ASPHALT RUBBER MIXTURES IN PORTUGAL: FATIGUE RESISTANCE

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Abstract

This paper presents a study concerning the fatigue behaviour of asphalt mixtures with bitumen modified with high content of crumb rubber used in Portugal.

For assessing the fatigue behaviour of this type of mixtures, four asphalt mixtures with high content of crumb rubber were used: two field bituminous mixtures – an open-graded and a gap-graded – both with granite aggregates; and two laboratory manufactured bituminous mixtures – an open-graded mixture with granite aggregates and a gap-graded mixture with crushed gravel aggregates.

Since this type of mixtures are mainly applied in wearing courses, the effect of ageing in the fatigue behaviour of one of the studied asphalt rubber mixtures was also assessed through laboratory testing.

The paper presents the main results achieved so far concerning the fatigue resistance and it could be concluded that all the materials have exhibited a good behaviour, in agreement with others previous studies. In the case of the aged gap-graded material, it was observed a slight reduction on the fatigue life comparatively to the un-aged one.

INTRODUCTION

In Portugal, bitumen modified with high content of crumb rubber is a blend of bitumen cement, reclaimed tire rubber, and certain additives in which the rubber component is at least 18 percent by weight of the total blend. This type of modified bitumen is usually known as "bitumen rubber" (BR) binder (Antunes *et al.*, 2006a). By definition, asphalt rubber (AR) mixtures produced with a BR binder are prepared using the "wet process" (Caltrans, 2003).

The use of BR binder in the production of asphalt mixtures for paving applications is considered an interesting solution for the resolution of different problems of pavements, since it contributes, in general, to an increase of the asphalt fatigue life and to its resistance to ageing and to a significant reduction of the traffic noise. These and other benefits of AR mixtures provide significantly improved engineering properties over conventional paving bituminous mixtures, reducing the costs associated with maintenance and preservation of the road network, resulting in economical and environmental benefits.

This paper presents the main results obtained in a study concerning the evaluation of fatigue behaviour and the effect of laboratory ageing on asphalt mixtures produced with BR binder. The study was carried out in the Portuguese National Laboratory of Civil Engineering (LNEC), in the scope of a broader study performed under a contract between LNEC and RECIPAV, and has concerned a master thesis submitted to IST (Technical University of Lisbon) (Miranda, 2007).

EXPERIMENTAL PROGRAM

The evaluation of the fatigue behaviour of the asphalt rubber mixtures was carried out through four points bending fatigue tests, with controlled strain, applying a 10 Hz sinusoidal load, according to the test procedure described in the European standard EN 12697-24:2004.

Furthermore, the effect of laboratory ageing on the fatigue resistance of the AR produced with crushed gravel aggregates was evaluated. In order to simulate long term field ageing, specimens were previously submitted to laboratory accelerated ageing according to the Long-term Oven Ageing (LTOA) process, developed by Bell and Sosnovske (1994) and Bell et al. (1994b) in the SHRP program. According to the LTOA procedure, test specimens are aged at 85 ºC for a period of 5 days. The results obtained in a study previously developed at LNEC (Batista *et al.*, 2006; Antunes *et al.*, 2006b) indicated that for a gap-mixture with 7% of AR, the fatigue performance of the mixture after being in-service for 6 years was very similar to the performance obtained for the lab aged specimens by the LTOA process.

Materials

The characterization of the four asphalt rubber mixtures was carried out at LNEC, and the materials were supplied by RECIPAV.

Table 1 shows the composition of the asphalt rubber mixtures used in this study.

Table 1 – Composition of the asphalt mixtures produced with BR binder

Mixtures	Mixture gradation	Aggregates nature	Bitumen grade	% crumb rubber total blend	% BR total asphalt mixture
ARO-granite	Open-graded	Granite	50/70	20	9.0
ARO-granite-lab	Open-graded	Granite	35/50	22	9.5
ARG-granite	Gap-graded	Granite	35/50	20	8.5
ARG-gravel-lab	Gap-graded	Gravel	35/50	20	8.5

The original binders used in the production of the bitumen rubber binders were either a 35/50 or a 50/70 penetration grade bitumen (according to European standard EN 12591:2000) supplied by CEPSA. These bitumens were modified with 20% or 22% of DC 3080 crumb rubber (with a 0/0.6 mm gradation). The crumb rubber was produced from tires though shredding followed by cryogenic grinding, supplied by RECIPNEU. The percentage of crumb rubber used in the modification of the bitumen (20% – 22%) is the most frequently used in the production of asphalt rubber mixtures, in Portugal.

The aggregates grading of each asphalt rubber mixture is represented in Figures 1 and 2, respectively for gap graded (ARG) and open graded (ARO) mixtures.

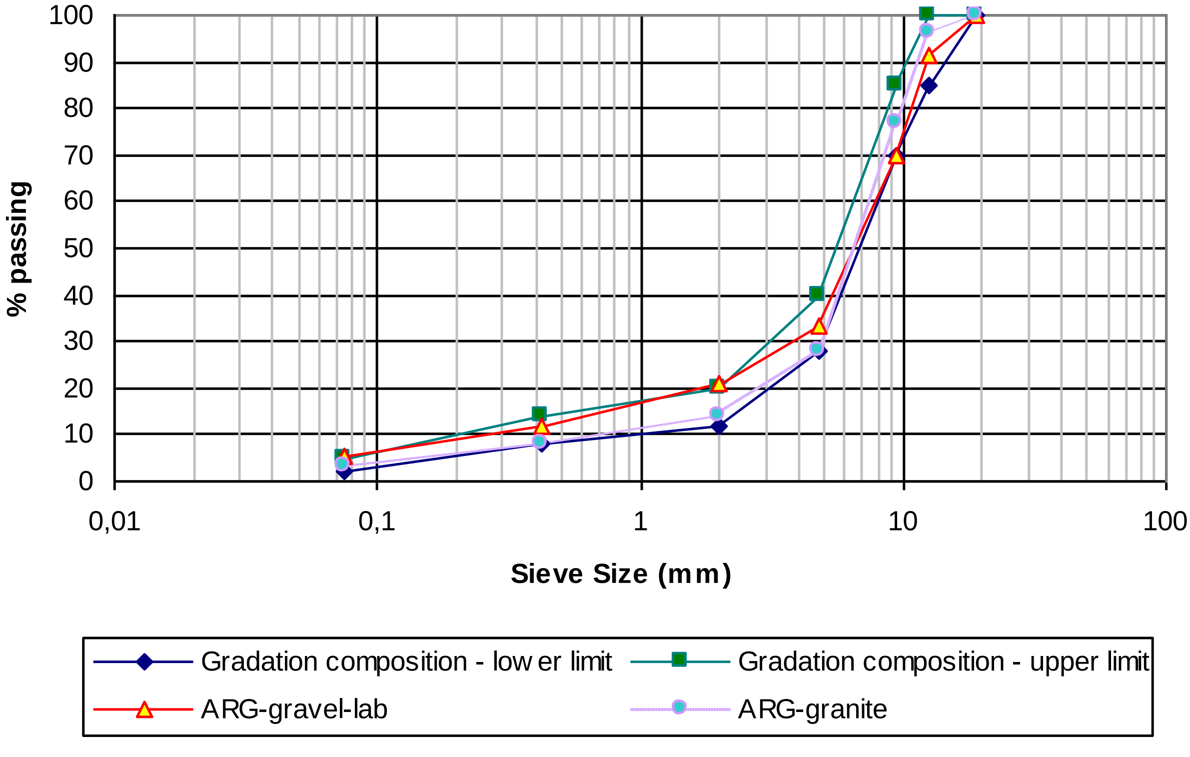

Figure 1 – ARG-gravel-lab and ARG-granite aggregate gradation and the corresponding specified gradation

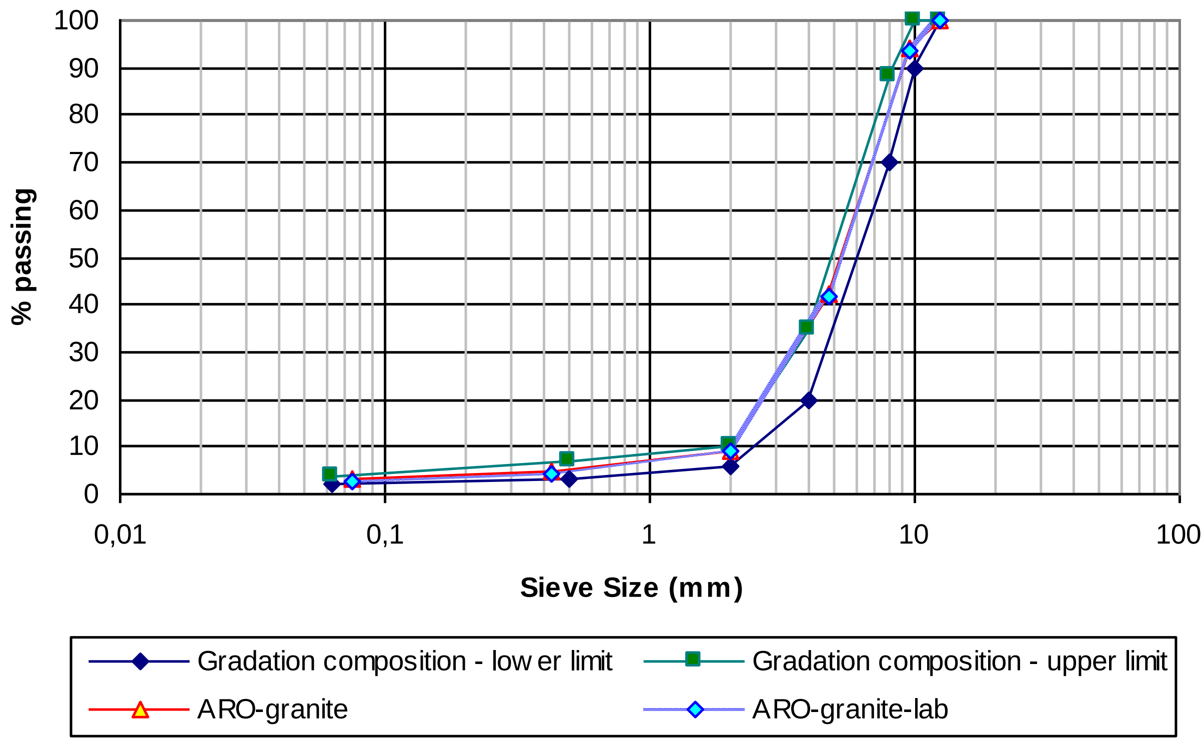

Figure 2 – ARO-granite and ARO-granite-lab aggregate gradation and the corresponding specified gradation

Test specimens

The specimens used for the experimental program were either extracted from the field by sawing (ARO-granite and ARG-granite) or mixed and compacted in the laboratory (ARO-granite-lab and ARG-gravel-lab).

In order to obtain test specimens for laboratory characterization, two slabs of the ARO-granite and the ARG wearing courses were extracted from the field (Figures 3 and 4). Each slab had dimensions of approximately 60×60×6 cm^3 and was later cut into beam specimens with approximately 53×53×400 mm^3 or 52×52×400 mm^3.

Figure 3 – Samples collected from field (ARO-granite)

Figure 4 – Samples collected from field (ARG-granite)

The laboratory produced mixtures, ARO-granite-lab and ARG-gravel-lab, were compacted in LNEC with a steel roller compactor (Figure 5). Several slabs were compacted and these were later cut into beam specimens with 51×51×400 mm^3 approximate dimensions.

Figure 5 – Laboratory mixtures manufacture phases (ARO-granite-lab and ARG-gravel-lab)

FATIGUE PERFORMANCE

The fatigue behaviour evaluation of the studied asphalt rubber mixtures was carried out through four points bending fatigue tests, according to test procedure based in the European standard EN 12697-24:2004. Tests were carried out with controlled strain, at a temperature of 20 ºC and a load frequency application of 10 Hz.

Since the tests were carried out in controlled strain, the fatigue life for a certain strain level was defined as the number of load applications corresponding to a decrease of the complex stiffness modulus to half of its initial value.

Figures 6 and 7 show the fatigue curves obtained for each of the asphalt rubber mixtures under study. For comparative effects, Figure 6 is complemented with a fatigue curve previously obtained for a gap-graded asphalt mixture produced with 7% of BR used in 1999 in the pavement rehabilitation of the Portuguese national road EN 104, also for tests performed at a load frequency of 10 Hz (Batista *et al.*, 2006).

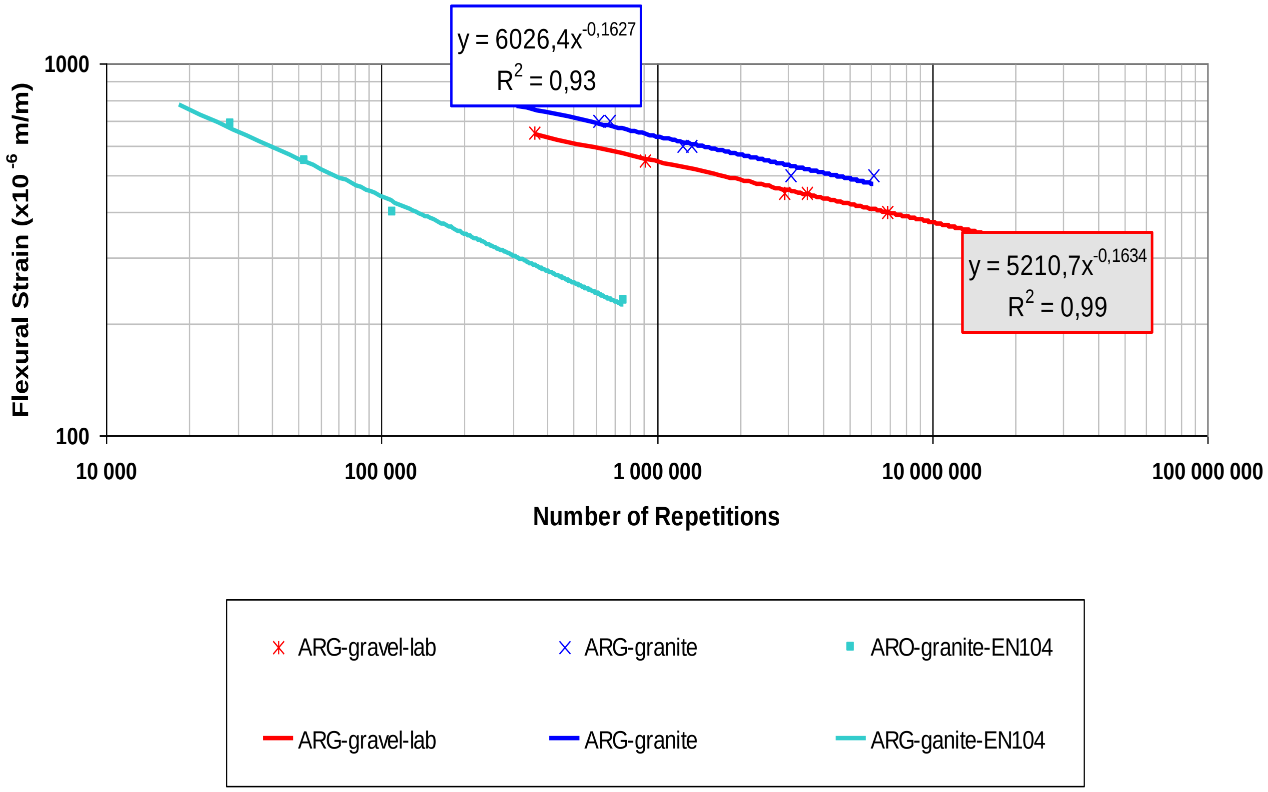

Figure 6 – Gap graded AR mixtures fatigue life (ARG-granite and ARG-gravel-lab)

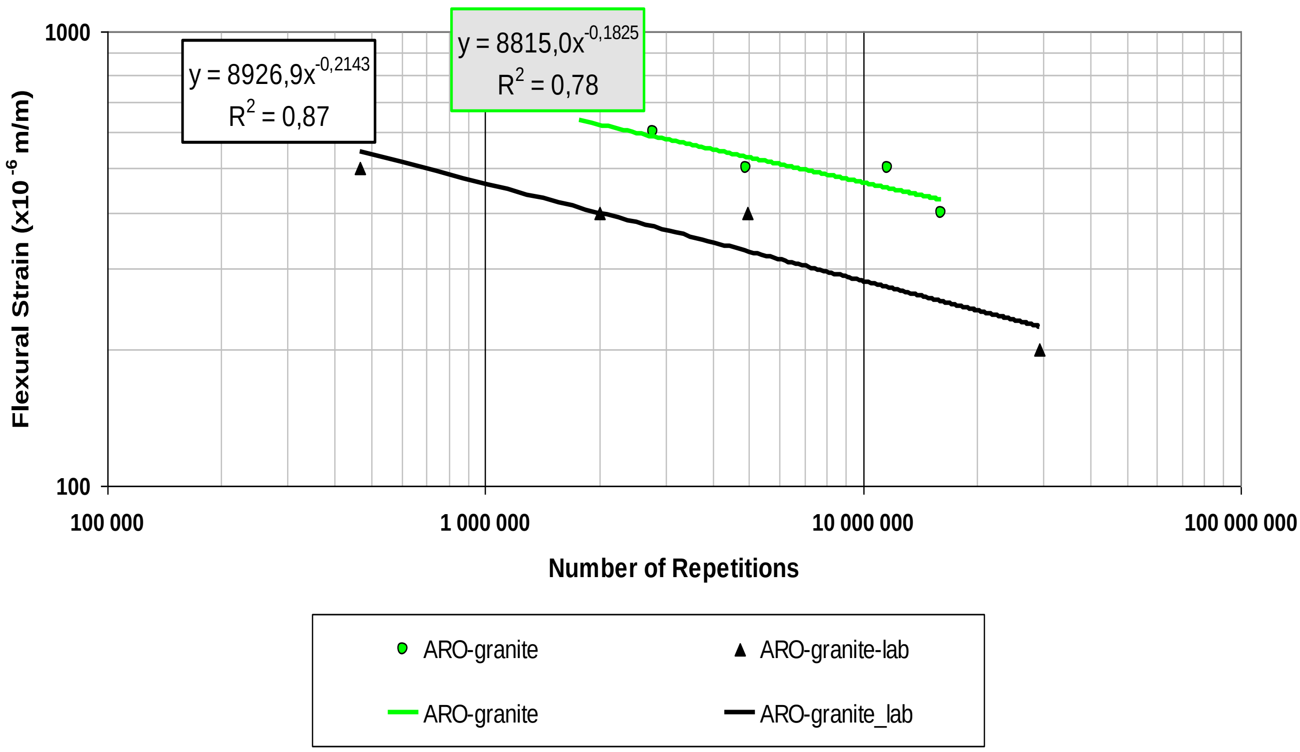

Figure 7 – Open graded AR mixtures fatigue life (ARO-granite and ARO-granite-lab)

Table 2 presents the main results obtained in the AR specimens fatigue tests, namely, the strain at which a fatigue life of one million of cycles can be expected (ε^6) and the slope of the fatigue line (p).

Table 2 – Results of the fatigue resistance tests obtained for the four AR mixtures (trials to the four points bending at 10Hz)

AR Mixture	Porosity (%)	Results	
		ε^6 ($\times 10^{-6}$ m/m)	p
ARO-granite	13.7	700	-5.5
ARO-granite_lab	12.7	460	-4.7
ARG-granite	8.1	640	-6.1
ARG-gravel-lab	6.0	550	-6.1

It is important to note that the ARG-granite specimens showed relatively high void contents, because the field samples were collected from an area close to the sidewalk where compaction can be less efficient.

From the test results presented in Figures 6 and 7 and in Table 2 is possible to conclude that both gap-graded and open-graded AR mixtures reveal a good fatigue resistance, exhibiting values of ε^6 (strain at which a fatigue life of a million of cycles can be expected) above 450×10^{-6}. Both types of AR mixtures (gap an open-graded) presented higher fatigue resistance than the generally obtained for conventional mixtures. In general, conventional mixtures present values of ε^6 of the order of magnitude of 100×10^{-6}, according to studies reported by Sousa *et al.* (1999) and Pais *et al.* (2001).

On the other hand, the results presented in Figure 6 also show that the gap-graded AR mixtures produced more recently, with a higher content of rubber in the modified binder and a higher binder content (ARG-granite) reveal an increase of the fatigue resistance comparatively to the gap-graded AR mixture used in the first application in Portugal (ARG-granite-EN104). This increase may be related to the use of higher percentages of binder.

The slope of fatigue line (p) at 10 Hz, for the gap (-6) and open-graded (-5) asphalt rubber mixtures, is similar to the observed behaviour for the conventional mixtures, when using the fatigue curve defined by Shell (1978).

INFLUENCE OF AGEING IN THE FATIGUE BEHAVIOUR OF ASPHALT RUBBER MIXTURES

The effect of laboratory ageing on the fatigue life of the ARG-gravel-lab mixture was assessed using the fatigue test procedures previously described, after conditioning the beam specimens in the oven at 85ºC for 5 days.

Figure 8 shows the fatigue curves obtained for the AR mixtures manufactured with crushed gravel using laboratory produced specimens, which were submitted to different conditioning before testing: “new” beam specimens (ARG-gravel-lab) and specimens submitted to laboratory oven ageing (ARG-gravel-lab-aged).

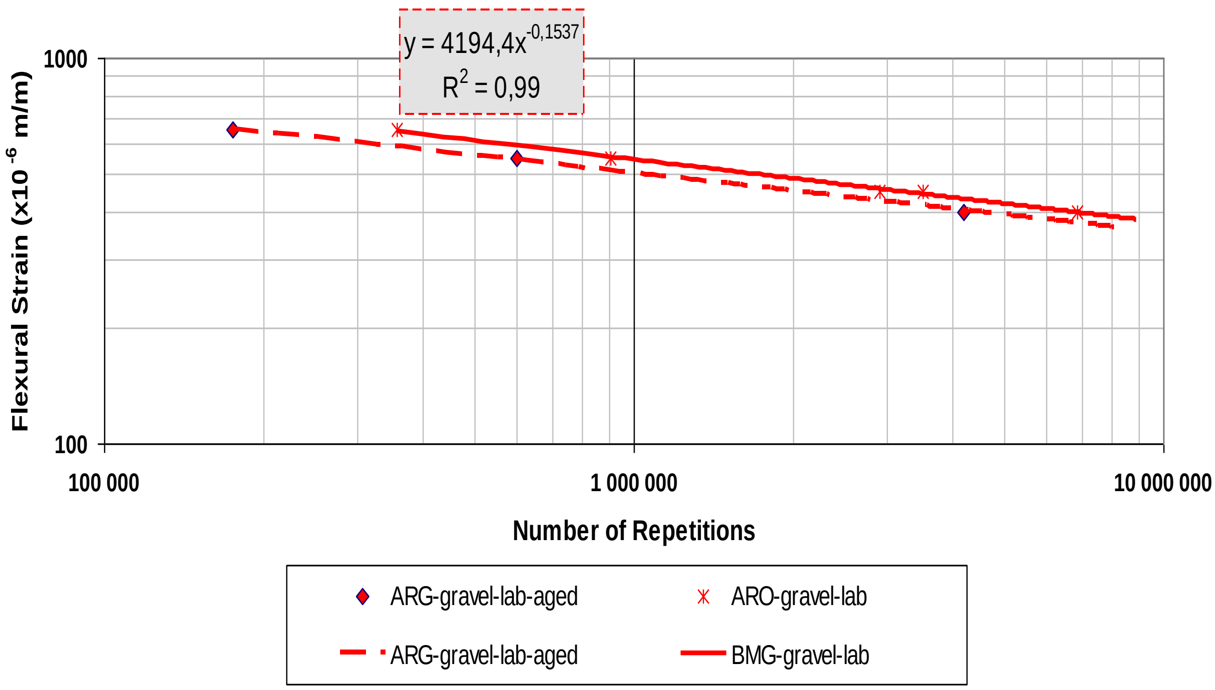

Figure 8 – “New” and laboratory aged AR mixtures fatigue life (ARG-gravel-lab and ARG-gravel-lab-aged)

The main results obtained on the fatigue tests performed with both “new” and oven-aged ARG-gravel-lab specimens are presented in the Table 3.

Table 3 – Results of the fatigue resistance obtained for the tested gap graded AR mixture with and without ageing

AR Mixture	Porosity (%)	Results	
		ε^6 ($\times 10^{-6}$ m/m)	p
ARG-gravel-lab	6.0	550	-6.1
ARG-gravel-lab-aged	6.8	500	-6.5

Figure 8 and Table 3 show that the mixture ARG-gravel_lab-aged has presented a good fatigue resistance, suffering however a slight reduction on the fatigue life comparatively to the un-aged mixture. This behaviour shows that the use of crumb rubber for modifying the bitumen induces a reduction of the ageing sensitivity of the bituminous mixtures.

The ARG-gravel_aged mixture presented a value of ε^6 of 500×10^{-6}. This value is higher than the one generally obtained for conventional mixtures not oven-aged.

As regards the slope of the fatigue line (p) of the oven-aged AR mixture, it is practically equal to the slope of the un-aged mixture.

CONCLUSIONS

From the results presented in this paper it is possible to derive the following main conclusions:

- The AR mixtures under study revealed a good fatigue resistance, since the strain that corresponds to one million load applications (ε^6) was above 500×10^{-6} for all the mixtures;
- Both types of asphalt rubber mixtures (gap an open-graded) have exhibited higher fatigue resistance than conventional mixtures;
- The gap-graded AR mixtures produced with a higher content of bitumen-rubber binder show an increase of the fatigue resistance comparatively to the AR mixtures used in the first application in Portugal, where a lower binder content was used;
- The slope of fatigue line (p) for the gap and open-graded asphalt rubber mixtures is of the similar to the one verified for the conventional mixtures.
- The aged gap-graded AR mixture (ARG-gravel_aged) shows a good fatigue performance, having suffered a slight reduction of the fatigue resistance comparatively to the un-aged mixture.

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