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CONTRIBUTION OF ASPHALT RUBBER MIXTURES TO NOISE ABATEMENT – TIME EFFECT

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Abstract
Wearing course layers with a rubberized asphalt binder have been lately recommended as a measure to mitigate noise. Their acoustical performance in an early age seems to be superior to that shown by conventional layers. Nevertheless, there is no deep knowledge in relation to their behavior throughout their lifetime. The research carried out aims at observing and studying this type of mixes. For this purpose, several road sections with gap-graded mixtures, two of which with rubberized asphalt, were selected. On each road section the tyre-road noise generated by two light vehicles was measured by means of pass-by tests. After three years, those tests were repeated under the same conditions. The results focused on the comparison of the noise level versus speed among layers at the same testing time and on the same layers with different ages. The results obtained three years ago showed that gap-graded asphalt rubber mixtures have a similar performance than that of other type of gap-graded thin mixtures. The same performance was observed in the recent tests. On average, an increase of 4.0 to 4.5 dB(A) was determined for the two surfaces with rubberized asphalt, which had the same increase on noise as the control surface.

Keywords: tyre-road noise, pass-by, rubberized asphalt, performance**,** time.

1 Introduction

A careful selection of the surface layer is being increasingly adopted as a mitigating measure to the problem which is traffic noise. In fact, several studies carried out in roads with different types of surfaces and ages showed that dense asphalt concrete, stone mastic asphalt and surface dressings are the ones that generate more noise in contrast with double and single porous asphalt, thin layers and poro-elastic 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 highly contribute to high levels of noise. In the second group, the reduction of the noise generated by the texture impact mechanism is caused by the small

aggregate size. The gap-graded nature (indented or negative texture) also gives to the surface good air drainage properties that contribute to the reduction of air-pumping noise and other similar mechanisms of noise generation [4]. From this group of asphalt mixtures, the poro-eslastic one must be highlighted 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. These experimental poro-elastic mixtures are characterized by high percentages of rubber granules, up to 90% by weight, and by a high void volume.

In its turn, the use of mixtures with a small amount of rubber used to modify the binder is widely spread. These mixtures have a composition comparable to that of dense asphalt concrete, porous asphalt and the asphalt mixtures used in thin layers. They have been extensively used in the United States for decades and more recently in Europe. In Portugal the first experiment with this type of mixtures was ten years ago and since then many roads were constructed.

It was also noticed that mixtures with rubberized asphalt reduced noise. The studies conducted to prove this showed that there were noise reductions from 2 decibels to 10 decibels, recorded in Europe and in the United States [6] [7].

In Portugal four studies were carried out with these types of mixture. Two of them had results similar to the ones presented above. One of those studies compared a gap-graded rubber asphalt with a “rough” dense asphalt and with cement concrete. Another 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 [8]. In the second case, a reduction of 3 to 5 dB(A) was reported [9]. The two other studies [10] [11] showed that mixtures with rubberized asphalt had similar acoustic behaviour when compared to mixtures with the same grading.

At this stage, it is important to emphasize that the level of noise abatement depends not only on the rubberized asphalt mixture properties, but also on the method used to calculate the noise level, which may depend on traffic composition and on the speed adopted on each road, as well as on the type and surface condition taken as reference for noise level comparison.

Taking into consideration these enthusiastic results achieved with the implementation of surfaces with rubberized asphalt and the lack of time since the construction of the first ones, there is a gap in what concerns the expected noise increase with time.

A study conducted by the Sacramento County Department of Public Works which addressed two rubber pavements and a conventional one, a reduction of about 4 decibels was reported in relation to the rubber pavement few months after laying. Several years later (5 and 6) an increase of 1 decibel in the noise level of the rubber pavements was registered while the conventional pavement had lost all its noise reduction capacity [6]. The author considers that the noise increase comes from the compaction that occurs immediately after construction. Other studies conducted in the same county have shown similar results for a time span of 10 years [12].

In Europe data addressing this topic are scarce. Thus, this paper intends to give a number of insights into this issue by comparing noise levels measured through the controlled pass-by method in mixtures with rubberized asphalt which were measured with a time span of 3 years.

2 Study Methodology

In order to study the effect of time, and therefore of the traffic volume and composition, on the tyre-road noise of rubberized asphalt mixtures, the methodology hereafter was followed in two experiments carried out in May 2007 and then in January 2010, in three asphalt

mixtures: two of them with rubberized asphalt and the other one without rubberized asphalt, which was selected for control purposes.
The method used to measure noise was the Controlled Pass-By Method (CPB), which is based on the procedure recommended in the standard ISO 118919-1:1997(E) *"Acoustics – measurement of the influence of road surfaces on traffic noise – Part 1: statistical pass-by method* [13]*".* For the pass-bys, two vehicles were selected – a light vehicle and a 4×4 light vehicle. The same vehicles and tyres were used in both experiments. A microphone was positioned at 1.2 m from the pavement surface and 7.5 m from the centre of the carriageway. With this procedure it was possible to guarantee that noise measurements were not going to be influenced by other vehicles and that measurements were carried out under the same testing conditions.
The following measurements were made on each pass-by: maximum noise level and corresponding noise spectra, vehicles speed, wind speed and air and surface temperatures. The surface properties, such as the mean profile depth, were also measured. The mixture properties were kindly provided by the Road Administration of the District of Braga.
For reasons which are not related with this work, one of the rubber sections was tested several times: first in late 2009, using the current traffic the method of which will be further identified by SPB; and again in March 2007, following the previous methodology.

3 Testing Conditions

3.1 Road sections and pavement surface

For the selection of the testing sections four main conditions were taken into account: i) type and condition of the surface; ii) security regarding the length required for accelerating and breaking; iii) presence of high reflective objects; iv) the slope of the road. In Figure 1 the aspect of the surfaces in each testing site is depicted. The main properties of the mixtures, such as the maximum aggregate size (MAS), porosity (n), bitumen percentage by total weight (BP), rubber percentage by weight of the bitumen (RP) and the age at the first experiment, are presented in Table 1. In Figure 1 and in Table 1 each surface is identified by the acronym of the corresponding mixture followed by the MAS.
The mean profile depth, converted then to the estimated profile depth (ETD), was measured with a High Speed Profilometer according to the Standard ISO 13473-1:1997, in a length of 30 m before and after the microphone location. The results can be found in Table 2. In the scope of time considered, the ETD increased 0.1 mm. One of the possible causes for this increase is the loss of particles in time due to traffic aggressiveness.

Open-graded asphalt rubber (OGAR10) | Open-graded asphalt rubber (OGAR12) | Gap-graded asphalt (GG12)

Figure 1 – Aspect of the surfaces on each test site (January 2010)

Table 1 – Properties of the mixtures

Open-graded asphalt rubber (OGAR10)	Open-graded asphalt rubber (OGAR12)	Gap-graded asphalt (GG12)
MAS: 10 mm n: 14.0% BP: 9.0% RP: 20% Age: <1 year	MAS: 12 mm n: 13.0% BP: 9.0% RP: 20% Age: <1 year	MAS: 12 mm n: 3.6% BP: 5.1% RP: 0% Age: 1 year

Table 2 – Estimated texture depth

Surface	Estimated texture depth (mm)	
	2007	2010
GG12	1.0	-
OGAR12	0.7	0.8
OGAR10	0.8	0.9

3.2 Traffic

The average daily traffic (ADT) was provided by the corresponding Road Administration (Table 3). It was determined by traffic counts made every 5 years.

Table 3 – Average daily traffic at 2005

Surface	ADT total	ADT heavies
GG12	12000	750
OGAR12	19000	1100
OGAR10	15000	800

3.3 Testing vehicles, tyres and speed

The vehicles selected for testing are light vehicles. According to the standard ISO 118919-1:1997(E), one vehicle is categorized as “car” and the other one as “other light vehicles”. Figure 2 shows the testing tyres used in both experiments. It is important to consider that results will be affected by the rubber hardening in time and by wearing.

(a) (b)

Figure 2 – Test tyres: (a) Bridgestone pottenza 185/55 R14 80H; (b) Bridgestone dueler 265/70 R16 112S

The testing speeds of the first experiment consider the road category and the legal speed limitations. Therefore, three speed levels were set. Accordingly, in each section the speeds established were:

- four pass-bys at 50 km/h, 70 km/h and 90 km/h for the light vehicle;
- two pass-bys at 50 km/h, 70 km/h and 90 km/h for the other vehicle.

In the second experiment, the speed range was set to provide data not only for this work, but also for other purposes [14]. Therefore, it was widened, from 30 km/h to 100 km/h, every 10 km. There was minimum one pass-by at each speed level.

3.4 Weather

The wind speed and the temperature were measured. The wind speed was always lower than 2.5 m/s, which is considerably less than the limit recommended to accept the measurement. In relation to temperature, both the air temperature range [5ºC to 30ºC] and the surface temperature range [5ºC to 50ºC] were totally respected, as shown in Table 4.

Table 4 – Weather condition

Surface	Temperature (ºC) – 2007		Temperature (ºC) – 2010	
	Air	Surface	Air	Surface
GG12	19-29	29-36	8-10	9-13
GGAR12	19-21	22-23	10-13	11-15
GGAR10	19-20	22-26	10-14* 13-18**	14-19 25-30

* January ** March

4 Analysis of the Results

The results presented hereafter addressed the noise level for surfaces GG12, GGAR12 and GGAR10. After the analysis of the noise level versus speed for all the sections, a corroboration of the results is made by comparing data obtained through the CPB method and by the SPB methods. Eventually, the effect of time is analysed.

4.1 Noise level versus speed for all sections

Figure 3 depicts noise level versus logarithm (base 10) of speed measured in each section for all the vehicles, with a time gap of 3 years. Table 5 presents the regression parameters: coefficients of determination (R^2), intersept and slope, derived from the regression analysis of the noise level with the logarithm (base 10) of speed.

In what respects to the data quality, it is excellent, except for the SPB measurement, as it can be confirmed by the high coefficient of determination. Furthermore, data quality increased in the second experiment, probably due to the alteration of the testing methodology.

The slope of the curves which represents the ratio noise level versus speed is similar to others presented in other studies [11]. For the OGAR10 there was an increase and for the GG12 there was a decrease in the slope from 2007 to 2010, being the first one more important. The OGAR12 kept its slope throughout time.

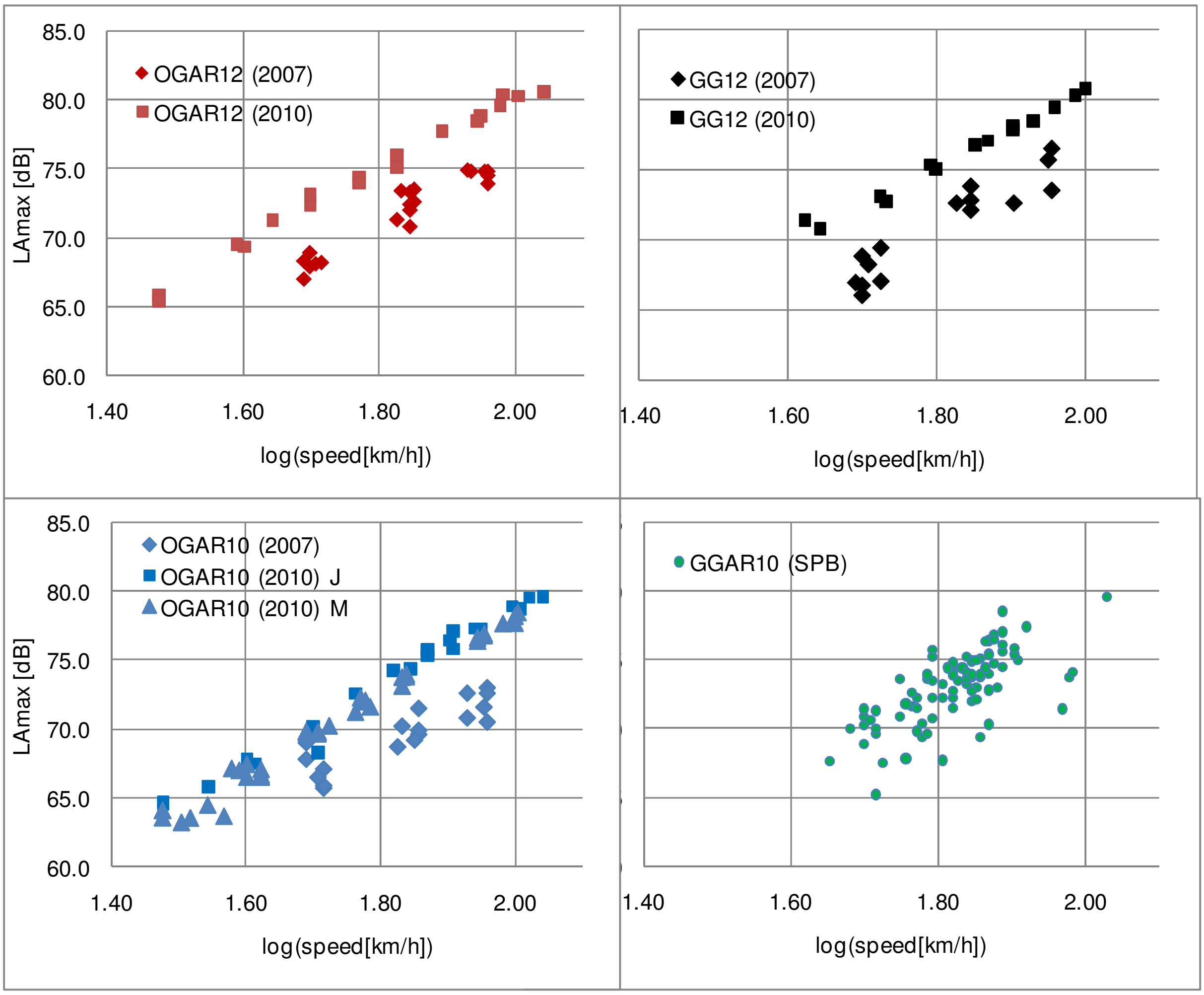

Figure 3 – Noise level versus log_{10} of speed

Table 5 – Regression parameters

Surface	OGAR10				OGAR12		GG12	
Date	2007	2010-J	2010-M	2009 (SPB)	2007	2010	2007	2010
Slope	19.6	27.9	28.8	30.3	26.4	26.9	31.4	26.6
Intersept	33.7	23.0	20.5	18.1	23.4	26.5	14.1	27.4
R^2	0.77	0.98	0.98	0.46	0.92	0.99	0.88	0.99

4.2 Corroboration of the results

Figure 4 depicts the regression lines between 50 km/h (1.70 log(km/h)) and 90 km/h (1.95 log(km/h)) for the OGAR10. The line which corresponds to the SPB method is between the ones determined by the CPB method. Therefore it can be concluded that the vehicles selected for testing represented light traffic appropriately.

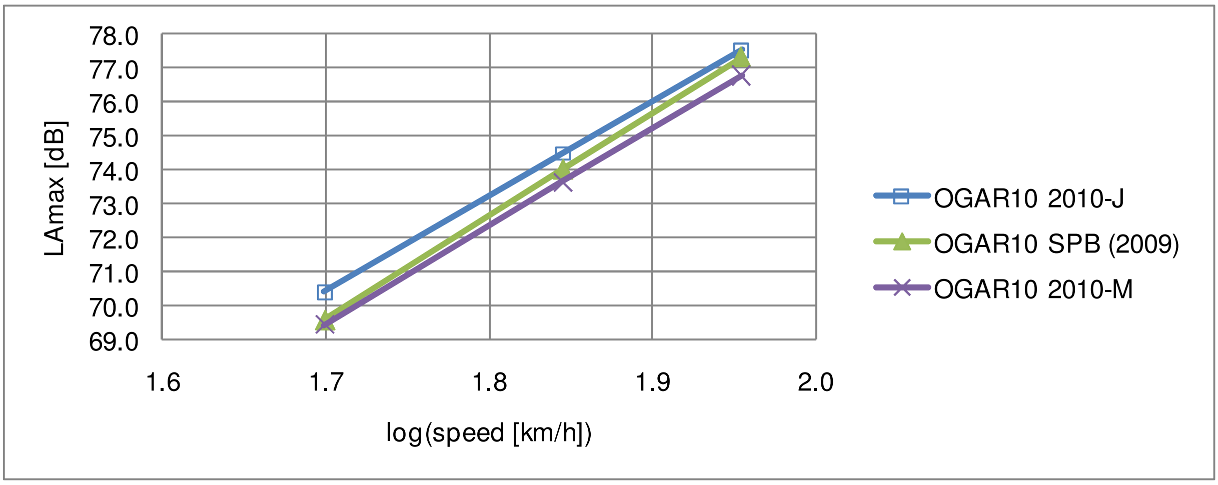

Figure 4 – Regression line LAmax versus speed in the speed range [50 km/h; 90 km/h] for the OGAR10 determined for the controlled pass-by method and for the statistical pass-by method

The results obtained through the CPB method differ between them from 1 dB(A). An explanation for this is the fact that the temperature of the surface was considerably higher in the second experiment, about 10ºC, as presented in Table 4. Nonetheless, if the temperature correction factor for the asphalt mixtures is considered and according to literature [15] the temperature correction to be applied to the data registered in March should be about -0.5 dB(A). Yet there exists a difference of 0.5 dB(A) which has not been explained. Further investigation on the effect of temperature on noise produced by rubberized asphalt is required.

4.3 Analysis of the effect of time on noise evolution

Noise levels, corresponding to three legal speed limits, were calculated from the regression parameters already presented in Table 5, in order to simplify the analysis of the effect of time on noise evolution. The resultant noise levels are gathered in Table 6 and illustrated in Figure 5. The highest values for the OGAR10 were considered for the assessment of the effect of time on noise because testing temperatures of all surfaces are reasonably approximated.
The surface made of OGAR continued being the one which presented the lowest noise levels, less 2 dB(A) than the others. Surfaces OGAR12 and GG12 had similar results in the last experiment. The variation of the noise level calculated between 2007 and 2010 is presented in Table 7.

Table 6 – Noise level calculated for speeds at 50, 70 and 90 km/h

Surface	OGAR10		OGAR12		GG12	
Date	2007	2010-J	2007	2010	2007	2010
LAmax50 [dB]	67.0	70.4	68.3	72.2	67.4	72.6
LAmax70 [dB]	69.9	74.5	72.1	76.1	72.0	76.5
LAmax90 [dB]	72.0	77.5	75.0	79.1	75.5	79.4

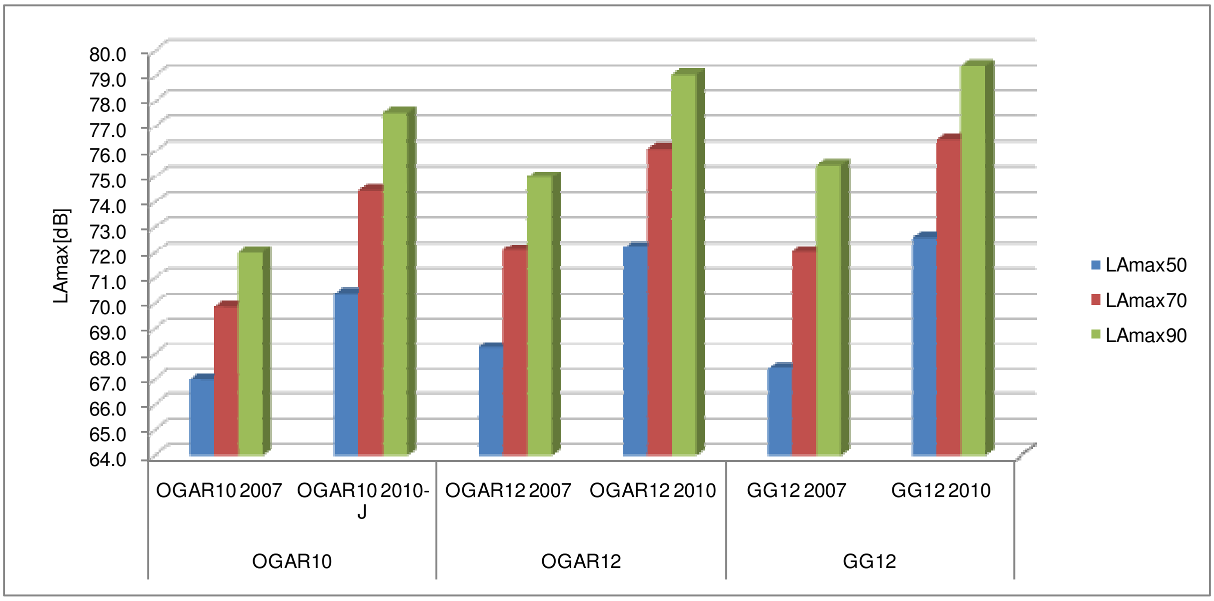

Figure 5 – LAmax versus speed calculated for 50, 70 and 90 km/h

Table 7 – Noise level variation calculated for speeds at 50, 70 and 90 km/h

Speed [km/h]	Noise level variation [dB(A)]		
	OGAR10 J	OGAR12	GG12
50	3.4	3.9	5.1
70	4.6	4.0	4.4
90	5.5	4.1	3.9
average	4.5	4.0	4.5

The following conclusions may be drawn:

- On average an increase of 4.0 dB(A) was determined for the OGAR12 and an increase of 4.5 dB(A) for the OGAR10 and for the GG12;
- Surfaces with rubberized asphalt have the same increase in noise as the control surface;
- After 3 years, the OGAR is more sensitive to high speeds while the GG10 is more sensitive to low speeds;
- The OGAR12 is equally sensitive to all speeds;
- The surface where the action of the traffic is higher (see Table 3) has an inferior increase in noise in opposition to what could be expected.

5 Conclusions

Surface layers made of asphalt which incorporates rubber, more extensively the rubberized asphalt, have been laid all over the world. In general, this type of surface layers has been recognized as noise reducers. This paper intended to provide a new insight in what respects to their performance throughout time. For this purpose, three road sections with gap-graded mixtures, two of which with rubberized asphalt, were tested twice using the same vehicles and methodology to register the tyre-surface noise within a time span of three years. The analysis of the ratio noise level versus speed showed that this ratio changed with time in two of the surfaces, one of which was the control surface. The surface with a smaller maximum grain size (10 mm) was 2 dB(A) more silent than the others. For this surface and for the control surface, an average increase of 4.5 dB(A) was determined, while the third surface had an increase of 4.0 dB(A).

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