Health & Safety

Cool and Low Noise Asphalt Life Project in Paris

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Abstract

The European Environment Agency indicates that 37 million of European citizens are exposed to transport-related noise at levels considered as dangerous for their health. In Paris, about 22% of the population is affected by noise pollution, mainly due to noise from road traffic. On another hand, climate change is also a major concern for European cities. Studies have shown that for 30 years, heat waves are increasingly intense and longer in Europe, the peak of heat in 2003 in Paris and its heavy health impact is a relevant example as well as the 2018 summer. The Cool & Low Noise Asphalt life project, initiated in 2017 for 5 years is managed by the city of Paris, Colas and Eurovia contractors companies and the Bruitparif association, its goal is to tackle these 2 environmental challenges, by developing innovative forms of asphalt mixes. The main goal is to devise these asphalt surfaces with both phonic and thermal properties and an acceptable durability, in order to create practical tools to directly improve city dwellers' quality of life. The project seeks to refine the properties of three widespread types of asphalt in Europe (2 compacted asphalt mixes, and 1 hot poured asphalt mix) allowing not only replicability all over Paris, but also all over Europe. This paper presents the objectives of the project and its progress to date. The mixes designs have been completed successfully, including a durability evaluation. The pilot sites have been implemented and the first results on noise measurements and thermal behaviour of the pavements are available. The monitoring of the pilot sites will be followed during 4 more years.

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1. INTRODUCTION

As part of its environmental policy, the City of Paris has decided to include in the European Commission's LIFE programme an ambitious project to develop urban bituminous surfaces to limit two nuisances with which the city is confronted: noise and excessive heat during heatwaves. To this end, it asked Bruitparif, an independent non-profit organisation, to assist in the assessment and measurement of noise. The companies Colas and Eurovia were approached in view of their capacity for study and innovation, their good knowledge of the Parisian context and the opportunity of ongoing asphalt maintenance contracts with the city. The thermal aspect is managed by the public domain of Paris laboratory (LEM) and the urban ecology agency (AEU) with the contribution of the interdisciplinary laboratory for the energies of tomorrow (LIED) of the University of Paris Diderot, which is supervising a thesis on the role of urban surfaces and new water uses in the adaptation of cities to climate change: evaporative urban cooling and its impact on the urban climate.
The team therefore formed proposed the "Cool & Low Noise Asphalt" project to the Life programme. This project was selected and officially began on 1st July 2017 for a five-year period [1].

The main objective of the project is to contribute to two major environmental challenges with major health impacts, namely noise pollution and adaptation to climate change. It aims to develop a joint innovative project to contribute to the fight against these two challenges by improving the current compositions of asphalt road surfaces in order to provide performances that are currently missing: the reduction of traffic noise and the reduction of temperature in urban areas, with a durability criterion and an economic constraint.
The project, which is estimated to cost €2.4 million, is supported by a €1.4 million grant from the European Commission's Life programme.

2. THE URBAN ENVIRONMENTAL PROBLEM

The City of Paris is very sensitive to environmental protection and is implementing a proactive policy to improve the living conditions of its inhabitants and combat the effects of global warming. These actions are carried out within the framework of the Environmental Noise Prevention Plan (PPBE) and the Air Climate and Energy Plan, led by the Department of Green Spaces and Environment (DEVE) of the City of Paris and in particular the Urban Ecology Agency (AEU).

Noise is a major concern for urban dwellers and a public health issue, as is air quality. It causes recognised harmful extra-auditory health effects: discomfort, sleep and learning disorders, stress, and cardiovascular problems [2] [3]. In October 2018, the World Health Organisation's Regional Office for Europe tightened its guidelines on noise exposure levels. The objective of the Paris Environmental Noise Prevention Plan (PPBE) is to reduce road noise in the city by acting on different levers: the evolution of modes of transport, motorisation, speeds, behaviour and also road surfaces. Since 2014, major low noise asphalt laying operations have been implemented on the périphérique, the motorway ringroad surrounding Paris, and the PPBE supports the objective of testing this type of surface on urban roads.

Similarly, the phenomenon of urban heat islands (UHI) is becoming more and more frequent in cities due to global warming [4]. UHI causes health issues well identified by the City of Paris, which intends to act on this phenomenon by a policy of greening the city. The 2018 Territorial Air Energy Climate Plan also intends to identify or create "cool islands" and "cool trails" in Paris that will be accessible each summer and to communicate with the general public, in order to offer the most vulnerable people, several hours of coolness on hot days.

3. KEY ASPECTS OF THE PROJECT

The different stages of the project consist of: formulating three innovative materials, identifying three sites suitable for experimentation, instrumentation and establishing zero points on these sites, laying the test sections and monitoring them over time. The final stage involves communicating around the project and disseminating the results. A scientific committee composed of specialist academics, specialist association representatives and specialist professionals has been set up and is kept regularly informed of the progress of the project.

3.1. The formulation of innovative materials

The principle of formulating innovative bituminous materials for surface layers is based on four basic requirements: to reduce the level of traffic noise compared to a traditional road, to reduce the temperature in the event of hot weather conditions, to remain at an economic cost similar to the traditional solution within the limit of a 10% additional cost, and finally to be replicable in other cities in France and Europe. A reduction in rolling noise emission is therefore sought as well as the absorption of both engine and rolling noise.

The reduction of temperature aim is to lower the temperature by a few degrees by increasing the albedo of the surface, and in the event of a major heat wave by watering it. The evaporation effect of the water induces a decrease in temperature.

3.2. The choice of sites

The choice of sites was made on the basis of several criteria imposed by the parameters of the experiment. First of all, these sites had to be roads with a maximum speed of 50 km/h without being limited to 30 km/h. They had to have a high level of noise exposure and an orientation as close as possible to the East-West axis without any significant presence of trees in order to maximise their exposure to direct sunlight from the perspective of the thermal criteria. In addition, for budgetary reasons, these roads had to be included in a surface layer repair programme for 2018. Finally, the experimentation on each site required a linear length of approximately 400 metres to allow the experimental surface coating to be laid over 200 metres and the reference surface coating to be laid over a further 200 metres. Three sites were finally selected: Lecourbe Street for a mastic asphalt product, Frémicourt Street and Courcelles Street for conventional asphalt.

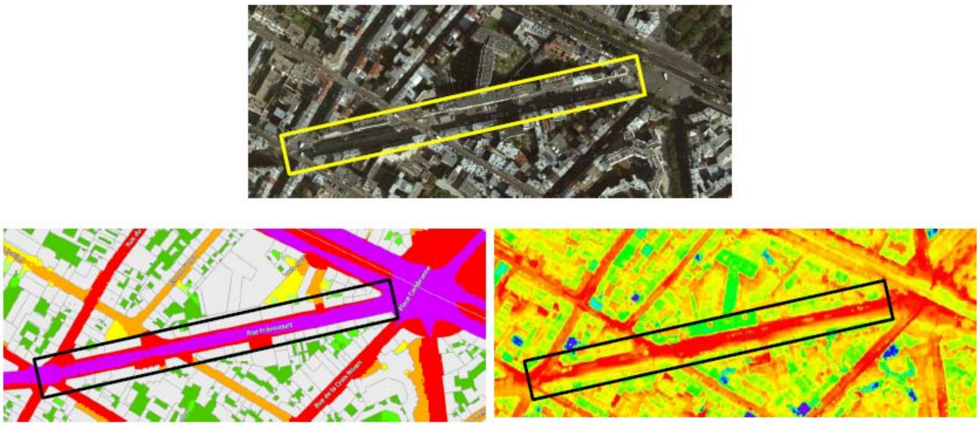

Figure 1 – Example of Noise (bottom left – purple colour shows excessive noise level) and temperature maps (bottom right- red colour shows highest temperature) used for site selection. (Here rue Frémicourt, Paris 15ème)

3.3. Site instrumentation

3.3.1 Noise measurement instrumentation [5] [6]
Six permanent measuring stations have been installed (photo 1) to evaluate the acoustic performance of the innovative surface coatings and compare them with standard solutions. The stations are positioned between the road and the facade of the buildings at a height of 4 metres for each test section laid: a reference surface and an innovative surface.
These measurements are made using stations equipped with Class 1 sound level meters, which are regularly calibrated. The LAeq1s levels and frequency band levels of one-third of an octave are recorded every second. Data transfer to Bruitparif's computer servers is carried out via the cellular network. Noise levels are published on the internet platform Bruitparif measurement network data (https://rumeur.bruitparif.fr/).

In addition, digital audio recordings were made to the right of each test section before and after work at the location of each permanent station approximately 1.70 m above the ground. They allow a high quality reproduction of sound environments and the immersion of the listener in real conditions.

Digital audio recordings at the roadside and continuous CPX (Close ProXimity) noise measurements, consisting of measuring the noise emitted in the vicinity of a rolling test tyre, complete the acoustic evaluation system (photo 2).

Photo 1 - Installation of a microphone for noise measurement on rue Frémicourt

Photo 2 - Continuous measuring device (CPX); measuring equipment of the City of Paris

3.3.2 Instrumentation for the evaluation of the project's thermal objectives

The thermal component of the project includes a monitoring of performance indicators based on an evaluation of the albedo effect and an evaluation of the watering effect of the innovative surface coatings. To this end, monitoring is carried out according to a double reference: a comparison of the indicators recorded on the innovative test section with respect to the existing road surface before installation; and a comparison of the indicators recorded between the innovative test section and the reference test section, both watered and implemented at the same time. Each street section has a weather station in the centre (photo 3) that measures the parameters required (figure 2).

- At 1.5 metres: temperature and relative humidity of the air, globe temperature;
- At 4 metres: temperature and relative humidity of the air, wind speed and net radiation.

Photo 3 - Reference weather station on rue Lecourbe

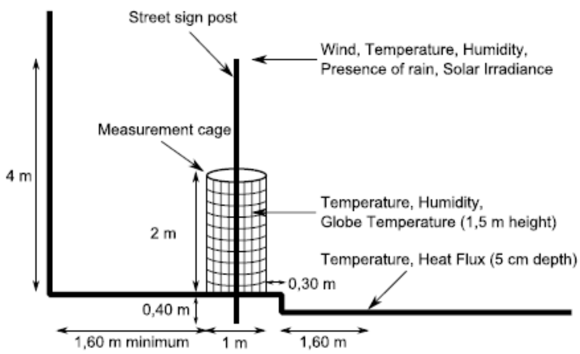

Figure 2 - Diagram of a weather station

Thermal comfort is estimated using the UTCI (Universal Thermal Climate Index) indicator, which takes into account these different parameters as well as assumptions made about clothing, metabolism, etc. in order to calculate an equivalent air temperature for the reference conditions.

These parameters are measured continuously and used in the event of a proven heatwave in Paris, i.e.

- On three days, the maximum temperature exceeds 25°C with a minimum temperature exceeding 16°C;
- Wind speed does not exceed 3 m/s on average;
- Cloud cover is less than 3 octas (good sunshine, clear sky).

In order to better characterise the thermal behaviour of innovative road surface, temperature (photo 4) and heat flow sensors were installed directly under the surface coatings.

Photo 4 - Installation of a heat flow sensor

The cooling of Parisian streets can also be achieved by watering the pavements, which can be carried out using its non-potable filtered water network (ENP). The city of Paris has already had initial feedback with the experimentation carried out on rue du Louvre since 2013.

3.4. The realisation of the experimental test sections

For the pilot sites, the structural condition of the road surface was checked upstream of the site and, if necessary, repairs were carried out to ensure acceptable support for the assessment of product durability and has been subject to a quality control plan that has not shown any significant non-conformity.

3.5. Monitoring of the experimental sections

The monitoring of the experimental sections is characterised by the use of an instrumentation and exploitation plan for the relevant indicators. The indicators will allow the evaluation of the innovative coatings in the three areas of study: noise, thermal and durability.
The evaluation is based on measurements at initial condition and then an annual follow-up for 5 years.
The main expected objectives correspond to a noise level reduction of -3 dB(A) at street level and -2 dB(A) at the residential facade as well as a decrease of -2°C in actual temperature and -3°C in perceived temperature.

3.6. Communication and dissemination

The project includes a programme for communication and dissemination of results. In addition, a stakeholder committee has been set up, bringing together representatives of European conurbations, associations and other entities interested in the project. This committee will meet regularly to be informed of the progress of the project. The project has a dedicated website: https://www.life-asphalt.eu/

4. THE FORMULATION OF BITUMINOUS PRODUCTS

4.1. Compacted asphalt mixes

For compacted asphalt, the reference was a Type A thin asphalt concrete (BBM A) mix of 0/10 discontinuous granularity with a polymer modified binder. This product is the reference in surface layer maintenance for the city of Paris, its application thickness is 4cm. Its average durability is estimated at 15 to 17 years in the city of Paris. The innovative products had to be usable instead of this product, with the same thickness, durability and low additional cost (+10% maximum). To meet these requirements and provide the desired phonic characteristics, two options were considered and pursued. The first was to start with a Stone Mastic Asphalt (SMA) 0/10 type surface coating, known for its high durability and improve its phonic properties by increasing the voids content and reducing the aggregates size. The second option was to start from a very thin asphalt concrete (BBTM) 0/6 formula known for its low rolling noise emission but characterised by poor resistance in urban environments, and improve its durability without penalising excessively its sonic properties. For these two approaches, the thermal aspect is achieved through the use of clear aggregates in the mixture and the preservation of a macrotexture to ensure sufficient surface water retention during spraying operations. For the innovative formulas, the lightness criteria used are L* ≥ 54. This minimum level of lightness has been used for many years in Paris to qualify whitish aggregates when required. The aggregates selected, which meet these criteria, come from the Montebourg quarry.

4.1.1 Design of the SMAphon

The formula derived from a SMA 0/10 asphalt mix has been named SMAphon (for SMA phonic). The SMA reference formula is a continuous formulation with a high mastic content contains Colflex N modified bitumen (BMP 25/55-50) and 0.3% cellulosic fibres. The formula is specified in Table 1.
The water sensitivity (EN 12697-12 method B) must be greater than 75 and rutting resistance (EN 12697-22 large size device) must be less than 10 % at 30,000 cycles. The tests performed give satisfactory performances.
In addition, in order to evaluate the resistance to superficial mechanical aggression, modified Cantabro wear and scuffing tests with the Darmstadt Scuffing Device (DSD) in severe mode were carried out. The Cantabro test modified by Colas consists of measuring the mass loss of a Duriez type specimen after conditioning at -10°C and passing through the Los Angeles drum for 500 revolutions. The DSD scuffing test is conducted according to the work of CRR [7] but under a 2000N force instead of 1000N and the number of cycles increased to 50 instead of 10. These more severe tests make it possible to take into account the aggressiveness of traffic in dense urban environments. The final formulation of the SMAphon containing the Montebourg chippings satisfies the initial characteristics of the reference SMA with a reduced granularity and an increased voids content. This was made possible by using a more efficient polymer modified bitumen BMP 25/55-65 instead of BMP 25/55-50 and by maintaining a high level of mastic and cellulose fibres. Table 1 presents all the characteristics measured for the innovative formula compared to the reference.
In addition, the capability of noise reduction by absorption has been evaluated withe the sound absorption impedance tube. On this formula the absorption is close to the reference.

BBM A reference		SMA 0/10 reference		SMAphon	
6/10 La Noubleau	62.0 %	6/10 La Noubleau	22%.	6/10 Montebourg	15.0 %.
0/2 La Noubleau	31.3 %.	4/6 La Noubleau	35 %.	4/6 Montebourg	17.3%.
Limestone filler	1.5%.	2/4 La Noubleau	10.7%.	2/4 Montebourg	36.7 %.
BMP 25/55-50	5.2 %	0/2 la Noubleau	18.3%.	0/2 la Noubleau	20.2%.
		Limestone filler	7%.	Limestone filler	3.7 %
		Viatop fibres	0.3 %	Viatop fibres	0.3 %
		BMP 25/55-65	6.7 %	BMP 25/55-65	6.8 %

Table 1

Wear resistance is maintained by the modified Cantabro test and DSD scuffing test (Table 2 and Figure 3).

	BBM A ref.	SMA	SMAphon
voids PCG V 40	10.4 %	10.8 %	15.3 %
Water sensitivity Duriez (I/C)	100	100	90
Rutting 30,000 cycles 60°C	4.6 %	7.3 %	3.9 %
Modified cantabro	30 %	17 %	16 %
Severe DSD scuffing test	126 g/m²	137 g/m²	282 g/m²
Maximum sound absorption (40 mm)	0.19	0.22	0.19

Table 2 - Characteristics measured on the reference mixes and the SMAphon

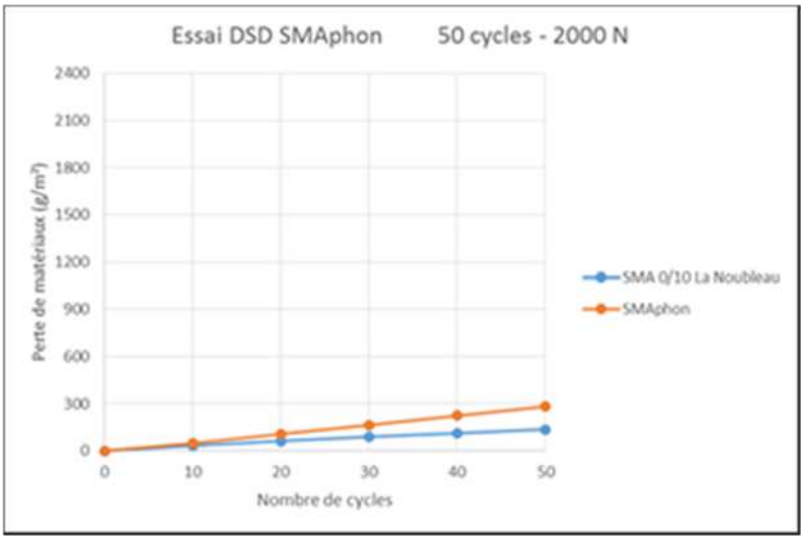

Figure 3 - DSD scuffing test on SMAphon

4.1.2 Formulation of the BBphon+

The formula derived from a BBTM 0/6 has been named BBphon+ for "more durable phonic asphalt concrete". The reference formula is commonly used in the Paris area as a noise reduction asphalt on highways, its discontinuous composition is given in Table 3.
The BBphon+ formula was established by increasing the sand content, adding a hydrated lime filler and by using the highly modified binder type BMP 25/55-65 instead of BMP 25/55-50. The voids content has been maintained at about 15%.
This formula adaptations have significantly improved the product's resistance to wear and scuffing tests as shown in Table 4 and Figure 4. The sound absorption is measured at a high level.
The other usual tests previously mentioned are satisfactory.

BBM A reference	BBTM 0/6 reference	BBphon+
6/10 La Noubleau 62.0% 0/2 La Noubleau 31.3% Limestone filler 1.5% BMP 25/55-50 5.2 %	4/6 La Noubleau 71.7% 0/2 La Noubleau 20.8% Limestone filler 2.1% BMP 25/55-65 5.4%	4/6 Montebourg 57.5% 0/2 la Noubleau 35.1% Hydrated Lime Filler 1.5% BMP 25/55-65 5.9%

Table 3

	BBM A ref	BBTM	BBphon+
voids PCG V 40	10.4%	21.6%	14.5%
Water sensitivity Duriez (I/C)	100	79	91
Rutting 30,000 cycles 60°C	4.6%	2.6%	2.4%
Modified cantabro	30 %	35%	16%
Severe DSD scuffing test	126 g/m²	2254 g/m²	205 g/m²
Maximum sound absorption (40 mm)	0.19	0.57	0.75

Table 4 - Characteristics measured on the reference mixes and the BBphon+

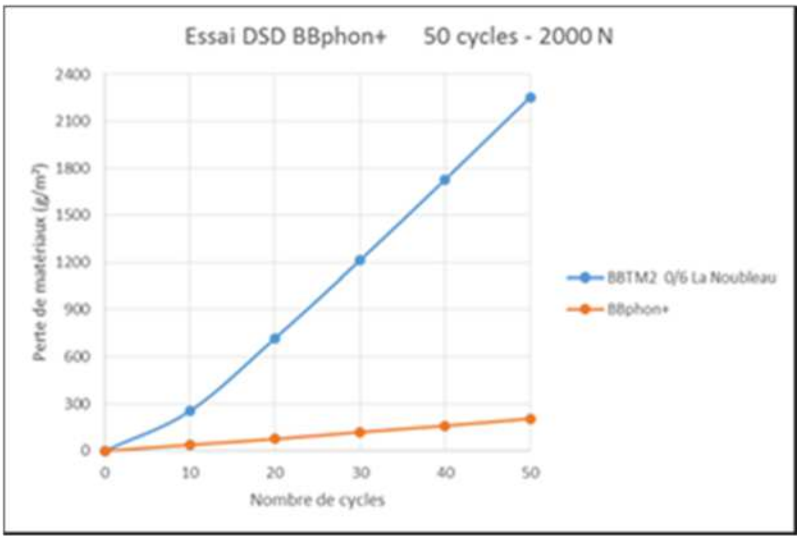

Figure 4 - DSD scuffing test on BBphon+

4.2. Mastic asphalt

Historically, the city of Paris has always frequently used mastic asphalt technology for both sidewalk and street surfaces. This choice is explained by the very good durability of this material (> 30 years). Mastic asphalt is an age-old technique that has evolved in recent years, mastic asphalt application temperature has been reduced to less than 200°C to comply with the European regulations. Logically mastic asphalt must today adapt to the new environmental constraints of the city.
Mastic asphalt must therefore meet the dual objectives of acoustic comfort and reducing the UHI effect.
EUROVIA has worked in the group's research centre in Mérignac and in its Technical Department in Saclay to develop the PUMA (Porous Urban Mastic Asphalt) product. This product has been developed according to two principles: Combine the albedo properties of a light-coloured aggregate with the porosity of lightweight aggregates. Light-coloured aggregates will limit the absorption of solar energy while porous aggregates enable water retention and reduce rolling noise by absorption. A surface treatment has to be carried out in order to remove the surface bituminous mastic and to highlight the light and porous aggregates.
About fifteen formulas have been tested using different type of clear and porous aggregates to get to the final recipe. The study checked the mechanical aspect in order to ensure the product's good performance. First, the rutting Hamburg Test method was the main test used. It allows the rutting under severe conditions (high temperature under immersion) to be highlighted. It was also necessary to ensure the durability of the product to the surface treatment. In a second step, the acoustic and thermal test were performed.
The thermal aspect was addressed according to the water retention of porous aggregates to promote the phenomenon of cooling evaporation during heat peaks. To characterise this parameter, a protocol has been developed internally. The clarity and albedo of the PUMA surface was checked after surface treatment.
For the acoustic aspect, Kundt tube absorption measurements were performed on different formulas. In addition, given the lack of experiments and of laboratory tests characterising the noise aspect, it was decided to assume that the vacuum from the lightweight aggregates is the only source of improvement in the noise aspect and therefore that the noise potential of the surface is characterised by the surface concentration of these aggregates. To support

this assumption, sound absorption measurements were performed on porous aggregates alone and in parallel to determine the concentration of lightweight aggregates on the surface of the asphalt by imaging.
The PUMA formula is shown in Figure 5.

Figure 5 - Aggregates composing the PUMA

The mechanical lab tests compliance with specifications of AC2 in NF EN 13108-2 has been achieved.
The thermal positive expected impact due to the porous and light-coloured aggregates has been shown:

- Water retention increases from 2% in reference formula to 12% in PUMA. This will allow to retain the aspersed water during heatwaves.
- The presence of clear aggregates has doubled the albedomeasured from 6.4 % to 12.8 %

The noise reduction will be checked in situ.

5. EXPERIMENTAL SITES

5.1. Compacted asphalt mixes

Each pilot site has two sections of approximately 200 metres long. One with the traditional reference surface and the other with the innovative Asphalt mix.
On rue de Frémicourt, the application of the SMAphon and the reference Rugoflex M 0/10 took place on 11 October 2018 (photo 5). For the rue de Courcelles, the application of BBphon+ and Rugoflex M 0/10 was carried out at night from 23 to 24 October 2018 (photo 6). All these products have been subject to quality control and manufacturing controls attesting to their conformity.

Photo 5 - Implementation of the SMAphon on rue Frémicourt)

Photo 6 - Implementation of the BBphon+ rue de Courcelles at night

5.2. Mastic asphalt

On rue Lecourbe, the 1320 m² PUMA experimental and the AC2 reference mastic asphalts were applied on 2018 September, 24 (photos 7 and 8). This project consisted in milling the existing asphalt, and applying a 0/6 rut-resistant layer with BmP under the PUMA. The innovative PUMA was applied and shot-blasted one month later to reveal the clear aggregates.

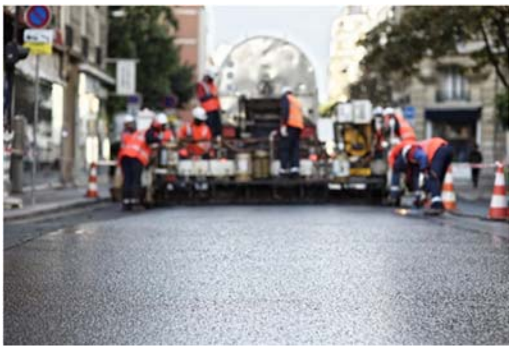

Photo 7 - PUMA mastic asphalt application

6. FIRST RESULTS

6.1. Noise reduction

Noise reduction using CPX measurement on new asphalts have been made in 2019, April and are summarized in table 5 and 6.

dB(A)	Project target	SMAphon rue Frémicourt	BBphon+ rue de Courcelles	PUMA rue Lecourbe
30 km/h	None	-3.6	-4.2	-2.8
50 km/h	-5	-4.4	-4.7	-2.1

Table 5 – noise reduction compared to previous pavement

dB(A)	Project target	SMAphon rue Frémicourt	BBphon+ rue de Courcelles	PUMA rue Lecourbe
30 km/h	None	-2.9	-2.3	-0.1
50 km/h	-3	-3.5	-3.3	-0.1

Table 6 – noise reduction compared to the reference BBMA 0/10 or AC2 pavement

Concerning the PUMA, the present results cannot be considered as significant owing to the problem of reference, and more particularly, the problem of chipping of the surface. The reference is less noisy than this type of mastic asphalt. Solution to deal with this point is going to be applied.

At the moment of redaction the measurements of noise in front of buildings are still being processed taking in account the traffic count and speed data to compare innovative and reference pavements. First partial results on the site “BBphon+ rue de Courcelles” shows a decrease of the traffic road noise of:

- 3 dB(A) compared to previous pavement,
- 1 dB(A) compared to reference pavement.

These decreases are observed during the night period when road traffic constitutes the prevailing noise source. More results will be available in the next months.

6.2. Thermal effect

First heat waves or peak occurred on last days of 2019, June and first days of July. The watering of the innovative pavements has been carried out and the effect on temperature is being processed.

7. CONCLUSION AND PROSPECTS

This project, led by the City of Paris as part of its environmental policy, aims to improve the living conditions of Parisians by reducing their exposure to noise and limiting the effects of heatwaves. The originality of the approach is to take into account not only a single parameter but to try to combine several effects while respecting the economic reality and expectations in terms of the sustainability of products and effects. It is therefore a question of reaching a compromise between constraints and objectives that may seem contradictory at first sight. The objectives may seem modest, but they represent a real step forward if they are met.

The skills of experts in road construction and noise measurement were mobilised around the City of Paris urban environment department and public space laboratory to carry out the first part of the project and ensure the follow-up of the experiment.

The solutions chosen were established in the spirit of the LIFE project, with solutions that can be replicated in other cities in France or Europe.

Subsequent publications will present more detailed results obtained during the 3 years of service. If these results are convincing, it is planned to continue monitoring the experiment for an additional 5 years.

ACKNOWLEDGEMENTS

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List the references with the respective numbers in square brackets and in the order in which they appear in the text, at the end of the manuscript. References must information as shown in the following example:

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Annex

1. INTRODUCION

The initial publication presenting the LIFE Cool and Low Noise Asphalt project presented the objectives of the project and the very first results of measurements at the pilot sites. This appendix presents the monitoring results in the areas of noise and microclimate at the three pilot sites two years after construction. The project is the subject of an annual meeting of a Scientific Committee (CoSci) and a Stakeholders Committee (CoSta), the last of which met on February 4, 2021.

2. NOISE REDUCTION

2.1. CPX rolling noise reduction

Following the measurements carried out in April 2019, presented in the initial publication, new CPX measurements were carried out in August and September 2020, the pavements being 22 to 23 months old.
Table 1 shows the new results compared to the previous ones for the three pilot sites.

Table 1. CPX measurements for the three pilot sites (dB(A))

Site (innovative pavement)	Noise reduction compared to:	April 2019 30 km/h	August - September 2020 30 km/h	April 2019 50 km/h	August - September 2020 50 km/h
Rue Frémicourt (SMAphon)	Previous pavement	-3.6	-1.8	-4.4	-2.3
	Control mix (BBM A)	-2.9	-1.8	-3.5	-2.2
Rue de Courcelles (BBphon+)	Previous pavement	-4.2	-1.8	-4.7	-2.4
	Control mix (BBM A)	-2.3	-0.6	-3.3	-1.5
Rue Lecourbe (PUMA)	Previous pavement	-2,8	-2.4	-2,1	-1.9
	Control mix (AC2)	-0,1	+0.3	-0,1	+0.3

For the streets of Courcelles and Frémicourt, we observe that the differences in the rolling noise level of the pavements with the control pavement and with the previous pavement are reduced, after nearly two years of service. However, the improvement compared to the previous pavement is still satisfactory (more than 2 dB(A) lower).
At 50 km/h for example, the reference surface evolves less than the innovative surface over this period. The noise level increases of +0.8 dB(A) for the rue Frémicourt and +0.4 dB(A) for the rue de Courcelles for the BBM, while the SMAphon increases by +2.1 dB(A) and the BBphon+ by +2.3 dB(A) between the two series of measurements separated by 17 months.
The asphalt mixes formulations objectives are finally well achieved since the 2 products have comparable performance today. Further analysis will be necessary with the next measurements to see if there will be differences in terms of durability.

Regarding Lecourbe Street, which is paved with mastic asphalt, we observe a different evolution. Due to application difficulties the reference pavement has evolved badly and has become almost perfectly smooth. The measurements should therefore not be taken into consideration. This reference section has been rebuilt later in 2020. On the other hand, the innovative section with PUMA has not changed much in terms of rolling noise emission. This seems to confirm that mastic asphalt has a slow evolution. The next follow-up tests will allow us to pursue these observations.

2.2 Noise measurements in facades by Bruitparif

The use of traffic data also made it possible to identify periods when traffic conditions are conducive to the generation of tyre/pavement contact noise that dominates the overall noise environment of the site. Thus, it appears that the night period is particularly relevant for analysis, due to the higher speed of vehicles and the absence of other noises.
The air temperature has an influence on the tyre/pavement contact noise. Thus, for identical traffic conditions, the noise levels are higher when the temperature decreases. A corrective measure, based on current standards for measuring rolling noise, was therefore applied to evaluate the results compared to the initial state (previous pavement).

The table present the average results of measurements carried out during the end of 2018 year and all the year 2019.

Table 2 – Comparison of noise levels in facades, innovative pavements vs previous and control pavement

Estimation of rolling noise reduction in dB(A) Δ LA10 22h-6h	Noise reduction compared to previous pavement		Noise reduction compared to control pavement	
	After installation (2018)	After one year (2019)	After installation (2018)	After one year (2019)
Project Objectives	**-3**	**≤ -2**	**-2**	**≤ -1**
rue Frémicourt (SMAphon)	-4,3*	-3.9*	-2,3	-1.8
rue de Courcelles (BBphon+)	-3,5*	-2.7*	-2,8	-2.6
rue Lecourbe (PUMA)	-1,2*	-1.1*	0	--

*with temperature correction, the reference period on previous pavement being during summer.

All of the objectives for reducing pneumatic/pavement contact noise in residential facades are achieved for the SMAphon and BBphon+. For PUMA, the lack of reduction compared to the reference pavement is due to a reference which is not representative of reality and which is favorable in terms of acoustic measurements. An assessment of acoustic performance will be produced with the new control pavement laid in August 2020.

3. Microclimatic measurements

The reduction of temperature was obtained by watering the pavements during heatwaves by spraying water from 7 a.m. to 6.30 p.m every 1h30 in the morning and every 30 to 45 minutes in the afternoon.
The measurement of temperature and calculated Universal Thermal Climate Index (UTCI) have been registered and processed for the heatwaves during 2019 and 2020 summers. The reference days without watering are compared to reference days with watering. Main results are shown in table 1 for the three sites and both innovative and control pavements. The mean values are calculated on 24 hours per day. Some values are missing due to sensors problems or lack of watered control section (rue Frémicourt).

Table 3 – Microclimatic effect of watering on three pilot sections

			Air Temperature 1.5 m / °C (maximum)	Air Temperature 1.5 m / °C (mean value)	UTCI °C (maximum)	UTCI °C (mean value)
Rue Frémicourt	SMAphon	2019	-1.1	-0.4	-3.0	-0.8
		2020	-1.6	-0.7	-3.6	-1.0
	Control (BBM A)	2019	--	--	--	--
		2020	--	--	--	--
Rue de Courcelles	BBphon+	2019	-1.1	-0.4	-2.9	-0.6
		2020	-1.2	-0.6	-3.3	-0.9
	Control (BBM A)	2019	-1.2	-0.4	-3.6	-0.6
		2020	-1.5	-0.8	-	-
Rue Lecourbe	PUMA	2019	-0.8	-0.4	-1.9	-0.4
		2020	-1.6	-0.6	--	--
	Control (AC2)	2019	-1.0	-0.4	-2.0	-0.5
		2020	-1.1	-0.4	-3.7	-0.4

The watering during heatwaves days is efficient on all types of pavements in terms of temperature and UTCI. The decrease of temperature and UTCI is higher in 2020 than 2019. The next years monitoring will give more information on the trend of this effect.

Conclusion:

The project shows that it is possible to reduce both traffic noise and temperature peaks using specific innovative asphalt pavements and watering. The monitoring of pilot sections will continue and provide long term information in the next years.