Contribution of Portuguese Pavement Surfaces to Traffic Noise

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Abstract

This paper aims at assessing the relative effect of Portuguese pavement surfaces on traffic noise. It presents the main results obtained with two distinct experiments, originally intended for other purposes, which address a significant number of thin layers and porous layers.

These experiments included nine road surfaces: three of them were gap graded, three contained rubberized asphalt, one had porous asphalt and two had dense asphalt. On these road sections the tyre-road noise generated by two-axle heavy trucks and three-axle heavy trucks and several light vehicles at three levels of speed were measured by means of pass-by tests. Surface texture tests were also performed.

The results focused on noise level variation versus speed and estimated noise level for each speed level versus type of surface. The best performances were achieved by gap graded mixtures with and without rubberized binder and small grain sizes. The fair behaviour shown by the porous asphalt indicates that the surface texture determined by the grain size seems to influence the noise level more than porosity.

1. Introduction

Several studies carried out in roads with different types of surfaces and ages usually show that dense asphalt concrete, stone mastic asphalt and surface dressings are the ones that generate more noise contrarily to double and single porous asphalt, thin layers and poroelastic surfaces [1], [2], [3]. In the first group the aggregate size, which is usually big, the low porosity and the positive texture are factors that greatly contribute to high noise levels. In the second group, the reduction of noise generated by the texture impact mechanism is due to the small aggregate size. The gap-graded nature (indented or negative texture) also gives them appropriate air drainage, properties that contribute to the reduction of air-pumping noise and other similar mechanisms of noise generation [4].

Among the most silent layers, the poroeslastic one outstands, since reductions up to 12 dB were achieved in experiments carried out in Japan, the Netherlands and Sweden [5] as a result of their composition. In the United States and in Europe noise levels similar to those of the porous asphalt on dense asphalt concrete surfaces with rubberized binder were found [6]. In Portugal two studies which included this type of mixtures were carried out. The first one compared a gap graded rubber asphalt with a “rough” dense asphalt and with cement concrete. The other one assessed the noise produced by a porous rubber asphalt mixture. In the first case, abatements of 5 to 8 dB(A) and 8 to 10 dB(A) were stated [7]. In the second case, a reduction of 3 to 5 dB(A) was reported [8].

This paper intends to give a number of insights into this issue by comparing noise levels measured in thin layers composed of gap graded asphalt concrete and rubberized asphalt concrete and porous asphalt surfaces taking as reference dense asphalt concrete.

2. STUDY METHODOLOGY

This paper groups the results obtained from two separate studies carried out on eight roads in the northern of Portugal. In both studies the Controlled Pass-by Method was adopted. The pass-bys were effectuated with the engine switched on at a speed range from 50 km/h to 130 km/h. A microphone was positioned 1.2 m above the pavement surface and 7.5 m from the centre of the carriageway.

The first experiment included seven in-service road sections, the surface layer of which is composed of three main types of mixtures: i) one on dense asphalt concrete; ii) three on gap graded asphalt; iii) three on gap graded asphalt rubber. The tests were performed with three vehicles grouped into the following categories, as recommended by the standard ISO 11819-1:1997(E) [9]: L_1 (cars and other light vehicles) – 1 Volkswagen Polo, 1 Nissan Strakar; L_{2a} (dual-axle heavy vehicles) – 1 Volvo; L_{2b} (multi-axle heavy vehicles – none. A total of 188 valid vehicles pass-bys were effectuated

The second experiment was carried out on a motorway under construction, in the northern of Portugal. Thus, it was possible to set two consecutive road sections, one with a dense asphalt surface and the other with a porous asphalt surface. In this case, the tests were performed with six types of vehicles grouped as follows: L_1 (cars and other light vehicles) – 1 Citroen XSara, 1 Volvo S40, 1 Nissan Terrano, 1 Renault Traffic; L_{2a} (dual-axle heavy vehicles – 1 Mercedes; L_{2b} (multi-axle heavy vehicles) – 1 Scania. The testing speed adopted was within the limits recommended at ISO 11819-1:1997(E) [9] for medium and high road speed. A total of 207 valid vehicles pass-bys were effectuated either with a dry surface or wetted by a water truck.

In view of the fact that these experiments were carried out in different category roads (national roads and motorway) and for comparison purposes, this study will be focused on pass-bys effectuated by light vehicles and dual axle vehicles and will adopt the following reference speeds: 50 km/h, 70 km/h and 90 km/h.

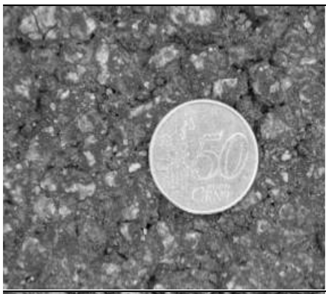
3. Testing conditions

3.1 Weather

The Directive 2001/43/EC of the European Parliament recommends the correction of temperature to the reference value of 20ºC and testing with wind speeds below 5 m/s. Throughout testing periods the wind speed was always inferior to 4 m/s. The effect of testing temperature was not taken into account because the variation in noise level is small (< 0.5 dB(A)).

3.2 Surface characteristics

Figure 1 shows the aspect of each surface and the main properties of the mixtures, such as the maximum aggregate size (MAS), porosity (P), bitumen percentage by total weight (BP), rubber percentage by weight of the bitumen (RP) and age, are also represented. In the same figure each surface is identified by the acronym of the corresponding mixture followed by the MAS.

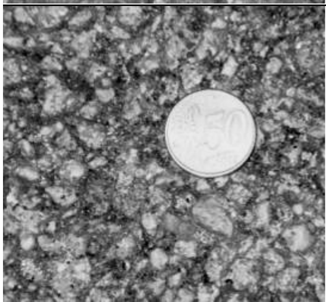


Surface 1: S1(GG12)

Gap graded (rough)
MAS: 12 mm
P: 3.6%
BP: 5.1%
Age: 1 year

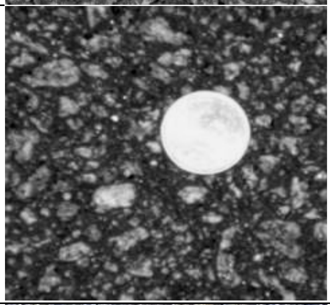
Surface 2: S2(GG6)

Gap graded
MAS: 6 mm
P: 6.6%
BP: 6.2%
Age: 2 years



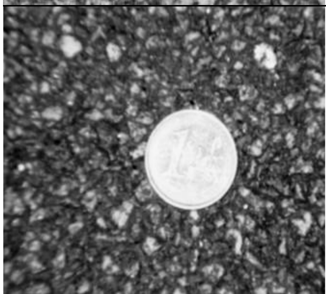
Surface 3: S3(RAR15)

"Rough" asphalt rubber concrete
MAS: 15 mm
P: < 5.0 %
BP: 7.0 %
RP: 18%
Age: 7 years



Surface 4: S4(DA16)

Dense Asphalt
MAS: 16 mm
P: 5.0%
BP: 4.9%
Age: 10 years

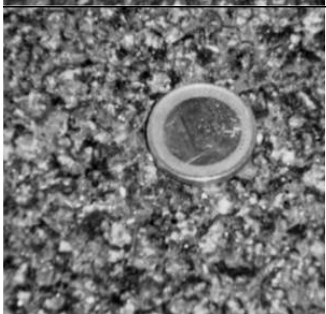


Surface 5: S5(GG7)

Gap graded
MAS: 7 mm
P: 6.1%
BP: 6.1%
Age: 4 years

Surface 6: (GGAR12)

Gap graded with asphalt rubber
MAS: 12 mm
P: 13.0%
BP: 9.0%
RP: 20%
Age: <1 year



Surface 7: (GGAR10)

Gap graded with asphalt rubber
MAS: 10 mm
P: 14.0%
BP: 9.0%
RP: 20%
Age: <1 year

Surface 8: (DA16*)

Dense asphalt
MAS: 16 mm
P: 4.5%
BP: 5.1%
Age: under construction

Surface 9: (PA15)

Porous asphalt
MAS: 15 mm
P: 22.0%
BP: 4.5%
Age: under construction

Figure 1. Test sites, aspect and properties of the surface

The estimated texture depth (ETD) was measured with a High Speed Profilometer in a length of 30 m before and after the microphone location on surfaces S1 to S7. For surfaces S8 and S9 the Sand Patch Method was used for measuring the texture depth every 12.5 m at three cross section locations. The skid resistance (SR) was measured with the British Pendulum and then corrected regarding the reference temperature of 20ºC. In Table 1 the average of the results for these properties is presented.

Table 1. Estimated texture depth and skid resistance of the surface

Surface	ETD (mm)	SR (BPN)	Surface	ETD (mm)	SR (BPN)
S1(GG12)	1.0	54.5	S6(GGAR12)	0.7	50.0
S2(GG6)	0.6	52.2	S7(GGAR10)	0.8	52.6
S3(RAR15)	0.6	50.6	S8(DA16*)	0.9	70.0
S4(DA16)	0.7	51.4	S9(PA15)	1.5	70.0
S5(GG7)	0.6	51.8	-	-	-

4. Analysis of the results

4.1 Noise level versus speed

In Figure 2 the noise level versus speed for all vehicles measured in each section is presented. The trend line and the corresponding regression parameters are also presented.

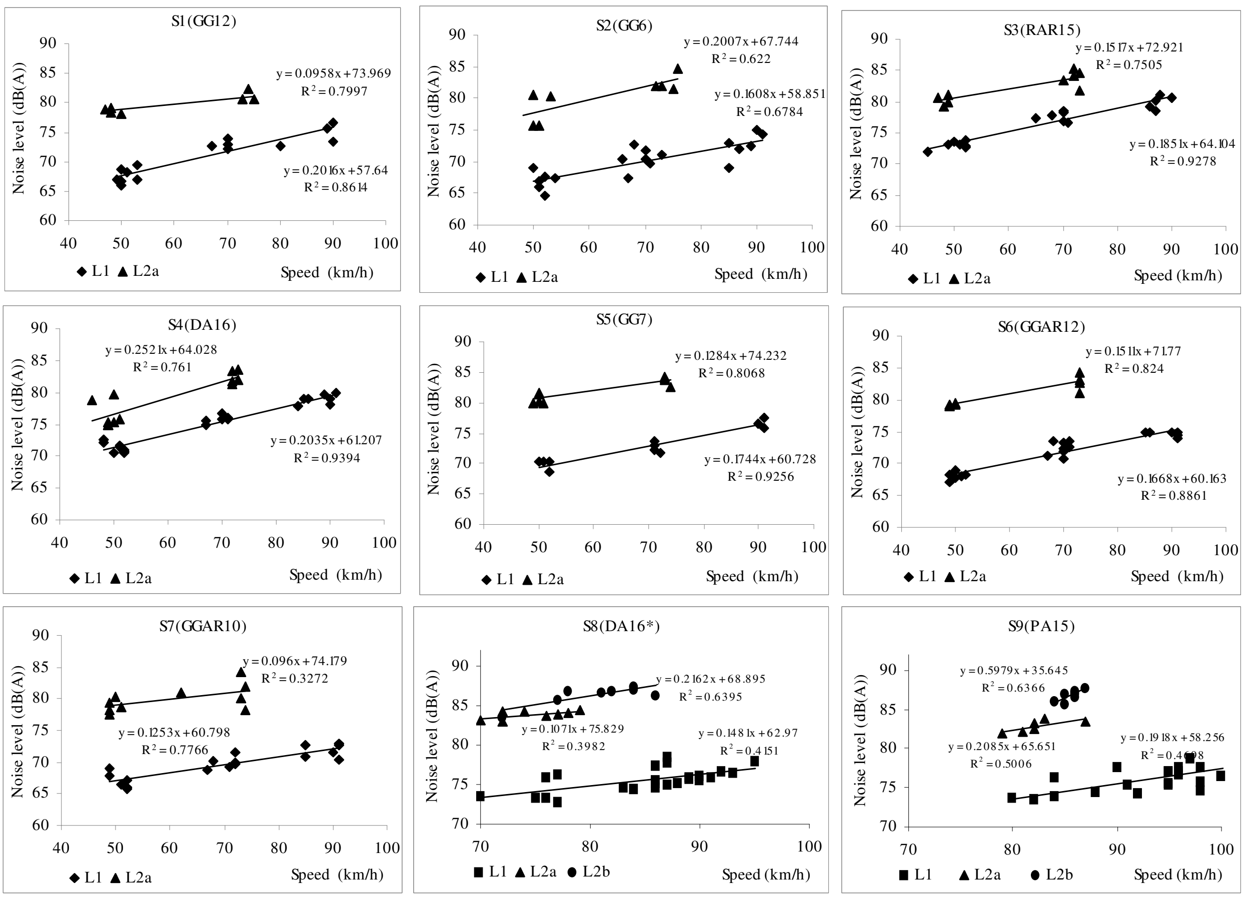


Figure 2. Noise level versus speed for all vehicles and sections

For presentation purposes, the linear regression analysis was preferred to a regression with the logarithm of the vehicle speed as the fitting quality is nearly the same for the adopted speed range. The curve slope indicates the variation of noise level with speed. When the light vehicles are concerned, noise mostly increases with speed on surface S4(DA16). The opposite is stated on surface S7(GGAR10). Therefore, for heavy vehicles the variation of the noise level with speed is similar in all surfaces. The curve slope for the vehicle category L2a is generally slightly smaller than for category L1 showing that noise level is less dependent on speed. The curve slope for the vehicle category L2b and for the porous asphalt S9(PA15) is considerably higher than for categories L1 and L2a.

4.2 Estimated noise level versus type of surface

For this analysis, the noise level was estimated for each nominal speed level (50 km/h, 70 km/h and 90 km/h) and for each type of vehicle using the fitted curves discussed above. Figure 3 depicts the results sorted into the increasing MAS.

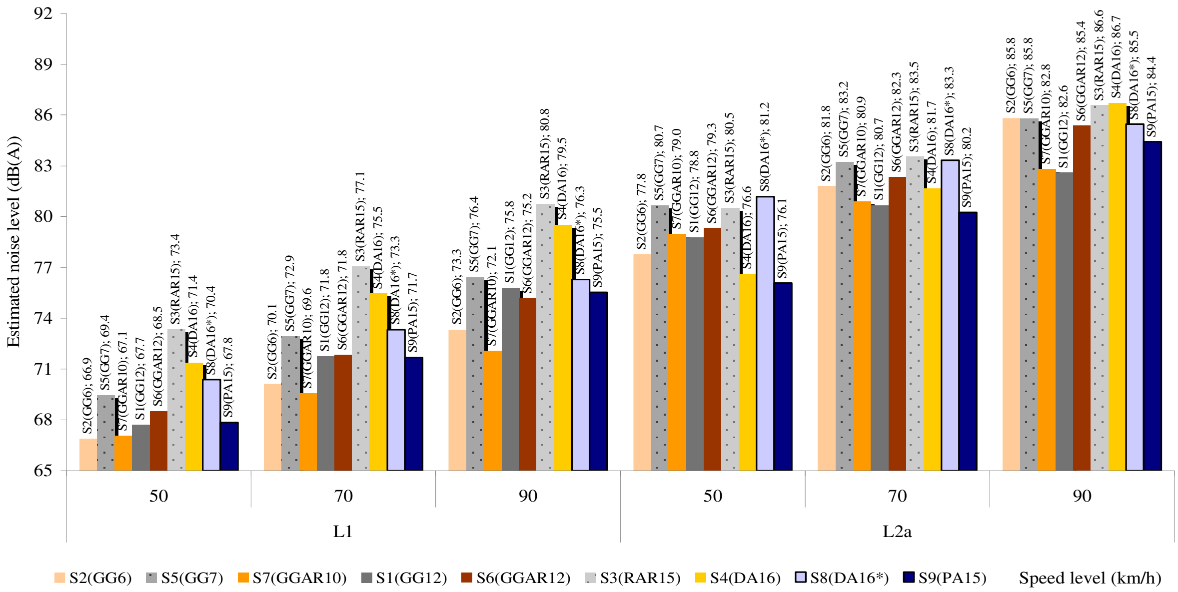


Figure 3. Estimated noise level versus speed in each section (sorted into the increasing MAS)

As far as light vehicles are concerned, surfaces S2(GG6) and S7(GGAR10) generate the lowest noise levels the range of which is [66 - 74] dB(A) for the three speed levels. These are followed by surfaces S1(GG12), S6(GGAR12) and S9(PA15), the range of which is [67 - 78] dB(A) and reference surfaces S4(DA16) and S8(DA16*), the range of which is [70 - 80] dB(A). Finally, surface S3(RAR15) generates the highest noise levels the range of which is [73 - 81] dB(A). For these conditions, the difference between the highest and the lowest value increases with speed and ranges from 6.5 dB(A) to 8.7 dB(A).

For what respects the heavy vehicles, three aspects must be taken into account. For this type of vehicles, the tyre-road noise may not surpass engine noise at 50 km/h. The differences in the noise level may be due to engine noise variation at the different pass-bys, what could be checked by switching off the engine during the pass-by. In addition, the testing range of the first experiment does not include speeds above 70 km/h and the second experiment does not include speeds under 70 km/h. Therefore, the results obtained for the speeds of 50 km/h and 90 km/h may be less reliable than for 70 km/h due to the extrapolation of the noise level.

In this case, at a speed level of 50 km/h, surfaces S9(PA15) and S4(DA16) generate the lowest noise levels while surfaces S3(RAR15), S5(GG7) and S8(DA16*) generate the highest noise levels, which are estimated in about 80 dB(A). At a speed level of 70 km/h surfaces S1(GG12), S7(GGAR10) and S9(PA15) have the best results with about 80 dB(A) and surfaces S3(RAR15), S5 (GG7) and S8(DA16*) have the highest values (83 dB(A)). At a speed level of 90 km/h surfaces S1(GG12) and S7(GGAR10) followed by surface S9(PA15) are the most silent. In this case, the difference between the highest and the lowest value is significantly smaller. Nevertheless, these differences are in increasing order of speed 4.6 dB(A), 3.3 dB(A) and 4.1 dB(A).

5. Conclusions

This paper deals with the noise produced in nine selected surfaces, seven of which on road sections under traffic loading and two on a motorway under construction. The noise tests were based on the Controlled Pass-by Method. The best performances were achieved with gap graded mixtures, with and without rubberized binder, and small grain sizes. In this study the grain size and consequently the texture of the surface seems to influence the noise level more than porosity, as it can be observed by the fair behaviour shown by the porous asphalt.

In order to verify these results, further research on thin layers should be carried out in Portugal. It should include a wider range of testing speeds for heavy vehicles, tests with wet surfaces, tests to provide texture spectrum and sound absorption tests.

6. References

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