance over time, which can be estimated for the moment at 0.9 dB(A) per year [6].

4. LIFE PROJECT: COOL & LOW NOISE ASPHALT

As part of the European LIFE program, the City of Paris, in partnership with Colas, Eurovia and Bruitparif, is testing three innovative pavement surfaces to fight against both noise pollution and global warming [7].

In 2018, three new types of asphalt mix (PUMA, Bbphon+ and SMAphon) gathering both phonic and refreshing properties, while maintening acceptable durability, were developed [8-10].

From 2018, 1200 meters of roads are surfaced with new asphalts having acoustic, thermal and mechanical properties. These new formulas are tested on three pilot sites, each 400 meters long, in three Paris sites heavily exposed to road noise: rue Frémicourt, rue Lecourbe and rue de Courcelles (cf. figure 7). Each site is equipped with various sensors and is coated half with an experimental formula and the other half with the Parisian standard pavement.

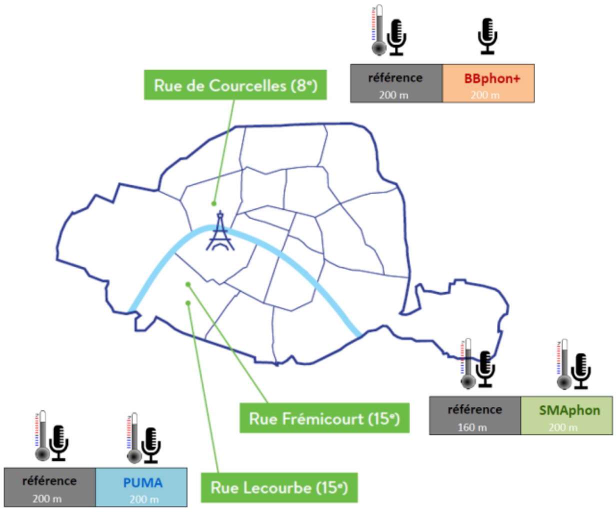

Figure 7. Pilot sites.

The new types of asphalt mix are tested on road sections of about 200 m and compared to the standard solution deployed by the City of Paris on Parisian roads: ACR 0/10 AC2 and BBMA 0/10. Also, sections of about 200 m of these standard asphalt mix were also laid on the three experimental sites (cf. figure 8). For the thermal evaluation, a third section keeping the original asphalt is used as a "control" section.

Figure 8. rue Frémicourt with new asphalt mixes, October 2018.

14 permanent measuring stations have been installed to evaluate the acoustic and thermal performance of the new types of asphalt mix and to compare them to standard solutions: 6 acoustic stations and 8 thermal stations positioned between the roadway and the facade of the buildings (cf. figure 9).

Figure 9. Acoustic station and thermal station; rue Frémicourt (SMAphon).

Digital audio recordings on the roadside and continuous ProXimity (CPX) noise measurements, consisting of measuring the noise emitted near a rolling test tire, complete the acoustic evaluation device (cf. figure 10).

Figure 10. CPX measuring equipment; City of Paris.

Measurements of mechanical durability microroughness (skid resistance tester: SRT), macrotexture (mean texture depth: MTD) and in situ survey of small degradations were carried out.

On the noise side, the priority objective is to reduce the noise pollution generated by road traffic on urban roads thanks to these new pavements, by reducing the noise emitted by the contact of vehicle tires with the asphalt (rolling noise).

On the facade of a building, the reductions in rolling noise are clearly observable during the passage of isolated vehicles at night, when road traffic speeds are relatively higher and the other sources of noise reduced (works, human activity, etc.). Thus, the LA10 22h-6h indicator clearly reflects the reduction associated with rolling noise (cf. figure 11). For the other periods of the day, the acoustic indicators show a reduced or zero benefit.

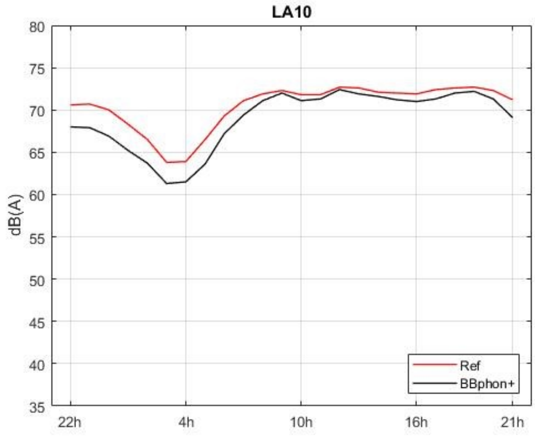

Figure 11. rue de Courcelles with new asphalt mixes; LA10 indicator.

The project objectives in terms of reducing rolling noise compared to standard solutions are achieved for the SMAphon and the BBphon + (cf. table 2). For the PUMA, a reference (ACR 0/10 AC2) that is not representative of reality does not allow the performance of the new pavement to be evaluated at this time.

	CPX		Facade
	30 km/h	50 km/h	LA10 22h-6h
Objective	**-**	**-3,0**	**-2,0**
SMAphon	-2,9	-3,5	-2,3
BBphon+	-2,3	-3,3	-2,8

Table 2. Rolling noise reduction with new asphalt mixes.

The first results show a significant reduction in noise levels associated with tire / road contact noise during the night period. However, the ability to distinguish sources of noise by the human ear, can make it possible to feel the benefit provided by innovative the innovative asphalt mixes.
A survey of users and residents of pilot sites made it possible to answer this question (http://www.life-asphalt.eu). A survey of users and residents of Frémicourt Street shows that 63% of those questioned noted a reduction in road noise following the change of road surface. Among them, 67% consider this reduction to be medium or significant. These additional qualitative elements in terms of feeling are interesting in the evaluation of the project.

On the thermal aspect, the objective is to mitigate the effect of Urban Heat Islands (UHIs), by testing the surface water retention capacities, the micro-climatic impacts generated by their spraying with non-potable water during hot periods, and the effects of their color (albedo) on heat restitution. The new coatings tested present a micro-granularity allowing to retain a water film which will refresh the air by evaporating [11-13].

On the durability aspects, the objective is to reinforce the durability of these coatings in terms of their sound, mechanical and thermal properties while limiting their additional cost compared to conventional coatings, in order to promote the dissemination of these solutions in urban areas.

The long-term monitoring will document the evolution of acoustic and thermal performance over time.

5. CONCLUSION

Today, the use of low noise pavement is common on roads with speeds above 70 km/h. The use of these solutions in the city center for speeds below 50 km/h is less usual.

For the three contexts studied: A4 and A6 motorways, Paris ring road, and Paris city center roads, early age evaluations of low-noise pavements provide very encouraging results in terms of effectiveness in reducing noise exposure of populations living near road infrastructures. The first results in Paris city center roads show a significant reduction in noise levels associated with tire / road contact noise during the night period. A survey of users and residents of Frémicourt Street shows that 63% of those questioned noted a reduction in road noise following the change of road surface.

The sustainability of performance over time remains a subject of study. Also, long-term monitoring should be conducted in order to study the durability of acoustic performance and the mechanical qualities of acoustic pavements in a context of dense urban road traffic. For the Paris ring road, six years after the start of the experiment, sound levels remain below initial levels on the portion of the Paris ring road studied.

6. ACKNOWLEDGEMENTS

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