

A METHODOLOGY TO EVALUATE PAVEMENT NOISE PERFORMANCES FOR CHARACTERISATION, CHECKING AND MONITORING PURPOSES

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ABSTRACT

Over the past decade, road industry developed efficient low noise pavements, providing rolling noise reductions up to 8 dB(A) compared to traditional dense asphalt pavements. With such a progress, road authorities are willing to introduce noise requirements in the tenders for road surface renewal. This implies that a general framework is accepted by both parties, defining the noise performance and describing the procedures to characterise or check it on site. Consequently, the National Working Group for Road Surface Characteristics (GNCDS) was tasked to develop a methodology to evaluate pavement noise performances for characterisation, checking and monitoring purposes. The members of GNCDS belong to public road authorities or institutes and private road companies. In this way, the methodology to be developed should integrate the concerns and possibilities of all stakeholders. In particular, special attention was paid to the difficulties that road contractors often face to reproduce noise performances of a given pavement product from one work site to another, due to unavoidable variations in the properties of aggregates or binder, in the laying process or in local practices. The methodology proposed is based on the method developed within the "SILVIA" EU project, but introduces several adaptations and simplifications to improve the practicability. Noise performance is defined by an absolute pass-by noise level at a reference speed (90 km/h in France). Therefore, the noise characterisation of a pavement is performed by a SPB measurement. At least two different sections on different sites with less than 1.5 dB(A) difference in noise levels, are necessary to define an average noise performance of the pavement product. A CPX measurement is also performed in parallel, to be used as a reference for the checking procedure of other sections of the same type of pavement. The paper will present the methodology developed, the experimental tests performed to check its applicability. Then some successful examples of application of this methodology will be presented.

1. INTRODUCTION

Low noise road pavements can be used as cost-effective means of reduction of road traffic noise. Over the past decades, road industry developed efficient low noise pavements, providing rolling noise reductions up to 8 dB(A) compared to traditional dense asphalt pavements. With such a progress, road authorities are willing to introduce noise requirements in the tenders for road surface renewal. This implies that a general framework is accepted by both stakeholders – authorities and contractors - to define the noise performance and to describe the procedures to characterise or check it on site. Furthermore, as highlighted by a recent PIARC survey [1], it is widely recognised that the lack of standard and reference procedures for acoustical characterization is an obstacle to further development and use of low noise pavements. At national and international level, a need is expressed for standard procedures to characterise the acoustical performances of pavements in order to better compare product performances and compile experiences.

In France, the National Working Group for Road Surface Characteristics (GNCDS) was tasked to develop a methodology to evaluate pavement noise performances for characterisation, checking and monitoring purposes. GNCDS was settled down in 1991 by the Road General Director with objectives to define the links between the quality of service and the technical requirements, to choose appropriate measurements methods, to publish practical reference documents and to prepare circulars for the Road Administration. The activity of GNCDS covers four domains: noise, skidding resistance, longitudinal unevenness and photometric properties. According to a public/private partnership, GNCDS is composed of 50% members from road authorities or public institutes and 50% members from road industry. In this way, the GNCDS is a place for constructive exchange of experiences and opinions, and for consensual production of informative notes, papers, workshops, etc. In the case of the methodology for pavement acoustic performances, the concerns and possibilities of all stakeholders were integrated. In particular, a special attention was paid to the difficulties that road contractors often face to reproduce noise performances of a given pavement product from one work site to another, even if the mix design is identical. Changes in the nature of the aggregates (petrography) or of the bituminous binder, changes in the laying process or in local practices of workers on site, may induce variations in noise properties of the surface that, for the time being are not mitigated.

2. THE METHODOLOGY FOR EVALUATING PAVEMENT NOISE PERFORMANCES

2.1. Context and basic concept

In Europe, classification systems are active or experimented in several countries (Netherlands, United Kingdom, Denmark, Germany, Switzerland, etc). They usually differ in the measurement methods used to evaluate the acoustic performances: either statistical pass-by methods (SPB), or close proximity methods (CPX), or even both. A system was proposed in the EU project "SILVIA" [2] and disseminated through the EU networking action "INQUEST". Recently, based on the outcome of a questionnaire, the CEN/TC227 has charged the WG5 to draft a technical specification on a classification system for acoustic performances of road surfaces. The work should start in a few months. In France, the GNCDS started to develop in 2007 a methodology based on the "SILVIA" system, with some simplifications and adaptations. Similarly, the methodology is organised in three phases dedicated to the three following aims:

- The acoustic characterisation of a pavement material (product labelling): it requires SPB and CPX measurements, the "label" being based on the result of the SPB measurement.
- The checking on site of acoustic performances after works (conformity of production), based on CPX measurements
- The long term monitoring of acoustic performances of road surfaces, based on CPX measurements.

The simplifications aimed at a higher applicability on site. For example, the number of test sites requested for the characterisation of a road surface product was reduced to two. The main adaptations to the French context consisted in using the national CPX standard (the ISO standard being at the moment only a draft), and using absolute noise levels instead of noise levels or corrections relative to a reference surface. Indeed, no such "reference surface" can be defined in France, and even if some techniques are more popular (for example Dense Asphalt Concrete 0/10), the variability of performance of these surfaces is

too large to be considered as a “golden reference” against which other surfaces should be compared with.

The proposed system for labelling was tested in real conditions and further adaptations were decided on the basis of the conclusions of the experimentation.

2.2. The methodology for road surface characterization (product labelling)

2.2.1. Description

The procedure evaluates the acoustic performance of the road surface material [3]. It is based on mandatory and optional measurements. The mandatory measurements are Statistical Pass-By (SPB) noise levels ($L_{SPB}(v_{ref})$) as described in NF EN ISO 11819-1 [4] and Close ProXimity (CPX) noise levels ($L_{CPX}(v_{ref})$) as described in a national standard XP S 31145-1 [5], the principle of which is similar to the draft ISO 11819-2 [6]. The optional measurements are supplementary results intended to be used as a reference in order to explain possible problems observed in the checking phase. These complementary measurements are texture spectrum according to NF EN ISO 13473 [7] and in the case of porous pavements, sound absorption coefficient according to ISO 13472-1 [8].

The reference value for the characterisation of the road product is the average of the SPB sound pressure levels at the reference speed ($L_{SPB, \text{caract}}(v_{ref})$), measured at least on two different sites. In France, the reference speed is set to 90 km/h on highways and intercity roads. It is set to 50 km/h on most urban roads. $L_{SPB}(v_{ref})$ is measured for passenger cars only and all results are corrected for an air temperature of 20°C. The CPX sound pressure levels $L_{CPX}(v_{ref})$ are measured to check the homogeneity of the section, to validate the position of the SPB measurement spot, and to serve as a reference for the checking tests to be performed in the future. For this later purpose, the reference CPX noise level for characterizing the road surface product ($L_{SPB, \text{caract}}(v_{ref})$) is the average of the CPX noise level measured on the two different sites. It is of importance that this reference CPX noise level is evaluated at various reference speeds v_{ref} , because the legal speeds on the sections where future checking tests will be performed may be varied.

The procedure can be applied on sites where the following requirements are satisfied:

- At least two road sections with the same surface layer of minimum length 100 m
- the road sections should be located in different geographical areas (different work sites)
- Surface layers of the road sections should be at least 2 months old when tested.
- The road sections must be such that both SPB and CPX measurements can be made at a speed (average speed of the traffic flow for SPB and test vehicle speed for CPX) close to the reference speed.
- The two road sections should have comparable acoustic performances, i.e. the difference in the results of the characterization test with SPB method should not exceed 1.5 dB(A).

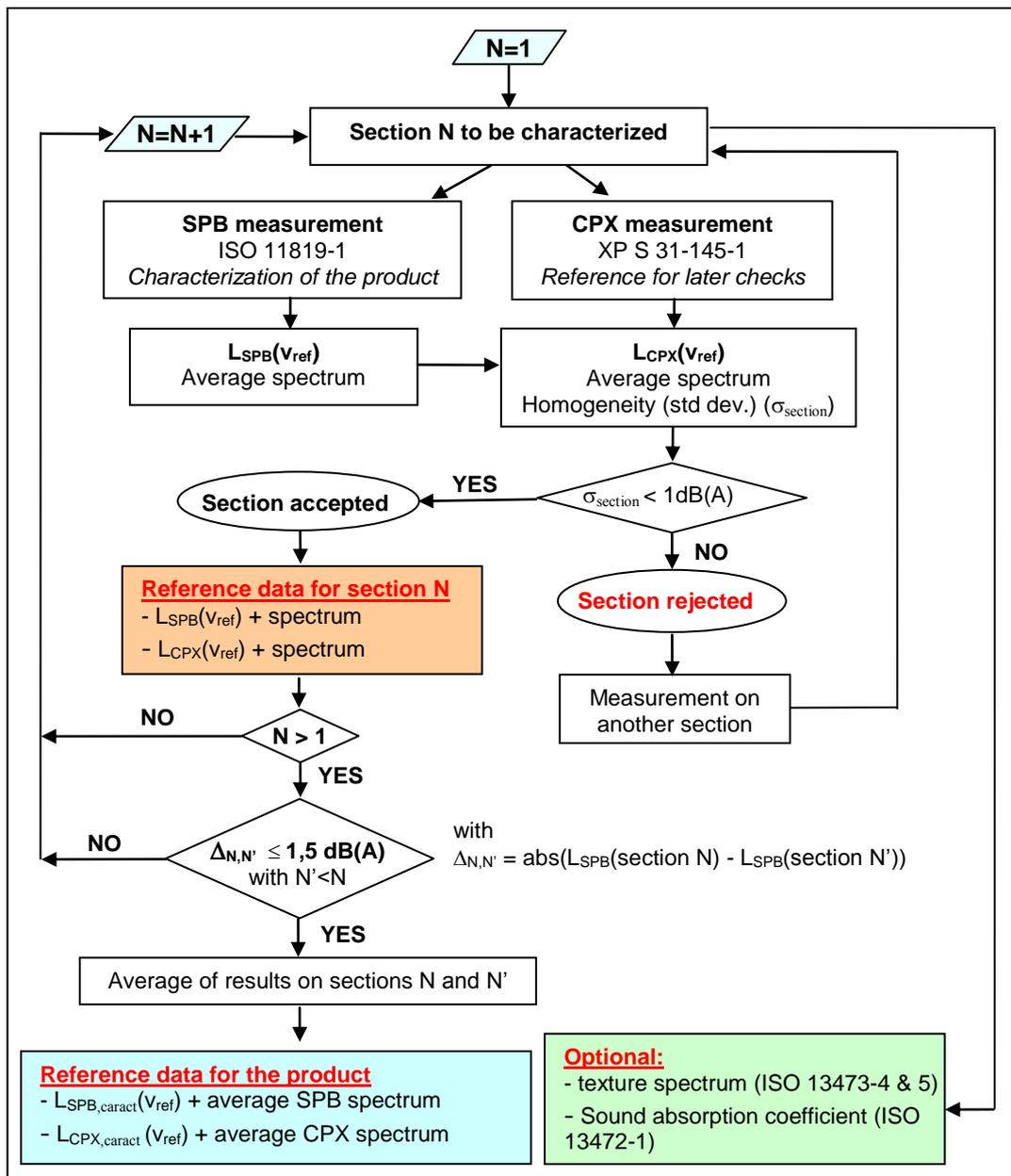


Figure 1 – Organization chart of the characterization part of the methodology

2.2.2. Experimental validation

The applicability and the consistency of the methodology for characterization were checked in a comprehensive experimentation in 2007, implying three road companies and five scientific institutes for the measurements and analysis.

Each of the three road companies were tasked to define a road surface product (E_i) and to select two road sections recently repaved with this type of surface at two different locations (s_{ia} and s_{ib}). A total of 6 test sites were selected over France. The three road surface products selected by the companies belong to the family of BBTM 0/6, i.e. very thin asphalt concretes as defined in the European standard EN 13108-2. This is an open asphalt mixture laid down on a layer 2 cm to 2.5 cm thick, with maximum chipping size of 6 mm.

Two institutes (L_1 and L_2) were in charge of performing SPB measurements on the six sites, two institutes (L_2 and L_3) performed CPX measurements, another institute (L_4)

performed the texture spectra measurements on all sites and the last institute (L₅) made the final analysis of the results.

The conditions of the experiments together with SPB and CPX results are summarized in Table 1. For the product E₁, the results on both sites are consistent, a different of 0.8 dB(A) is observed for SPB measurements and 0.4 dB(A) for CPX measurements. However for product E₂ and E₃, much higher differences between the two sites are observed. Thus for E₂ a difference of 3.6 dB(A) is observed for SPB measurements and 2.3 dB(A) for CPX measurements. On the top of the error due to the reproducibility of the road surface (raw materials, laying procedures, etc) the differences in noise results can be attributed to:

- A significant age difference between both tested surfaces (8 months on site s_{2a} and more than 3 years on site s_{2b})
- The error of reproducibility between the two laboratories. It is of the order of 1.5 dB(A) for both methods SPB and CPX.
- For CPX measurements, the difference in section length can bring discrepancies in the noise levels if the section is not homogeneous.
- Last but not least, the difference in reference and operational speed between sites. On site s_{2b}, the average speed of the vehicles in the traffic is 107 km/h. The noise level at 90 km/h is estimated with a confidence index of 0.49 dB(A). Whereas on site S_{2a}, the posted speed of 70 km/h causes an average flow speed of 78.5 km/h, and forces a CPX measurement at 70 km/h. Thus, noise levels at the reference speed of 90 km/h have to be extrapolated in the case of CPX, or estimated with a very high confidence index of 3.02 dB(A) in the case of SPB.

Table 1 – Experimental conditions and results

Road surface Product	Sites	Posted speed (km/h)	Age when meas ^d (years)	SPB			CPX			
				Lab	Avg traffic speed (km/h)	L _{SPB} (90 km/h) (dB(A))	Lab	Speed (km/h)	Section length (m)	L _{CPX} (90 km/h) (dB(A))
E ₁	s _{1a}	90	3	L ₁	87	73.0	L ₂	90	300	94.2
	s _{1b}	90	2.8	L ₁	79	72.2	L ₂	90	620	93.8
				$\Delta_{SPB} = -0.8$			$\Delta_{CPX} = -0.4$			
E ₂	s _{2a}	70	0.7	L ₂	78.5	72.0	L ₂	50	700	94.1 ^(*)
	s _{2b}	110	3.3	L ₁	107	75.6	L ₃	90	3000	96.4
				$\Delta_{SPB} = 3.6$			$\Delta_{CPX} = 2.3$			
E ₃	s _{3a}	130	0.6	L ₁	114	74.3	L ₂	90	4400	96.3
	s _{3b}	110	1.2	L ₁	91	76.1	L ₂	90	1400	95.4
				$\Delta_{SPB} = 1.8$			$\Delta_{CPX} = -0.9$			

(*) derives from extrapolation with regard to speed

2.2.3. Stricter requirements defined from the conclusion of the experimentation

Based on the outcome of the experimentation, stricter requirements were established, for the test sites on which the characterization tests are to be performed.

- Sections must be covered with pavements of similar age. The maximum difference was set to 1 year.
- Test sites must allow an average measurement speed (SPB) close to the chosen reference speed (in our case 90 km/h), i.e. the average speed of the traffic flow should be close to the reference speed.
- Acoustic performances of the two sections of a same product should not be more than 1.5 dB(A) different when evaluated with SPB measurements

- Because CPX measurements will be used as a reference for future checking tests, test sites for the characterization must allow CPX measurements at all speeds within the speed range of use of the road surface.

It can also be noted that discrepancies between both sites can be limited when a same team performs the measurements.

2.3. The methodology for checking the conformity of production (COP test)

This test must be performed on a road section opened to the traffic for at least 2 months, so that the film of binder on the surface is rubbed out, and a usual texture is restored. A CPX test is performed at the reference speed, i.e. 90 km/h or the posted speed in case of lower legal speeds. Then, the result of the measurement is compared to the reference CPX noise level obtained during the characterization test. A tolerance $Y = 2 \text{ dB(A)}$ is introduced to take into account the reproducibility of the CPX measurement method and the reproducibility of the manufacturing and the laying process of the road material. This value of 2 dB(A) has been fixed as a default approximation. It should be defined more accurately in the future, on the basis of further experimental results. If the measured CPX noise level ($L_{\text{CPX,site}}(v_{\text{ref}})$) is lower than the reference level at the same reference speed $L_{\text{CPX,charact}}(v_{\text{ref}})$ plus the tolerance Y , then the conformity of the road surface is validated. In the opposite situation, the road surface is not accepted and additional measurements of texture and sound absorption (in the case of a porous or semi-porous pavement) may be performed in order to better understand the failure. It is left to the road owner to define in the initial contract whether in this case the surface should be replaced or financial penalties should be applied.

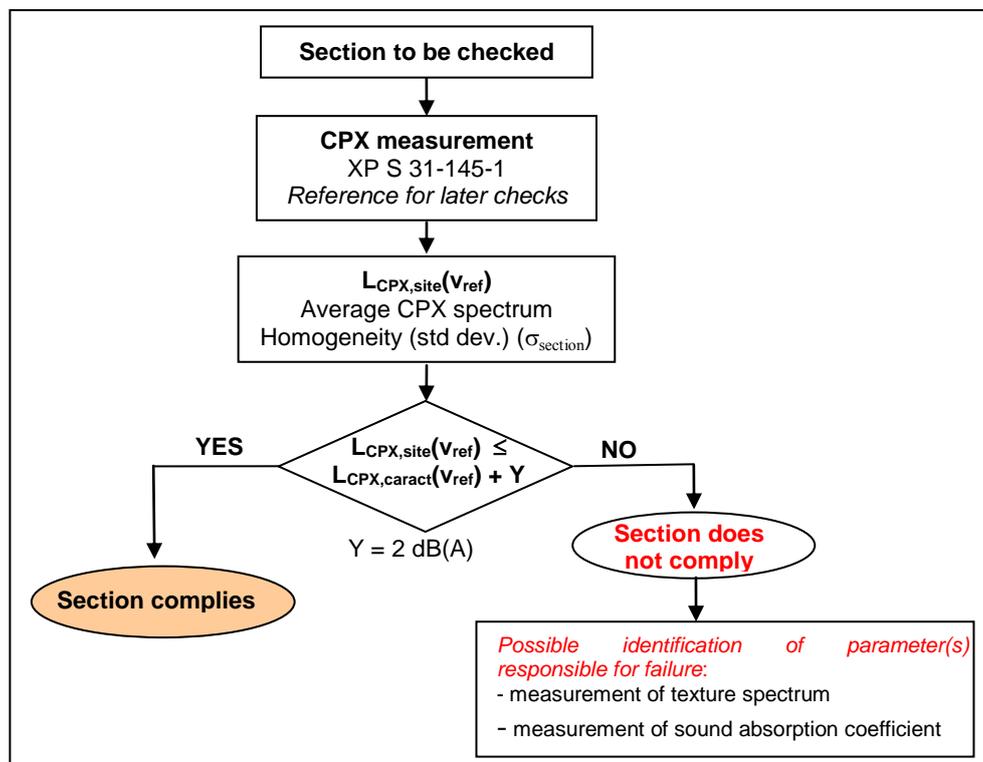


Figure 2 – Organization chart of the COP part of the methodology

2.4. The methodology for monitoring acoustic performance

For monitoring the evolution of acoustic performance over time, CPX measurements should be performed at a speed close to a chosen reference speed. The measured CPX

levels should then be compared with the CPX level at the same reference speed obtained during the initial test, or the checking test if any. A special attention should be paid to keep the measurement speed as close as possible to the reference speed. Deviations of the measurement speed higher than $\pm 5\%$ from the reference speed are not allowed. This requirement can be very restrictive, especially for long sections or network monitoring. Another special attention should be paid on the calibration of the measurement vehicle, as deviations introduced in the measurement equipment may have effect on noise emission of the same order as the variation in the road surface properties. Thus, it is recommended to use the same test equipment (test vehicle or test trailer) over the years in order to minimize the deviation due to equipment reproducibility. Furthermore, test tyres properties may also be altered over time. Therefore, it is recommended to regularly – at least once a year – calibrate the measurement system on a reference test track not opened to the traffic.

3. IMPLEMENTATION OF THE METHODOLOGY FOR THE CHARACTERISATION OF PAVEMENT NOISE PERFORMANCES

3.1. Characterisation of a product by three road companies

The methodology was published in 2010. Three road companies selected a low noise product and applied the methodology for characterization. The road surface products selected are BBTM (very thin asphalt concretes) as traditionally used in France for resurfacing roads where noise reducing properties are requested. They are open asphalt mixes laid down on a 2 cm to 2.5 cm thick layer, with maximum chipping size of 6 mm or 4 mm. Low noise BBTM usually have high void content, typically between 20 and 25% as measured with a gyratory shear compactor after 25 rotations. With tighter requirements for the selection of test sites as set after the experimental validation (see section 2.2.3), all three companies have succeeded in characterizing their product in quick enough and satisfactory conditions. The results are provided in Table 2 where P_i stands for the road surface product of company i and S_{ia} and S_{ib} are the two sites for characterization tests. The product P_2 was tested on three different sites.

Table 2 – results of the implementation of the methodology for acoustic characterization on 3 different road surface products

Road surface Product	Sites	Age (years)	SPB		CPX		Final reference values		
			L_{SPB} (90 km/h) (dB(A))	$\Delta_{a,b}$ dB(A)	L_{CPX} (90 km/h) (dB(A))	homogeneity σ (dB(A))	L_{SPB} (90km/h) (dB(A))	L_{CPX} (90 km/h) (dB(A))	$\Delta_{SPB-CPX}$ (dB(A))
P_1	S_{1a}	< 1	69.5	1.4	93.2	n.d.	68.8	94.2	25.4
	S_{1b}	< 1	68.1		95.1	0.95			
P_2	S_{2a}	< 1	69.6	0.1	95.6	0.48	69.5	95.3	25.8
	S_{2b}	4	69.9		93.7	0.83			
	S_{2c}	< 1	69.5		95.1	0.74			
P_3	S_{3a}	< 1	72.4	0.7	97.0	0.33	72.7	96.2	23.5
	S_{3b}	< 1	73.1		95.5	0.42			

In table 2, $\Delta_{a,b}$ represents the SPB sound pressure level difference between the two sites where the product was tested. For the product P_2 , it corresponds to the difference between site S_{2a} and S_{2c} . The case of product P_2 illustrates the possible variability in the results of characterisation:

- if sites S_{2a} and S_{2b} were the only sites to be considered for the characterisation, then the final reference values would be $L_{SPB} = 69.7$ dB(A), $L_{CPX} = 94.6$ dB(A) and $\Delta_{SPB-CPX} = 24.9$ dB(A)
- if sites S_{2b} and S_{2c} were the only sites to be considered for the characterization, then the final reference values would be $L_{SPB} = 69.7$ dB(A), $L_{CPX} = 94.4$ dB(A) and $\Delta_{SPB-CPX} = 24.7$ dB(A)
- because site S_{2b} was significantly older than the other sites, it was removed from the final averaging, which finally leads to the reference values for the product characterisation: $L_{SPB} = 69.5$ dB(A), $L_{CPX} = 95.3$ dB(A) and $\Delta_{SPB-CPX} = 25.8$ dB(A)

For all the products, the SPB noise levels at 90 km/h on the different test sites did not differ by more than 1,5 dB(A). Furthermore, the homogeneity of all test sections was below 1 dB(A).

With their final reference values, the three road companies are now in a position to respond to any call for tender for road surface renewal in which acoustic requirements are inserted.

3.2. Monitoring the implementation

In order to follow-up the implementation of this methodology, the GNCDS has recently created a monitoring centre where all the cases of implementation of the methodology for characterization will be registered. The aim of this virtual centre is also to collect information on the work sites where the methodology for the checking of acoustical performances has been applied. In 2010, the National Road Directorate tried to push the local authorities willing to launch public works contracts with low noise road surfaces to set requirements of performance and refer to the GNCDS methodology. A legal scheme was even proposed. However, it must be recognised that at present, despite the three major road companies in France are ready to compete with characterized low noise products, no such contract has been launched. If this situation persists, the reasons should be investigated and a clarification of the procedure may need to be proposed.

4. CONCLUSIONS

A methodology for the characterization, the check and the monitoring of the acoustical properties of road surfaces has been developed in France by a working group of the GNCDS involving road companies, public scientific and technical institutes and representatives of the road managers. This methodology is similar to the 'SILVIA' procedure with some simplifications and adaptations. It has been applied experimentally as a first step for validating the procedure and requirements, and in a second step, for establishing reference performance of three low noise road surface products from three different companies. From these experiments, the following observations were made:

- It is difficult for road contractors to reproduce noise performances for a given pavement product from one work site to another, due to unavoidable variations in the properties of aggregates or binder, in the laying process or in local practices
- It is possible to lay down a same product on two different test sites with a variation in the SPB noise level lower than 1.5 dB, provided some precautions are taken
- The average speed of the traffic when measuring statistical pass-by noise is of importance on the result expressed at a reference speed. When comparing performances, the average vehicle speed should be as close as possible to the reference speed in order not to introduce any bias with the speed correction.

- The road section on which the characterization tests are to be performed should be at least 2 months old but the age difference between the sections should not be more than 1 year.
- It is also advisable that measurements on both sections are performed by the same team in order to limit the errors of measurement reproducibility
- Sound absorption can not be easily evaluated on trafficked roads because the measurement method is static and requires the traffic to be stopped during the installation of the equipment and the measurements. Furthermore, the effect of road texture spectra on road noise spectra is not easily connected. Therefore, in the case of a failure to meet the acoustic requirements, an a posteriori understanding of the reasons cannot be easily achieved.

Despite all these experimentations, the methodology is still at an experimental stage. More experience on the introduction of acoustic requirements in tendering process, on the implementation of the methodology on work sites of the check procedure and on the long term monitoring procedure is still to be gained.

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