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NOISE REDUCTION INDUCED BY USE OF VERY THIN WEARING COURSES AND CRUMB RUBBER PARTICLES

M. Ballié, J. Gal

Colas France, 2, rue J. Mermoz BP 31, 78771, Magny Les Hameaux, France

Tel.: 01 34 52 13 13 / Fax: 01 30 57 96 29

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ABSTRACT

For some years now, road innovations are mainly devoted to the comfort and safety for road users. The surface properties of wearing courses linked to these two parameters are of paramount importance for road companies and road authorities. Today it is a clearly established fact that the tire/pavement contact noise is the main source from which savings can be made. The use of silent pavement allows for major reductions of the tire/pavement contact noise. Wearing courses that include crumb rubber particles are able to ensure drastic reductions in traffic noise when compared to results of conventional hot mixes. In this paper we present a survey of noise reduction studies using various measurement methods. Many sites: urban, periurban, main roads, highways in France or abroad were investigated. The methods are presented first. The noise reduction are then pointed out.

1 - INTRODUCTION

Surveys on residents in Western Europe have shown that 75% of them are inconvenienced by noise, particularly road traffic generated noise.

Urban planning decision-makers have made the control of this major nuisance one of their overriding concerns.

The implementing orders of the December 1992 Noise Act require Project Owners in France to take noise nuisance into account when building or improving road infrastructure.

The progress achieved by vehicle manufacturers has enabled mechanical noise to be considerably reduced. It is now an established fact that the reduction of tyre-pavement contact noise is the main source of acoustic and economic benefits in terms of traffic-related noise emissions.

This means that the measures to be taken primarily concern road surfaces and, to a lesser extent, tyres.

This paper presents an asphalt overlay of original design, which achieves a particularly significant reduction in traffic-related noise while meeting user safety requirements though high skid resistance.

2 - PRESENTATION

The overlay presented here is a Very Thin Asphalt Concrete, 0/6 or 0/10 mm, laid over a 25 to 35 mm thickness, which greatly reduces rolling noise, particularly on urban and peri-urban roads.

The selected gap grading makes it possible to add small rubber granules from recycled tyres, rigorously selected according to a specific Quality Assurance Plan implemented by the company.

Owing to its mix design and special texture, this road surface thus reduces the influence of rolling noise generating factors, which include vibration and resonance. It is just as efficient in this respect as the best porous asphalts but without their drawbacks. This is because the mix itself is not porous and does not clog and does not therefore lose its noise efficiency.

Its binder modified with SBS rubber provides cohesion and durability of its mechanical, noise and surface characteristics.

The overlay is manufactured in conventional mixing plants and applied by ordinary laying equipment. In-house instructions establish the manufacturing and installation rules.

This overlay is a patented, low-noise product which has been used on several worksites since 1994 within the framework of the Road Innovation Charter with the French Directorate of Roads.

Owing to its ability to greatly reduce rolling noise in comparison with traditional overlays, in 1998, it was awarded a Certificate by the Service d'Etudes Techniques des Routes et Autoroutes (Roads and Motorways Engineering Department), for worksites under the Innovation Charter.

3 - A BRIEF REVIEW OF NOISE AND HOW IT IS MEASURED

3.1 - General

To better understand the benefits of this overlay in terms of noise reduction, a few acoustical concepts need to be recalled.

Noise is due to a rapid change in time-related atmospheric pressure. It is characterised by its frequency, by its timbre, i.e. its spectral composition related to the superposition of a large number of pure tones, by its duration and by its sound pressure level.

To take into account the high sensitivity of the human ear - which ranges from the threshold of audibility (2×10^{-5} Pa) through urban background noise ($\approx$ 0,1 Pa) up to the threshold of pain (20 Pa) - and to better represent our auditory sensations, the sound pressure level expressed in dB, and represented as L_p, is used. This sound pressure level indicates the amplitude logarithmically

$$L_p = 10 \times \log \left(\frac{P^2}{P_0^2} \right)$$

where P_0 is the sound pressure corresponding to the threshold of audibility: 2×10^{-5} Pa.

The threshold of audition is thus: L_p: 0 dB, and the threshold of pain is: L_p: 120 dB.

The auditory sensation depends not only on the noise level but also on the frequency components of the acoustic signal. This is because the ear is much more sensitive in the frequency range between 1,000 and 4,000 Hz than in the low frequency (bass) and high frequency (treble) range. To take this auditory characteristic into account, the noise spectrum in dB is weighted by attenuating low- and high-frequency sounds, thereby giving the pressure level expressed in dB(A).

As a result, the noise level addition law follows a logarithmic law. A 3 dB(A) noise reduction thus amounts to dividing the noise level in half and 10 dB(A) reduction amounts to dividing it by 10.

3.2 - Methods of measuring road noise

L_{Aeq} level (NF S 31-085)

The concept of nuisance related to environmental noise conditions is complex.

The noises generated by vehicle flow fluctuate. It is therefore necessary to be able to characterise them by a fairly simple method in order to establish the discomfort level associated with them.

To do this, the equivalent energy level concept represented as $LAeq$ is used. This value corresponds to the continuous sound signal which, on the selected timebase, gives the same energy as the measured fluctuating signal. It expresses the mean value of the received energy over the relevant period.

Two nuisance indicators have been adopted for French regulations on noise:

- L_{Aeq} 6h - 22h for the diurnal period.
- L_{Aeq} 22h - 6h for the nocturnal period.

The L_{Aeq} method consists in evaluating the mean noise level of the site at a fixed point. L_{Aeq} is the noise perceived by local residents. In terms of the surface-generated noise reduction, this level must be interpreted with an exact knowledge of the other sources of noise on the site under consideration, including that of the traffic carried by the road.

To better characterise the acoustic benefit from the road surface, other methods are used. They must be sufficiently reliable and reproducible.

Methods of measuring on lane edge (NF S 31-119)

The French standard S 31-119 enables the part played by the overlay in road noise to be evaluated in its environment.

For this purpose, the maximum noise level is measured in well-determined conditions by the passby method.

The reference level $L_{A\ ref}$ of the road surface is calculated at a theoretical speed of 90 kph and at a temperature of 20°C.

Compliance with the implementing conditions of this standards means that it can only be used on a comparative basis in urban areas. However, it is appropriate for use in rural or peri-urban areas.

Near field method

This method enables the consistency of acoustic performance levels of a surface to be tested and compared with other types of wearing courses in the same conditions. It thus enables the effect of a surface to be evaluated, by comparing measurements before and after the overlay is applied.

It has the advantage that it can be used in urban areas irrespective of surrounding noises other than the rolling noise.

It also enables a spectrum analysis of the noise emitted by the road surface to be made at a speed of 50 kph, which is the reference speed of traffic in urban areas.

Whichever method is used to measure the noise level, the proposed overlay records a considerable reduction in rolling noise. This reduction at least amounts to dividing the sound level emitted by the rolling noise by a factor of three, which is equivalent to that of a road traffic level reduced by two thirds.

And the reduction is usually greater, around 6 dB(A), amounting to a noise level divided by four.

4 - EXAMPLES OF NOISE MEASUREMENT RESULTS

4.1 - Examples of the reference noise level $L_{A\ ref}$ by the passby measurement method (NF S 31-119)

Controlled Vehicle Procedure (VM) at 90 kph and at a temperature of 20°C (zero point):

Location	***Road & Traffic***	***Grading (mm)***	$L_{A\ ref}$ ***VM***
Cours Langlet Reims (*)	Urban	0/6	69.7 dB (A)
R.N.[1] 415 (68)	Heavy traffic T0	0/6	70.8 dB (A)
R.N. 138	Heavy traffic T0	0/6	70.2 dB (A)
R.N. 83 Benfeld (67)	Very heavy traffic TS	0/6	72.6 dB (A)
R.N. 138	Heavy traffic T0	0/10	73 dB (A)
R.D.[2] 183 Lille	Urban	0/10	74 dB (A)

Table 1: (*) measured at 80 kph and extrapolated at 90 kph, [1] R.N.: National road, [2] R.D.: Département level (secondary) road.

It is common knowledge that the 0/6 mm grading gives lower $L_{A\ ref}$ VM levels than the 0/10 mm grading. The variations observed in the measurements reflect the variability and influence of site configurations: urbanised or rural.

Isolated Vehicle Procedure, Light Vehicle Procedure (VI / VL):

The $L_{A\ ref}$ VI/VL passby noise reference levels deduced from this procedure are not very different from those given by the controlled vehicle procedure related to the same speed. Table II gives examples measured on 0/6 mm gradings.

Location	***Grading (mm)***	$L_{A\ ref}$ ***VI/VL***	$L_{A\ ref}$ ***VM***
Cours Langlet	0/6	67.8 dB (A)	69.7 dB (A)
R.N. 415	0/6	71.2 dB (A)	70.8 dB (A)
R.N. 83	0/6	72.9 dB (A)	72.6 dB (A)

Table 2.

Note also the effect of the site on the mean observed value for the same mix design.

The result in Table III is taken from the "Rolling Noise" Database of the Laboratoire Régional des Ponts et Chaussées in Strasbourg, for the same procedure, but expressed as L_{rev} instead of L_{ref}, which amounts to relating the reference levels to the reference temperature T_{ref}: 20°C according to the relationship: L_{rev}: $L_{ref} + 0.1\ (T-T_{ref})$.

L_{rev} dB (A) VI/VL	***Min***	***Max***	***Mean***
Low-noise overlay	68	73	71
0/10 mm porous asphalt	69	77	73.5
0/6 mm ultra-thin asphalt concrete	72	76	73.5
0/6 mm very thin asphalt concrete	71	78	74.5
0/10 mm semi-coarse asphalt concrete	75	80	78

Table 3.

The $L_{A\ ref}$ VM passby noise levels show that the proposed low-noise overlay is among the best noise-reducing overlays in existence (database of the Laboratoire Régional des Ponts et Chaussées – Regional Road Research Laboratory –in Strasbourg).

Benefit compared to the old overlays:

Noise level measurements on the old overlay and after laying the low-noise overlay were made on several worksites. The examples in Table IV show the reduction achieved.

Procedure and Speed	***Location***	***Grading (mm)***	***$L_{A\ ref}$ Before***	***$L_{A\ ref}$ After***	***Reduction***
VM at 90 kph	Allée Baco	0/10	80 dB (A) 0/10 mm semi-coarse asphalt	75 dB (A)	5 dB (A)
	R.N. 83	0/6	80 dB (A) 0/14 mm very thin asphalt	72.6 dB (A)	7.4 dB (A)
VM at 50 kph	Saint-Vrain	0/10	73.2 dB (A) 0/10 mm semi-coarse asphalt	69.2 dB (A)	4 dB (A)

Table 4.

At 90 kph, the benefit from the low-noise mix depends on the selected grading and the configuration of the measurement site.

At 50 kph, which is the reference speed on urban roads, the benefit is still substantial, the level of $L_{A\ ref}$ VM naturally depending on the measurement speed.

For this type of measurement, it is essential to make a site-by-site comparison.

4.2 - Example of noise level $L_{A\ eq}$ (NF S 31-085)

Table V gives an example of noise measurements made in urban areas by the standardised method "Determination of the mean equivalent noise level $L_{A\ eq}$".

They were made in Avenue Daumesnil in Paris. The reduction in noise level achieved by the low-noise surface is particularly significant. A reduction of approximately 5 dB (A) is obtained.

Time segment	***Old surface, semi-coarse asphalt 0/10***	***After applying 0/10 mm low-noise surface***	***Reduction***
6 to 22 hours (diurnal)	71.7 dB (A)	67.1 dB (A)	4.6 dB (A)
22 to 6 hours (nocturnal)	66.1 dB (A)	60.3 dB (A)	5.8 dB (A)

Table 5.

The less active nocturnal period makes it easier to assess the effect of the road surface on the lowering of the rolling noise level. But to interpret this measurement, sudden changes in noise levels during this period must also be taken into account, as they may distort the analysis of the effect of the surface alone, by significantly increasing the resulting $L_{A\ eq}$ level.

4.3 - Example of the noise level measured by the "near field" method: analysis of the rolling noise spectrum

The graph in Figure 1 gives an example of the rolling noise spectrum at the 50 kph reference speed, obtained by the "near field" method on the old 0/10 mm semi-coarse asphalt concrete surface and on the proposed low-noise asphalt concrete subsequently applied on the same site.

The analysis of the sound energy of rolling noise as a function of the frequencies is particularly interesting. The noise reduction obtained due to the low-noise surface is:

- 2 to 3 dB (A) between 250 and 500 Hz
- 5 to 9 dB (A) between 800 and 5,000 Hz.

The maximum rolling noise abatement is between frequencies 1,000 and 3,000 Hz, which is in the maximum sensitivity area of the human ear.

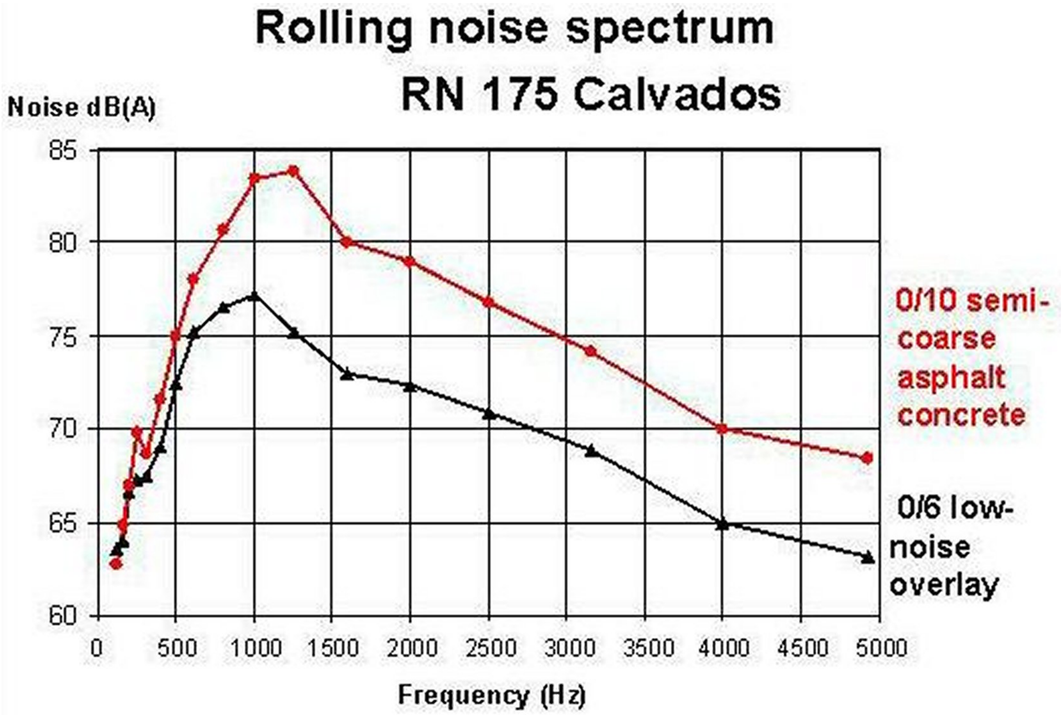

Figure 1: Example of rolling noise spectrum at 50 kph.

In this example, the noise reduction generated by the low-noise overlay is particularly significant. The gain in terms of the sound energy attenuated by the overlay gives rise to a real reduction of the most aggressive sounds for the local resident.

5 - DURABILITY OF THE ACOUSTIC PERFORMANCE LEVELS

The mix design and the use of an elastomer-modified binder enable the acoustic properties of the low-noise surface to be maintained over time.

Measurements on several worksites show that after three years of traffic, there is practically no change in the $L_{A\ ref}$ level, which remains within the standard deviation of measurement reproducibility. Further monitoring is in progress to evaluate its acoustic characteristics over the longer term as a function of the traffic load.

6 - SKID RESISTANCE AND USER SAFETY

Among the other interesting characteristics of the low-noise surface is its considerable roughness and its high braking force coefficient.

It has a high level of macrotexture, characterised by a mean texture depth measured by the sand patch test of between 0.8 and 0.9 mm for a 0/6 mm grading and between 1 and 1.2 mm for a 0/10 mm grading.

The surface has a braking force coefficient at the upper end of the French range for all overlays, whatever the measuring speed, as shown by Figure 2.

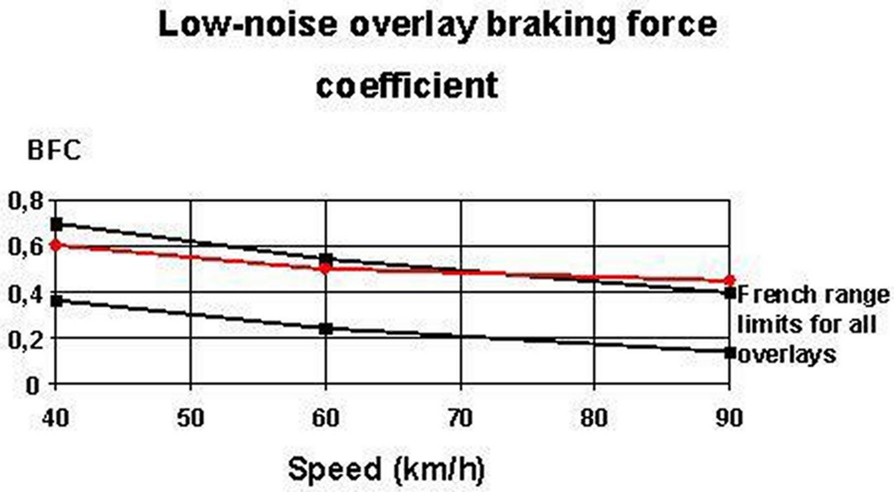

Figure 2: Change in BFC as a function of speed.

These surface characteristics, associated with a high surface drainage capacity, ensure user safety at the various traffic speeds.

7 - CONCLUSIONS

The acoustic and surface performance levels of the road surface presented here, show that it can be used to significantly reduce tyre-pavement contact noise. The data presented are the results of measurements on very different sites and they demonstrate the high efficiency of this surface, particularly in urban areas and even at the 50 kph reference speed.

In November 1995, this patented low-noise overlay of original design received the Ministry of the Environment's Golden Decibel for its acoustic qualities - an award for meritorious companies working to control noise nuisance.

With more than 1.2 million sq metres installed on different types of urban and peri-urban roads and motorways both in France and abroad, it confirms the advantages of low-noise overlays. Through its two-fold beneficial action on the environment - noise reduction and waste tyre recycling - it provides a road surface tailored to the demands of road users, local residents and project owners.

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