[CI-06]

Pereira, P.A.A., **Pais, J.C.**, Azevedo, M.C.M.

"Improvement of permanent deformation and fatigue life of bituminous mixtures by using modified bitumens"

Fifth International Conference on the Bearing Capacity of Roads and Airfield, Trondheim, 1998

VOLUME II

Proceedings

Editors: Rasmus S. Nordal and Geir Refsdal

BCRA'98

Fifth International Conference on the
Bearing Capacity of Roads and Airfields

TRONDHEIM, NORWAY 6 – 8 JULY 1998

BEARING CAPACITY OF
ROADS AND AIRFIELDS

Fifth International Conference on the
BEARING CAPASITY OF
ROADS AND AIRFIELDS

IMPROVEMENT OF PERMANENT DEFORMATION AND FATIGUE LIFE OF BITUMINOUS MIXTURES BY USING MODIFIED BITUMENS

PAULO A. A. PEREIRA[1], JORGE C. PAIS[2]
M. CONCEIÇÃO AZEVEDO[3]

[1]Associate Professor, University of Minho, Guimarães, Portugal,
Fax: +351-53-510-217, Email: ppereira@ci.uminho.pt
[2]Research Assistant, University of Minho, Guimarães, Portugal,
Fax: +351-53-510-217, Email: jpais@eng.uminho.pt
[3]Thecnical Director, APORBET, Portugal,
Fax: +351-1-793 1212, Email: aporbet@mail.telepac.pt

ABSTRACT

This paper describes the results of a study aiming the evaluation of pavement performance improvement by using a polymer modified bitumen as binder. Two dense graded bituminous mixtures were produced in laboratory. The first one was produced with conventional bitumen and the second one with polymer-modified bitumen.

Permanent deformation tests were carried out in a shear servo-hydraulic machine using the repetitive simple shear test at constant height. Fatigue life tests were carried out in an axial servo-hydraulic testing system using a flexural beam.

A comparison between these two mixtures was made for tensile strains calculated for a typical flexible pavement structure where these two mixtures were considered.

Key words: Bituminous Mixture, Permanent Deformation, Fatigue Life, Conventional Bitumen, Polymer Modified Bitumen.

INTRODUCTION

In order to increase the stiffness and the permanent deformation resistance of flexible pavements to high summer temperatures and to improve their resistance to crack initiation in winter conditions, the use of modified binders has begun in Portugal, namely in the North and Northest regions.

The purpose of this paper is to present information on the improvement of permanent deformation resistance and fatigue life of bituminous mixtures when using polymer modified bitumen (SBS).

In order to carriy out a comparison and to reveal the difference between a traditional mixture and a modified one, the mixtures to compare were subjected to the following tests:

- Repetitive simple shear test at constant height, according to SHRP program;
- Dynamic four point bending test.

ANALYSED MATERIALS

The bituminous mixtures of this study are a dense graded for a binder course with a maximum aggregate size of 25 mm according to the Portuguese standards. The aggregate used was a crushed granite with the grading curve shown in Table 1.

Table 1. Aggregate gradation

Sieve size (mm)	Percentage passing (%)
25.0	100
19.0	94
12.5	80.5
4.75	52.5
2.00	39
0.425	21.5
0.180	13.5
0.075	7.5

Two different bitumen types were used; a conventional 50/70-penetration grade bitumen and a polymer modified bitumen (SBS). The bitumen properties are presented in Table 2. The bitumen content was 5% by aggregate weight and the void content was 6%.

Table 2. Properties of bitumen

	Conventional	Modified (SBS)
Penetration, 25°C, 100 g, 5 seg., 0.1mm	62	61
Softening point, °C	53.1	58.0

SPECIMENS PREPARATION

The specimens were prepared in laboratory with the rolling wheel compaction method. So, the compaction was made with a lightweight vibratory steel roller in a steel coated wooden mould. The roller was repeatedly passed over the mixture placed in the mould. Rolling wheel compaction involves the use of weight and volume calculations to determine the mass of material to be compacted into a known volume to the desired void content.

After the mixture cooling, beams for the four point bending test and cylindrical specimens for shear tests were sawed.

Cylindrical test specimens with 15 cm diameter were cored from slabs compacted in laboratory for permanent deformation tests and prismatic specimens with 38.1 cm long by 6.25 cm wide by 5.0 cm high for fatigue tests.

It is interesting to note that the mixtures with polymer modified binder exhibited a better workability than the mixtures with unmodified binder.

TEST EQUIPMENT

The test equipment existing in th University of Minho, aiming the permanent deformation characterization, and used in this study, was a CS7400S shear servo-hydraulic machine, introduced during the SHRP program.

The machine testing capabilities and accommodation of add-on testing modules permits fatigue and stiffness testing as well as permanent deformation evaluation using axial and shear mode of loading (Pereira et al, 1997).

Specimens are glued to axial and shear plates such as represented in Figure 1.

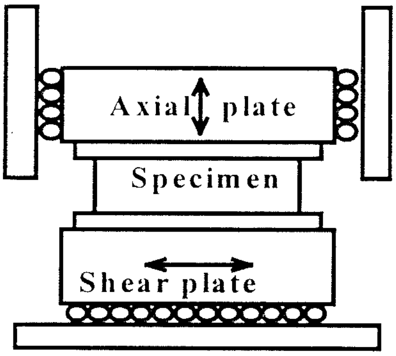

Figure 1. Schematic representation of shear apparatus.

Aiming the stiffness and fatigue life determination a servo-hydraulic equipment allowing four point bending test on beam specimens was used. The flexural beam device used to transfer the load to the specimen has a free translation and a free rotation at the reaction points and at load points (Pais et al, 1998).

Those equipments are controlled by a microcomputer using a software that provides a feedback closed-loop control to the servo-hydraulic system, test temperature and data acquisition. The flexural beam device, in association with the software capabilities, has considerably improved the reliability of results compared with earlier devices (Tayebali, 1994).

STIFFNESS AND FATIGUE PERFORMANCE

The four point bending tests were carried out under displacement control (strain control) at a 20°C temperature. For the stiffness evaluation, a cyclic load and frequency sweep, between 10 Hz and 0.1 Hz, were used.

For fatigue performance evaluation the same sinusoidal wave was used and the tests were performed for 3 strain levels and 10 Hz.

Figure 2 presents the stiffness of bituminous mixtures as a function of frequency, for the two types of mixtures analyzed.

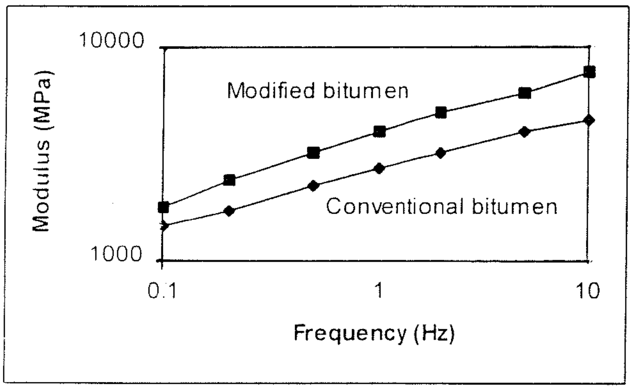

Figure 2 – Stiffness of bituminous mixtures as a function of frequency.

Figure 3 presents the fatigue life of the two bituminous mixtures.

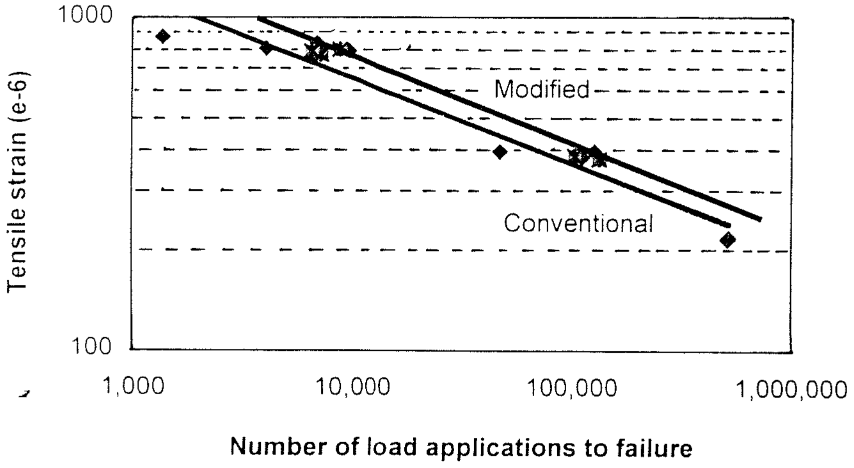

Figure 3 – Fatigue life laws for the two mixtures.

The comparative tests have explicitly shown the positive contribution of the SBS modified bitumen to improve the bituminous mixture behaviour, regarding fatigue life.

As a matter of fact, for an usual pavement tensile strain level of about 200 microstrain, the fatigue life of mixture with modified binder can be improved of about 49%.

On the other hand, a pavement design was performed, using a mechanistic approach, considering a typical pavement structure, within national conditions.

The pavement structure (whose response was calculated using a structural model where the materials were assumed as linear elastic) and the ALIZE computer program was set-up, assuming the materials properties presented in Table 3.

Table 3 – Layer modulus (E) and Poisson ratios (v) adopted.

Surface course Bituminous mixture		Binder course Bituminous mixture		Base course Granular material		Sub-base course Granular material		Subgrade	
E1 (MPa)	v1	E2 (MPa)	v2	E3 (MPa)	v3	E4 (MPa)	v4	E5 (MPa)	v5
3000	0.40	4000 a) 6000 b)	0.40	300	0.35	150	0.35	80	0.35
5 cm		12 cm		20 cm		20 cm			

a) Traditional mixture
b) Modified mixture

The stiffness of bituminous mixture for the binder course were the values obtained in this study (200 microstrain at 20 °C and 10 Hz), for the two types of mixtures analyzed.

The tensile strain calculated for a 80 kN load at the bottom of binder course was $185*10^{-6}$ and $147*10^{-6}$, for the traditional mixture (without modified binder) and modified mixture, respectively.

Using the laboratory fatigue life it can be observed that the number of load applications to failure is $1.4*10^{6}$ and $5.1*10^{6}$, for the traditional mixture and modified mixture, respectively.

Thus, the use of a polymer modified bitumen (SBS) can improve the bituminous fatigue life of about 2.6 times.

PERMANENT DEFORMATION AND FATIGUE CRACKING BEHAVIOUR

The repetitive simple shear tests at constant height were performed according to the SHRP program recommendations, as stated in AASHTO TP7 standard. These tests were undertaken at 60°C.

Figure 5 and 6 present the shear complex modulus and the phase angle as a function of frequency, for the two types of mixtures. Table 4 shows the ESALs values obtained for the two types of mixtures.

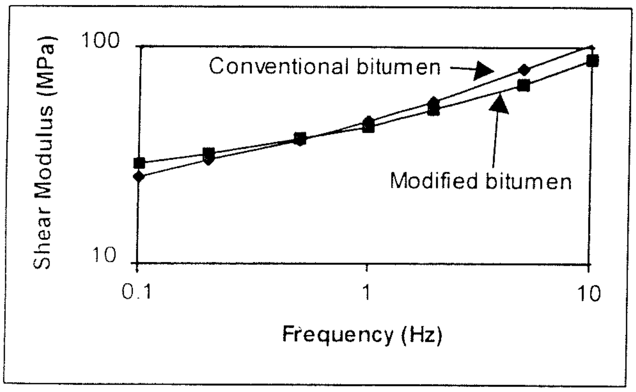

Figure 5 – Shear modulus as a function of frequency.

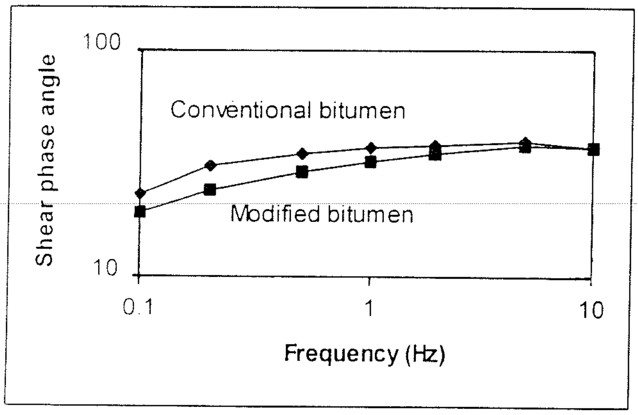

Figure 6 – Shear phase angle as a function of frequency.

Table 4 – ESALs obtained in shear tests

	Conventional	Modified
Specimen	ESALS	ESALS
	to 12.5 mm	to 12.5 mm
1	1 113 688	1 147 556
2	4 990 649	1 035 891
3	1 608 790	2 576 734
4	5 616 796	3 677 276
5		1 518 406
average	2 662 117	1 764 470

The permanent deformation behaviour of the two different types of mixtures have not revealed an expressive difference, such as the fatigue behaviour.

Nevertheless, the phase angle values of traditional bituminous mixtures are higher than for mixtures with modified binder, specially for the lower frequencies. As a matter of fact, for higher frequencies (2 to 10 Hz) the mean difference between the phase angle is about 5 to 10%, whereas the difference is about 20% for lower frequencies (0.1 to 0.5 Hz).

CONCLUSIONS

This study has compared fatigue response and permanent deformation behaviour of bituminous mixtures with conventional binder (50/70 pen) and polymer modified binder (SBS).

The use of elastomer modified binder was most expressively shown in the improvement of the fatigue behaviour. The service life of such materials can reach 2.6 times when compared with unmodified ones.

REFERENCES

1. Tayebali, *Stiffness of asphalt-aggregate mixes*, Report A388, SHRP A003A (1994).
2. Pereira, J.C. Pais and M.C. Azevedo, *Shear tests for bituminous mixture characterization,* (1997).
3. Pais, J.C., P. Pereira, J. Sousa, *The reflective cracking in thin surfacings*, First world Conference on Highway Surfacings, (1998).