Three Approaches to Study the Reduction of Pavement Noise Performances over Time

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Summary
Low noise pavements are part of the techniques available for road traffic noise reduction. However, the unpredictable reduction of their acoustic performances over time is an obstacle to a wider development. Studying the ageing effect of pavement on noise reduction is difficult because of many parameters involved in the ageing process, linked to the mix design, to the traffic and the weather conditions. Furthermore, variations of noise levels over time can be small compared to the measurement accuracy. The paper presents a set of studies performed in France to better understand the reduction in noise performances of road surfaces, according to three different approaches. One is purely statistical and consists in analysing from the large national database of pavement noise performances, the average trend of noise level increase with age, for different types of pavements. The second one consists in measuring at a specific time, the noise performances on different sections of different ages of a same type of pavement. Both approaches lead to an observation and quantification of noise level increase, however, they generally do not help in understanding the phenomena involved, because detailed information is often missing in large databases or for existing pavements. In the third approach, a specific monitoring program is implemented regularly on a set of identified sections, starting when the section is newly laid and finishing some years later when the section is removed. Noise levels and texture profiles are measured every year. The paper presents some results of all the three approaches, concentrating on the most common type of low noise surface in France (i.e. semi porous thin layer called VTAC0/6). A synthesis of the results is finally made and respective advantages of the methodologies are discussed.

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1. Introduction

Low noise road surfaces are part of the techniques available for road traffic noise reduction. Newly laid low noise surfaces can reduce tyre-road noise by up to 10 dB, and thus reduce significantly noise levels at façade of nearby buildings. Low noise road surfaces can thus be of particular interest in the frame of noise action plans in cities or along main roads, as required by the European Noise Directive 2002/49/EC. However, many road authorities are reluctant to using low noise road surfaces as noise abatement tools because their acoustic properties decrease overtime, in an unpredictable way. Consequently, the decrease of acoustic performances of road surfaces over time is an obstacle to their wider development. Studying the ageing effect of pavement on noise reduction is difficult because many parameters are involved in the ageing process, linked to the mix design, to the traffic and to the weather conditions. Furthermore, variations of noise levels over time can be small compared to the measurement accuracy. The paper presents a set of studies performed in France to better understand the reduction in noise performances of road surfaces, according to three different approaches. One is purely statistical and consists in analysing the average trend of noise level increase with age, for different types of pavements from the large national database of pavement noise performances. The second one called the "patchwork" method consists in measuring at a specific time, the noise performances of a same type of pavement on different sections of different ages. Both approaches lead to an observation and quantification of noise level increase, however, they generally do not help in understanding the phenomena involved, because detailed information is often missing in large databases or for existing pavements. In the third approach, a specific monitoring program is performed regularly on a set of identified sections, starting when the section is newly laid and finishing some years later when the section is removed. Noise levels and texture spectra are measured every year. The paper presents some results of the three approaches, focusing on the most common type of low noise surface in France, i.e. Very Thin Asphalt Concrete 0/6 of class 2 (VTAC 0/6 or BBTM 0/6 originally in French) as defined in EN 13108-2 [1].This material is a very thin layer (between 20 and 30 mm thick) of semi-porous asphalt concrete with 20% to 25% void content and with aggregates of 6 mm maximum chipping size. A synthesis of the results is finally made and the respective advantages of the methodologies are discussed.

2. The statistical analysis of a large database

2.1. Methodology

Tyre/road noise measurements in France – mainly with SPB measurements according to ISO 11819-1[2] - are regularly collected in a large national database managed by the LRPC Strasbourg (now Cerema) since 1995. In this database, the road surfaces are distinguished by their generic type and maximum chipping size. The database contains standardized pass-by noise levels for light vehicles and most often for heavy vehicles, and when available, other information on the location, the surface material and age, the type of road, the traffic, the speed limit, etc. The output of the database is accessible on line [3] and a detailed analysis has been published in [4] in 2011. A focus on VTAC 0/6 class 2 is presented here.
Data corresponding to sections covered with VTAC 0/6 of class 2 can be selected and classified according to their age. The results are presented in figure 1, where all light vehicle pass-by noise levels at 90 km/h reference speed contained in the database are represented as a function of age class: less than 1 year, between 1 and 3 years, between 3 and 5 years and over 5 years. Each dash represents a test section, and for each age class, results for sections with high traffic (3 lanes, dual carriageways) appear on the left and sections with low traffic appear on the right.

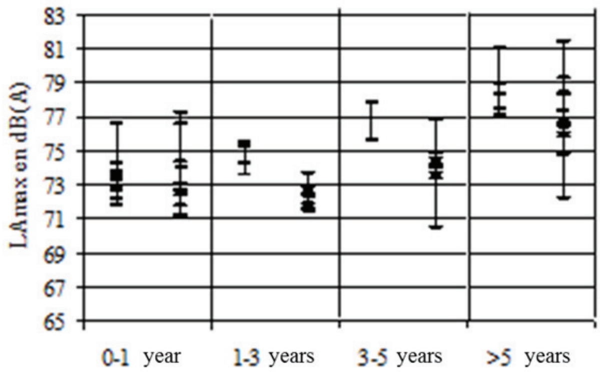

Figure 1. Maximum pass-by noise levels for light vehicles à 90 km/h on VTAC 0/6 sections of different age. High traffic roads (left) and low traffic roads (right) [4]

There is a large disparity in the results, especially on low traffic roads. From the results in figure 1, it is difficult to derive a general law for tyre/road noise level increase with time or with traffic. It seems that noise levels increase is lower on low traffic roads that on high traffic roads, however due to the limited amount of data, this would need to be confirmed.
Therefore, the methodology was adapted. Within this database, several road sections have been measured at the same location at different ages. The analysis concentrated on these sections exclusively and consisted in identifying the longest period on which at least five sections (arbitrary number) have been monitored. This period is defined by considering the available data every 6 month steps. To avoid bias in averaging, the final set of selected sections contains all those for which measurements are available on the whole period. Finally, the average noise level and standard deviation are calculated for each 6 month steps.

2.2. Results for low noise thin layer (VTAC 0/6 class 2)

The results for VTAC 0/6 class 2 are presented in figure 2. They correspond to the analysis of five selected sections on the period [2 years - 9 years], but only 4 sections on the periods [6 months – 2 years] and [9 years – 10 years]. Average pass-by noise level for light vehicles at 90 km/h reference speed are represented as a function of time, by 6 month steps, from 6 month to 10 year old. The dark diamonds represent the average and the pink triangles the average±standard deviation.

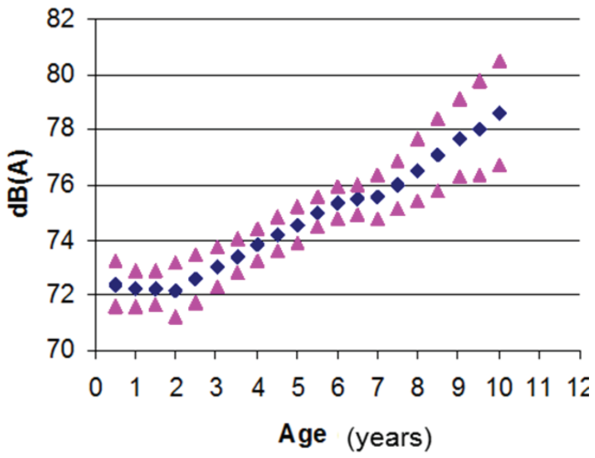

Figure 2. Average pass-by noise level increase with age on VTAC 0/6 class 2.♦ Average ▲ Average±standard deviation [4]

The average trend shows a stability of noise levels until 2 years, and then an overall increase of 0.8 dB(A) per year between 2 years and 10 years. However, when looking at individual results, it appears that individual results are neither linear over time nor identical from one section to another.

3. The "patchwork" ring road

3.1. Methodology

The Nantes ring road (France) is a forty kilometre long motorway supporting a high volume of traffic between 60 000 and 95 000 vehicles per day on average, with approximately 12% of heavy trucks. For several years, the different road authorities in charge of the maintenance have promoted a common policy for noise limitation, including an integrated program for pavement re-surfacing with the same type of low noise pavement, a VTAC 0/6 of class 2. A five year program was established for the re-surfacing of sections based on the observed degradations, on the proximity of sensitive build-up areas and the budget availability. Consequently, the ring road is now a patchwork of pavement sections of the same type but of different ages. Thus, the measurement of CPX noise levels around the ring road could give all at once an interesting comparison of the acoustic performances of this thin layer technique over time, from new until approximately 9 year old, for similar weather and traffic conditions.

A more detailed description can be found in [5].

3.2. Results for low noise thin layer (VTAC 0/6 class 2)

The average CPX noise levels measured according to [6] at 80 km/h on a 100 m segment are presented in figure 3 as a function of the age of the road section. The youngest sections correspond to the low noise VTAC 0/6 class 2, whereas the oldest sections correspond to the ancient DAC 0/10. The youngest sections (3 year old) offer a 5 dB(A) noise reduction compared to the ancient dense asphalt. However, this noise performance deteriorates over time and noise levels increase steadily, not exactly in a linear way but rather in a logarithmic way. Nine year old sections are 4.5 dB(A) noisier than 3 year old sections which makes them nearly as noisy as old sections with DAC 0/10.

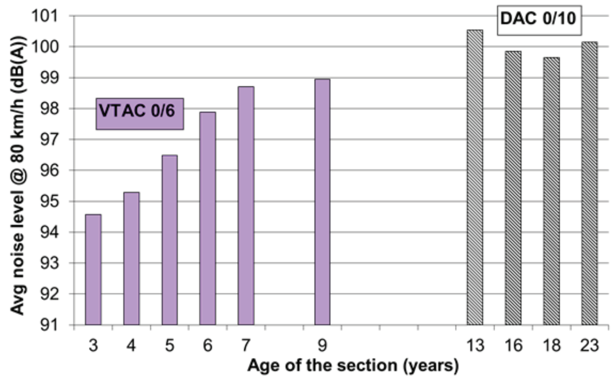

Figure 3. Average overall A-weighted CPX noise levels measured at 80 km/h on 100 m long segments according to the age of the section [5]

When only the pavements between 3 and 7 years are considered, a rather linear increase can be observed, with an increase in noise level of 1.1 dB(A) per year. But because of the relatively low noise observed for 9 year old sections, the overall increase of noise level between 3 years and 9 years is 0.7 dB(A) per year. However, in this case, the increase in noise levels is closer to a logarithmic trend than a linear one. A logarithmic regression on the results gives a better correlation coefficient $R^2 = 0.82$ than with a linear one ($R^2 = 0.75$). The study concluded with the following equation:

$$L_{CPX} = 10.5\, log_{10}(\mathrm{N}_{year}) + 89.6 \qquad (1)$$

where L_{CPX} is the CPX noise level measured at 80 km/h on a 100 m long road section and N_{year} is the age in years of the pavement.

4. The monitoring approach

4.1. Methodology

4.1.1. Sites

The third approach consists in monitoring over time a set of selected road sections, starting with new or newly repaved sections. A set of eight road sections were first selected and the first measurements were performed in 2006. Eight other new sections were added to the monitoring program in 2007, 2008 and 2010. However, amongst these sixteen sections, three sections have been prematurely resurfaced after three years of service for unknown reasons and one urban section was totally re-configured in such a way that comparative measurements could not be performed anymore. Finally, twelve sections were kept in the test program, out of which two are on motorways, seven on highways and three are urban roads.

4.1.2. Road surfaces

Most surfaces considered are low noise, mainly very thin layers (VTAC) with maximum aggregates sizes of 10 mm, 8 mm, 6 mm or even 4 mm. Two sections covered with dense asphalt were also included in the test program to serve as a reference on which noise level increase is expected to be limited. In the set of twelve, four sections were paved with VTAC 0/6 class 2, the traditional low noise surface used in France. Their main characteristics are presented in Table I.

Table I. Characteristics of the VTAC 0/6 class 2 sections selected in the test program.

Section	*TMJA*	*%HV*	*HV/d*	*Year*	*V*
S1	36700	15	2293	2007	130
S2	40300	16	3200	2010	110
S3	31000	13	1950	2007	90
S4	5900	--	Low	2008	50

TMJA: average (over the year) daily traffic
%HV: percentage of heavy vehicles (HV)
HV/d: number of HV in one direction per day
Year : year of laying
V: maximum allowed speed of the road section in km/h

4.1.3. Measurements

The monitoring procedure included rolling noise measurements and texture measurements. Initially, it was intended to measure sound absorption of the porous surfaces. However, the measurement method (described in ISO 13472-1) is static and requires the road to be closed to traffic, which turned out to be impossible on most sites. Therefore, sound absorption measurements were finally not performed. Rolling noise was measured by two different teams according to the geographical location of the site. They both performed measurements with SPB method according to [1], and with CPX method according to [6], using a specific test vehicle. The results were analysed at the reference speed of 90 km/h for the sections on motorways and highways, and 50 km/h for the urban roads. One of the CPX test vehicle and test tyre had to be changed after three years and the measurements with the new device gave poor comparability with former results. Therefore it was preferred not to continue CPX measurements after 2010. Finally dynamic texture measurements were made according to ISO 13473 series, using a laser profilometer mounted on a test vehicle (Rugolaser). The same device was used on all the sites. Several texture indicators were studied, the traditional MDP (Mean Texture Depth) as defined in 13473-1 [7] and spectral indicators of megatexture (spectral values between 0.0449 m and 0.707 m) such as L_{me}, L_{63} and L_{500} as defined in ISO 13473-5 [8].
All the measurements were first performed when the road surfaces were new (less than 6 months), then if possible every 6 months during the first two years, and then once every year. Measurement series were performed preferably at the same period of the year (in autumn) in order to minimize seasonal effects on the measurements.

4.2. Results for low noise thin layer (VTAC 0/6 class 2)

As in the previous approaches, we will focus here on the results of the four sections covered with VTAC 0/6 class 2.
The results of SPB noise measurements as a function of years are presented in figure 4. The lowest curve corresponds to noise measurements at the reference speed of 50 km/h whereas the upper four curves correspond to measurements at the reference speed of 90 km/h. The black dashed line shows the results for the reference section in dense asphalt concrete 0/10.

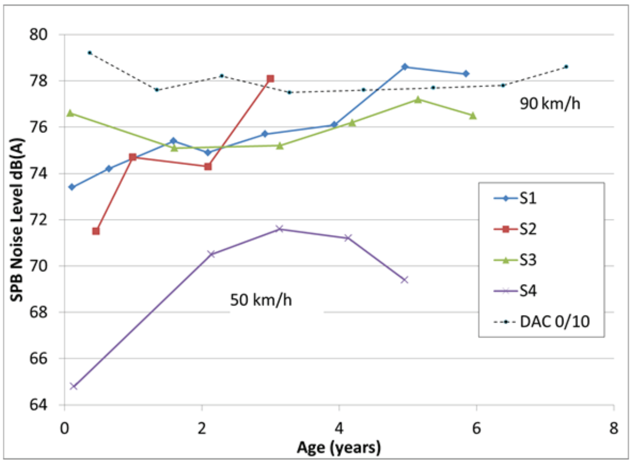

Figure 4. Measured evolution of pass-by noise levels of light vehicles with age

Again, it clearly appears that individual results are very different and unsteady.

First, the reference in dense asphalt shows an expected stability over time. Noise levels decrease by 1.6 dB(A) over the first year, probably due to a smoothing of the surface, and then stabilize over the next 5 years. The observed average noise level increase on DAC 0/10 is -0.05 dB(A) per year over the 6 year period.

Noise levels in section S1 increase regularly from the initial state until 6 years old, at an average rate of 0.9 dB(A) per year. In section S2, noise levels increase drastically between 6 months and 1 year, then stabilize until 2 years and increase rapidly again between 2 and 3 years, reaching a level 6.6 dB(A) higher than when 6 month old. Both S1 and S2 are high speed roads and the traffic and heavy vehicle proportion on S2 is slightly higher than on S1. On the contrary, noise levels on S3 do not evolve significantly until six years and even decrease after 1 month by 1.5 dB(A), stabilize between 2 and 3 years and then increase moderately. The difference between noise levels measured when the surface is 1 month old and when 6 years old is null. Traffic cannot explain the really different behaviour of section S3. This section is still considered as a road with an important traffic although it is a little less intense than on S1 and S2. Finally, section S4 shows another unexpected behaviour, with a drastic increase of noise levels from 1 months until 3 years (+6.6 dB(A)) and then a decrease (-2.2 dB(A) between 3 and 5 years). From initial state (1 month old surface) and 5 years, noise level has increased by 4.6 dB(A). However, a rate of 0.9 dB(A) per year cannot really be announced as the behaviour is far from linear. Section S4 is a urban road with low traffic. The strange behaviour seems to be totally uncorrelated with the traffic.

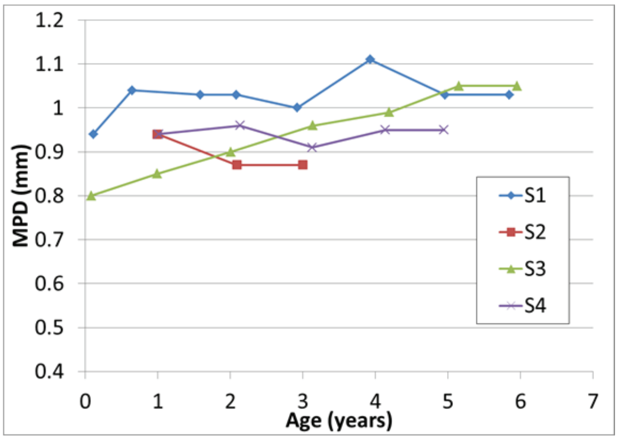

Figure 5. Evolution of Mean Profile Depth (MPD) over time for the four sections in VTAC 0/6 class 2

The variation of texture over time is presented in figure 5 for the same four sections in which the Mean Profile Depth (MPD) is displayed as a function of the age of the section. In general, this texture indicator shows little variation. The most varying MPD over time is the one of section S3 with a linear increase of about 0.04 mm per year from 1 month to 6 years. S3 is the less varying surface in terms of noise. There is obviously no correlation between MPD and noise levels.

Other texture indicators are investigated. The evolution of Lme indicator is presented in figure 6. This indicator expressed in decibels with reference 10^{-6} m integrates the texture spectral bands between 63 mm and 500 mm and thus takes into account the surface deformations in the domain of megatexture. This indicator is relatively steady for sections S1 and S2. It shows a slight increase for S3 and a significant increase for S4 between 3 and 4 years. Surprisingly, this step corresponds to the period when the noise level started to decrease, although the inverse correlation would be expected.

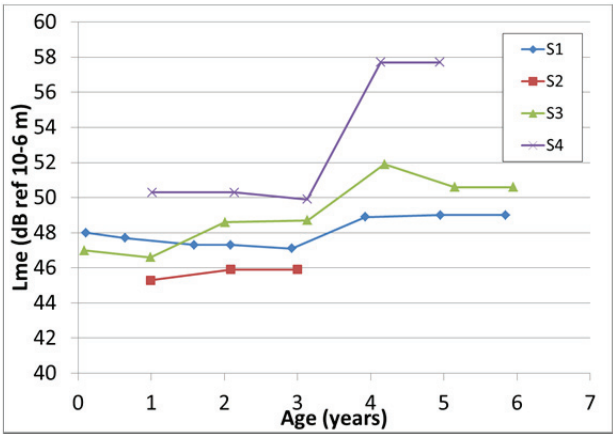

Figure 6. Evolution of Lme texture indicator over time for the four sections in VTAC 0/6 class

Further analysis of the correlation between noise level and texture spectra are in progress, in particular by use of tyre-road noise prediction models.

5. Conclusion

Three different approaches were used to evaluate and understand the ageing effect of low noise surfaces. The paper focused on the specific results for the most common type of low noise road surface in France: the semi-porous Very Thin Asphalt Concrete of class 2.

All the approaches demonstrated a significant increase of tyre-road noise levels over time. They also showed that individual behaviours regarding age are varied and usually non linear. On some sections, noise levels increase regularly every years. On other sections, noise levels are stable during the first years and then increase more or less the following years. On other sections, noise levels increase drastically at the early stage and then stabilize. In some sections, noise levels can also decrease at some periods.

The first approach was based on the statistical analysis of a large set of tyre-road noise data which were not specifically measured with this goal in view. The analysis results in a fairly linear average relationship of pass-by noise level increase according to age, at an average rate of 0.8 dB(A) per year between 2 years and 10 years.

The second approach was based on the instant observation of tyre-road noise levels on different sections of the same type of surface but of different ages. A similar trend was observed with an overall increase of CPX noise level of 0.7 dB(A) per year between 3 years and 9 years.

The third approach was based on a thorough and regular monitoring of a selected set of surfaces, starting from new and measuring every year tyre-road noise and texture characteristics. This approach proved to be very heavy and complex. Therefore, until now, no average simple law can be derived with such a methodology. In several cases, the road surface was prematurely changed or the road layout was modified. The stability of measuring devices and methods is also an issue fur such long term experiments. However, monitoring is the only approach that, in principle, permits to go beyond a simple observation and better understand the physical phenomena. The traffic flow, the number of heavy vehicles, the speed of the traffic do not seem to have a direct correlation with noise increase. The modification of the texture could be an intermediate parameter in the ageing process. However, traditional texture descriptors are not enough correlated to tyre-road noise to be usefull indicators. The use of tyre-road noise prediction models is expected to provide better understanding but studies are still in progress. Finally, sound absorption of low noise surfaces should also be monitored as most of the products are semi-porous. However, the measuring method is stationnary and unpractical on roads with high traffic as it requires to close the road during the measurements (safety and mobility is the priority of road owners).

References

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