TOWARDS NOISE CLASSIFICATION OF ROAD PAVEMENTS

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Abstract

Noise classification of road surfaces has been addressed in many European countries. This paper presents the first approach towards noise classification of Portuguese road pavements. In this early stage, it aims at establishing guidelines for decision makers to support their noise reduction policies and the development of a classification system adapted to the European recommendations. A ranking to provide guidance on tire-road noise emission levels for immediate use by decision makers, road authorities, contracting parties and environmental officers will be established. This research was based on the results provided by three early studies covering more than ten different surfaces, among which, rubberized asphalt and experimental non conventional surfaces with optimized grading. On each road trial, the tire-road noise generated by light vehicles and heavy trucks at three speed levels were measured by means of the Controlled Pass-By method (CPB). Three of these runs were also tested by the Close ProXimity method (CPX). Additionally, tests to characterize texture and skid resistance were performed. The early noise classification studies of road pavements focused only on the CPB tests. Three groups with similar acoustical performance were identified. Noise level abatements of about 10 dB were achieved for the gap graded mixtures with a maximum aggregate size inferior to 10 mm.

INTRODUCTION

The negative effects of noise on human health are well recognized and documented. Measures have been taken at the European level for its reduction on all fronts. Road traffic contributes to the overall environment noise levels to a great extent, both in urban and in rural areas. Therefore, a classification system to assess the acoustical performance of road surfaces, which has different

requirements according to the end-user, has become a fundamental tool in road design. In this context, a standard method for the classification of the acoustical performance of road surfaces is required. A first approach towards noise classification of Portuguese road pavements is presented herewith.

NOISE CLASSIFICATION OF ROAD PAVEMENTS

Different European countries are implementing programmes for noise classification of road surfaces (Descornet et al., 2006). Most of them take a surface as reference and apply correction terms for the other surfaces types or group of surfaces. Factors such as the type of vehicle, percentage of heavy vehicles, longitudinal road gradient, noise spectrum and mean texture depth are occasionally considered as correction factors. Some countries, such as France and The Netherlands, predict rolling noise levels for different types or categories of surfaces versus vehicle category and speed.

The absence of a common approach to assess the acoustical performance, and thus, the diversity of the existing classifications creates problems to end users and to suppliers. End users may not be fully aware of the different options and of their relative benefits leading to more difficulties to operate in markets outside their own country (SILVIA, 2006). The European projects HARMONOISE/IMAGINE and SILVIA were developed to overcome these problems.

The HARMONOISE project proposed an enhanced method for predicting the influence of the road surface on vehicle noise emission. This method estimates the noise emission from vehicles on a standard reference surface at a standard temperature and provides corrections for the ageing porous surfaces and for wetness (HARMONOISE, 2005). The reference surface corresponds to one surface chosen by a certain country that is part of a "cluster" of reference surfaces having fairly similar noise characteristics.

The SILVIA project report proposes a classification system for the assessment of the acoustical performance of newly laid surfaces and a method for assessing the conformity-of-production (COP). The classification system identifies specific measurement procedures, described below, necessary for labelling the acoustical performance of a road surface (Padmos et al., 2005). This project establishes the following two labelling procedures:
• Label1 – the assessment is based on Statistical Pass-By (SPB), and Close ProXimity (CPX), methods;
• Label2 – the assessment is based on SPB measurements and measurements of intrinsic properties of the road surface, such as texture and sound absorption.

Both labels are based on SPB, which was chosen as the reference noise classification method due to its better representativity in relation to the acoustical environment within the community. Nevertheless, it only evaluates a small section of a test surface. Therefore, additional measurements are required to assess the acoustical performance over the full length of the trial section (Table 1).

Label1 is the preferred one. It includes a direct assessment of noise over the entire length of the trial surface using the CPX method. Label2 allows for an indirect assessment based on

measurements of the intrinsic properties of the surface which can be related to the generation and propagation of the noise (Padmos et al., 2005).

For the assessment of the COP, the CPX method is used in surfaces with a noise Label1 and the measurement of the relevant intrinsic properties is used with a noise Label2.

Table 1 – Recommended labelling system for assessing the acoustical performance of different types of road surfaces: determining the noise label (Padmos et al., 2005)

Label	Dense graded	Open graded	
	Rigid*	Rigid	Elastic
Label1	SPB CPX	SPB CPX	SPB CPX
Label2	SPB Texture	SPB Texture Absorption	SPB Texture Absorption Mechanical impedance

* Rigid surfaces are defined as normal asphalt (dense and open graded) and concrete

Noise measurement methods

The noise performance of a road surface may be determined by three basic methods:
1. the Statistical Pass-By method (SPB);
2. the Controlled Pass-By method (CPB);
3. the Close proximity method (CPX).

1. SPB method
In this method, the peak noise level of each individual vehicle is measured from the undisturbed traffic with the microphone fixed at 7.5 m from the centre of the lane. The speed is also measured by means of a radar. The regression line parameters of noise levels versus logarithm of speed are used next for characterizing each vehicle category by an average noise level at any reference speed. This method is further described in ISO 11819-1:1997 – "Acoustics – Method for Measuring the Influence of Road Surfaces on Traffic Noise – Part 1: Statistical Pass-By Method" (ISO 11819-1, 1997). The main disadvantages of the method are the large area required without reflecting surfaces around the microphone and the section of the lane perpendicular to the microphone line and its application in roads holding high traffic flow.

2. CPB method
The testing procedure is the same as in the SPB method. In this case, vehicles are purposely chosen allowing the control of their operation conditions such as selection of tires, speed and gear ratios, run with engine on or off.

3. CPX method
This method consists of the measurement of the noise generated by the tire-pavement interaction using microphones mounted near to a tire on a vehicle or on a dedicated trailer. A standard method for measuring the influence of road surfaces on traffic noise by close proximity measurements is being developed (ISO CD 11819-2, (2000)).

AN APPROACH TOWARDS NOISE CLASSIFICATION OF ROAD SURFACES

Noise classification is addressed by two different approaches. The first one is based only on the CPB tests. The aim is to characterize the noise performance of Portuguese road surfaces by establishing a rank in relation to the noise performance of the surfaces. It will provide some guidance in relation to tire-road noise for immediate use by road authorities and builders.

The second approach is based on CPX and CPB tests. It is a first rough approach to the application of the classification system developed by the SILVIA project and, simultaneously, it constitutes the first step for the development of a classification system adapted to Portuguese conditions.

In the next sections, considerations on the selected noise measurement methods are presented together with the description of the main characteristics of the tested surfaces.

Selected noise measurement methods

For the noise measurements, the CPB and the CPX methods were adopted. The CPB was preferred to SPB since in the north of Portugal, where the measurements took place, national and urban roads are characterized by considerably high slopes, small straight lines and a rather intensive traffic flow. For those reasons, difficulties arise regarding regular traffic operation conditions adequate in SPB measurements.

Thus, in order to guarantee reliable results, the measurements were performed mostly at night, with the road closed to the normal traffic in both directions, so that the influence of other vehicles was eliminated and speed and engine acceleration could be well controlled. Several pass-by tests were carried out with more than two light vehicles and one heavy vehicle. The pass-bys were carried out with the engine switched on at a speed range from 50 km/h to 130 km/h. A total of 470 valid pass-bys was recorded.

For the CPX measurements, a support system was designed to hold the mandatory microphones steady and in the right position, as recommended in ISO CD 11819-2 (2000). The experimental set-up is depicted in Figure 1.

Figure 1 – Close proximity system used for the CPX tests

The captured signals were stored and processed in a specific audio module based on the Matlab toolbox platform. The overall noise emission signals were post-processed by applying a linear average approach to the signal for several road sections with an extension longer than 100 m. The noise levels measured at the 'front' and at the 'rear' microphones were arithmetically averaged. In this study, the length of the three pavement surfaces tested extended for more than 100 m, avoiding the need for averaging different runs on the same road.

Selected road surfaces

The road surfaces selected for noise classification were collected from three separate studies carried out mainly on national roads, one of which included two thin layers intentionally constructed for noise abatement (Freitas et al., 2006; Freitas et al., 2008). They are composed by a set of ordinary surfaces and by a set of non conventional road surfaces included in the group of thin layers. Twelve different surfaces catalogued by S1 to S12 were tested. The main properties of each surface type are described as follows:

Thin layers
- Surfaces S1, S2 and S5 - are composed by gap graded asphalt mixtures (GG) with less than 6% of voids;
- Surface S3 - is a "rough" asphalt rubber concrete (RAR);
- Surfaces S6 and S7 - are gap graded asphalt rubber mixtures (GGAR), the void content of which is about 13%. The rubber content by weight of bitumen varies from 18% to 20%;
- Surfaces S10 and S11 - are thin layers of with grading curve adapted from French low noise surfaces and optimized for noise abatement with 15% and 18.5% of void content, respectively.

The thickness of these eight layers falls within the range of [2.5 - 4] cm.

Porous asphalt (PA) layer
- Surface S9 – is constituted by 4 cm of thickness and 22% of voids.

Dense asphalt concrete (DA)
- Surfaces S4, S8 and S12 - are the most common type of surface. It is used in all types of roads (rural or urban).

Figure 2 shows eight grading curves representative of the grading curves used by road administrations, with the exception of GG 7 and TL 8, which are two non conventional surfaces analyzed in this study. The rough surfaces without rubberized asphalt were not studied, but they will be considered within the scope of the noise classification of Portuguese road surfaces.

Table 2 shows the acronym of each surface followed by the corresponding maximum grain size and the texture depth measured either with a High Speed Profilometer according to the Standard ISO 13473-1 (1997) (S1 to S7 and S10 to S12) or by the Sand Patch Method (ASTM E965-96, 2006). The skid resistance measured with the British Pendulum (ASTM E303 – 93, 2003) and the surface age are also shown.
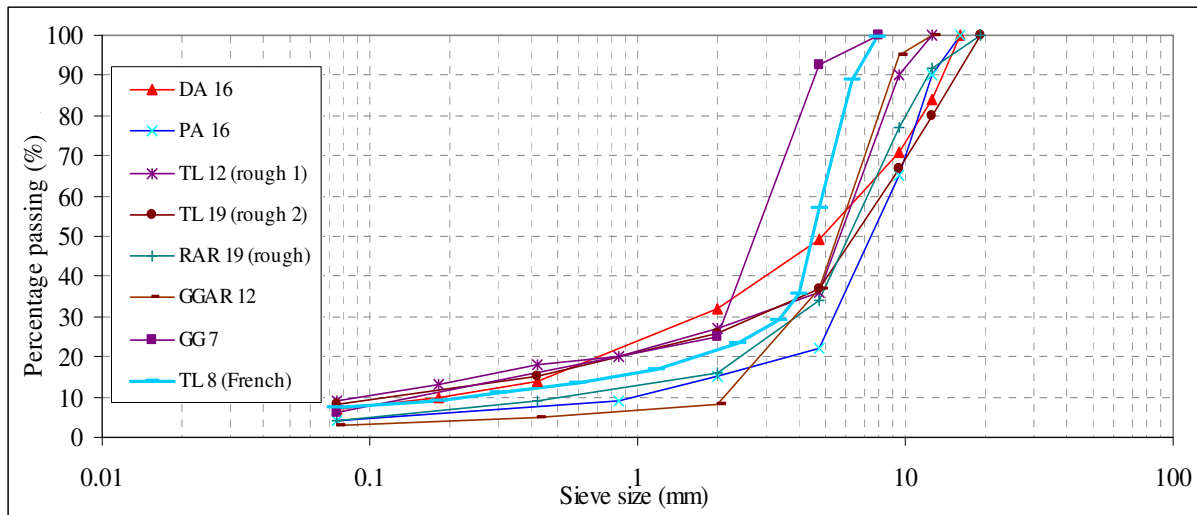
Figure 2 – Grading curves adopted by Portuguese specifications and non conventional grading curves used in the study

Table 2 – Estimated texture depth and skid resistance of the surface

Surface	Estimated texture depth (mm)	Skid resistance at 20ºC (BPN)	Age (years)
S1(GG12)	1.0	54.5	1
S2(GG6)	0.6	52.2	2
S3(RAR15)	0.6	50.6	7
S4(DA16)	0.7	51.4	10
S5(GG7)	0.6	51.8	4
S6(GGAR12)	0.7	50.0	< 1
S7(GGAR10)	0.8	52.6	< 1
S8(DA16*)	0.9	70.0	construction
S9(PA15)	1.5	70.0	construction
S10 (TL1-8)	1.0	55.0	< 1
S11(TL2-8)	1.3	55.0	< 1
S12(DA12)	0.7	60.1	< 1

ACOUSTICAL PERFORMANCE BASED ON THE CPB

In the SPB or CPB methods, once far field conditions are considered, the noise radiated by the vehicle can be modelled by an equivalent noise source estimated by the contribution of the four tires, assuming the noise power from the engine is insignificant at the speeds involved. The resulting noise levels are estimated by taking into account the attenuation of the sound waves between the equivalent noise source and the receptor. The sound attenuation is related to the geometric wave spreading and to the attenuation due to the ground between the vehicle and the target microphone (the air absorption attenuation can be neglected). Once the testing geometry is kept up, the attenuation due to the ground has a significant effect on the noise levels.

Temperature, wind and wet surface are the factors responsible for the major deviations of noise levels. The European Directive 2001/43/EC recommends the correction of the temperature by the reference value of 20ºC and wind speeds below 5 m/s during the measurements. Nevertheless, the

results presented below were not corrected due to temperature variation. Figure 3 shows the *Lmax* noise levels for the twelve surfaces calculated for light vehicles by the regression line of noise level versus the logarithm of the speed for 50, 70 and 90 km/h.
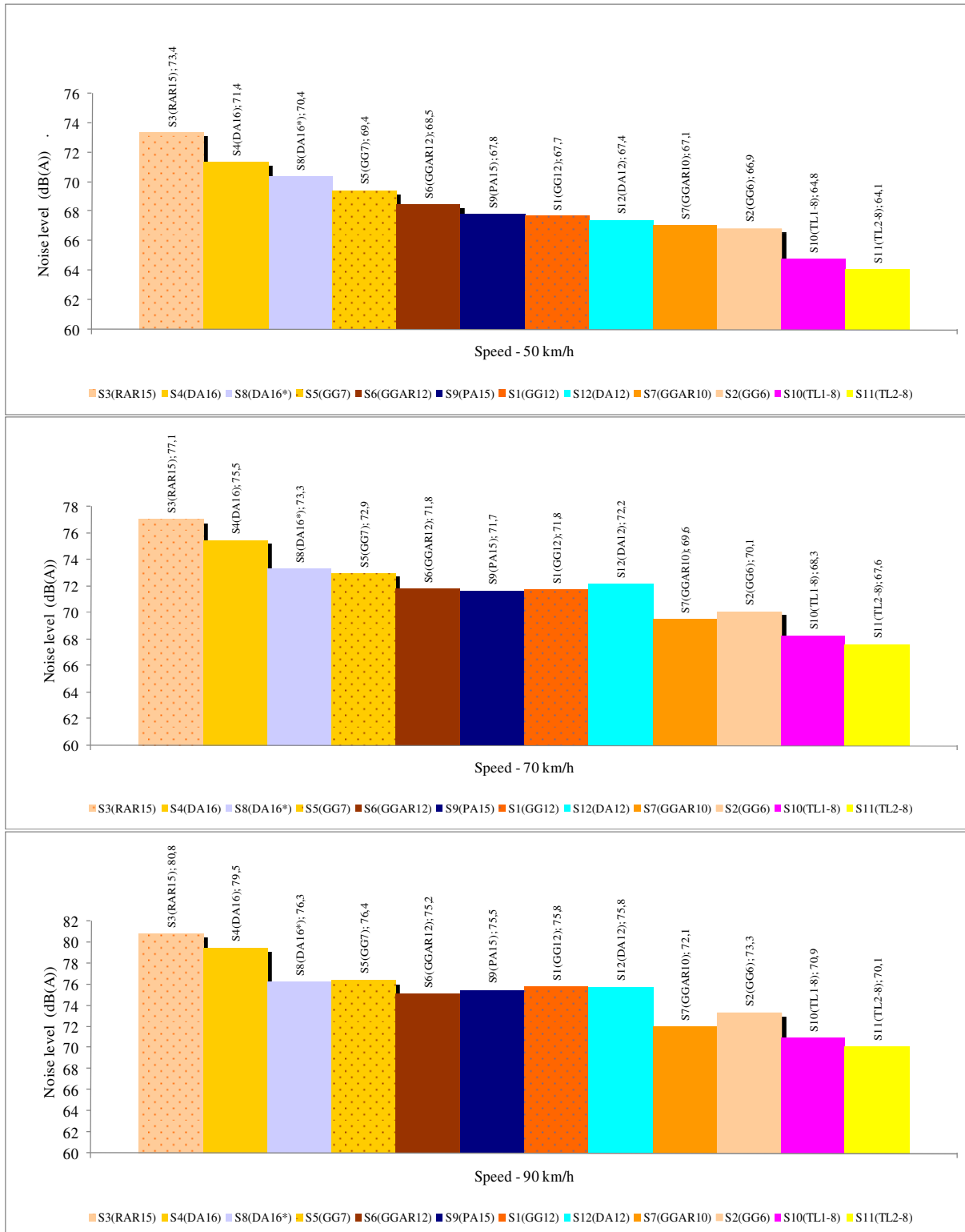

Figure 3 – CPB noise levels measured for light vehicles at 50, 70 and 90 km/h

For all the vehicle speeds considered, a significant difference of about 10 dB(A) between the most silent (S11) and the noisiest (S3) surfaces was found. Taking into account the effect of the grain size on noise, the performance of S5 is worse than the others with similar grading.

This can be explained by the age of the surface, which is older, and by the higher traffic density. If this section is despised for further analysis, three groups of surfaces at speeds of 70 km/h and 90 km/h are easily recognized:

i) the first group, with low performance, is characterized by high maximum grain size (surfaces S3, S4 and S8);
ii) the second group has an "intermediate" and similar performance (S1, S6, S12), with 12 mm maximum grain size and the porous asphalt surface S9;
iii) the third group, showing the best performance, is characterized by maximum grain size smaller than 10 mm (surfaces S2, S7, S10 and S11).

At a speed of 50 km/h, the performance of the intermediate group is closer to the group with best performance, and at 90 km/h it is closer to the group which showed a worst performance.

Therefore, instead of selecting a specific pavement as the reference surface and then applying a correction factor (normalization) to the noise levels for the rest of the pavements, the procedure of gathering the available surfaces in groups with similar noise performance was adopted.

ACOUSTICAL PERFORMANCE BASED ON THE CPX

The noise measured by the CPX method is basically related to the rolling tire/pavement interaction of the wheel to which the microphones are coupled to. Figure 4 shows the noise levels measured by the CPX method for surfaces S10 to S12 and for two additional surfaces, one (S13) made of Gap Graded Asphalt Rubber (GGAR12) and the other one (S14) made of Porous Asphalt (PA15).
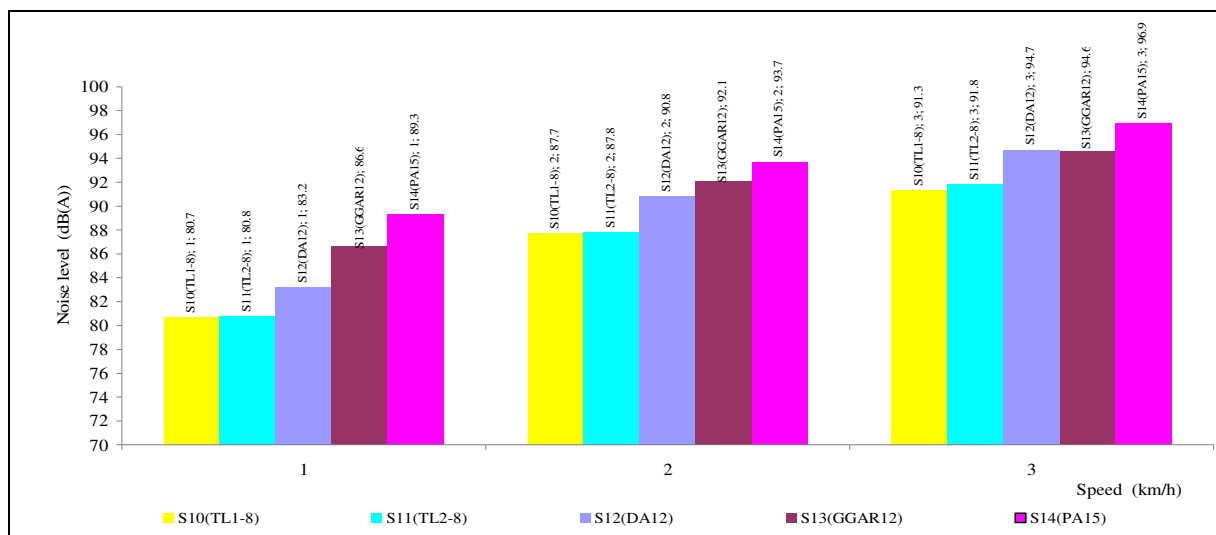
Figure 4 – CPX noise levels measured for light vehicles at 50, 80 and 110 km/h

Despite the reduced number of surfaces tested, it is possible to observe, as expected, that the CPX method, being a near field measurement procedure, is less sensitive to the type of surface and to the speed level than the CPB method. In the CPB procedure the effect of noise propagation path plays an important role for the determination of the overall noise levels and strongly depends on the type of surface and its age.

In this study, the noise levels generated by S10 and S11 nearly have the same value. The difference of noise levels between these surfaces and S12 is about 3 dB(A) at almost all speed levels. While with the CPB method these differences raised up to 5 dB(A) at 70 and 90 km/h.

Among the different types of pavement studied, the S13 and S14 mixtures hold the highest noise emission levels. Although these mixtures have rubber material in its constitution or are of porous asphalt type, the grading curve, which is not optimized to noise reduction purposes, must have led to higher noise emission levels, at least for the near field measurements. In order to properly evaluate its overall performance, these results should be compared to the CPB method.

The results point out that the approach applied to noise classification, based on CPB tests by grouping surfaces with the same acoustical performance lead probably to different results. For this reason, CPX results must be complemented by the analysis of the effect of other parameters capable of explaining the differences encountered, such as an enhanced analysis of the surface texture and the analysis of the attenuation due to the surface type.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

A short review of the European classification of road surfaces in relation to their influence on traffic noise and of the available noise measurement methods was presented. A first approach to the noise classification of the Portuguese road surfaces was described mainly based on the Controlled Pass-By (CPB) tests carried out on twelve road trials, five road trials were also tested by the Close Proximity Method (CPX).

From the CPB tests, three groups with similar acoustical performance were identified: i) the first, composed by surfaces with high maximum grain size, is characterized by poor performance (S3, S4 and S8); ii) the second group, with an "intermediate" performance and grain size of about 12 mm, is composed by gap graded surfaces S1, S6, S12 and porous asphalt surface S9; iii) the third, with the best performance, is also composed by gap graded surfaces, with maximum grain size smaller than 10 mm (S2, S7, S10 and S11). All groups include a surface with rubberized asphalt.

The CPX tests showed to be less sensitive to the variation of the type of the surface if compared to the Controlled Pass-By results, thus indicating a lower ability for noise pavement classification. The CPX, as an acoustical measurement in near field conditions, better characterized the sound sources responsible for the tire/pavement noise generation. The CPB method includes the effect of noise propagation path on the total noise levels. These two different approaches suggest the use of both measurement techniques on the classification system for the assessment of the acoustical performance of the surface (as a special approach to Label1 referred in the SILVIA project (2006)).

The results are still preliminary, but they proved to be consistent. Future phases of this work should include "rough" asphalt and pavements composed of paving stones, which are used in Portuguese historical centres. New surfaces of the same type, as those already studied, but with different ages for representativity purposes, should also be tested. Cement concrete surfaces have been rarely used in Portugal and, in the future, they will be replaced by asphalt concrete. Thus, the need for their characterization is not mandatory. All surfaces should be thoroughly tested periodically by both the CPB and the CPX methods in order to study the variation of the acoustic behaviour with time.

CPB tests have also been carried out with heavy vehicles. However, they were not presented in this paper. Further studies on the representativity of the results need to be undertaken. Further testing is required for a reliable classification of noise produced by this type of vehicle.

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