STUDY OF THE BEHAVIOUR OF BITUMINOUS MIXTURES RESISTANT TO FUEL

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ABSTRACT

Fuel spillage on the wearing courses of road and airport pavements can significantly affect fuel resistant bitumen performance. The use of modified bitumen specifically manufactured to give the asphalt mixture a better resistance to the action of the fuel is an interesting solution for use in areas with specific requirements of that point of view.
In order to assess the performance of asphalt resistant fuel a study, sponsored by PETROGAL, was developed in LNEC, in which asphalt mixtures were produced with three types of bitumen - a 35/50 pen grade bitumen penetration, and two modified bitumen – were studied for application in wearing courses.
One of the modified bitumens has been specially developed to provide increased resistance to fuel. The study comprised a comparative analysis of the behaviour of different asphalt action by fuel, as well as the evaluation of their performance in fatigue tests and permanent deformation behaviour.
This paper presents the results obtained from the study, analyzing the benefits of using fuel resistant bitumen in the performance of asphalt mixtures subject to the action of fuel spillage.

1. INTRODUCTION

At the request of Petrogal - Petróleos de Portugal, SA, LNEC developed a laboratory study in order to evaluate the performance of asphalt mixtures applied on wearing courses of road and airport pavements when subjected to the action of fuel spillage. Asphalt mixtures produced with different types of bitumen were studied. The experimental program was based on the test method EN 12697-43 "Bituminous mixtures - Test methods for hot mix asphalt - Part 43: Resistance to fuel", complemented with other laboratory tests to determine the performance of asphalt mixtures.
The study was conducted using materials provided by Petrogal (aggregates, filler, bitumen and fuel). The asphalt mixtures were made with one type of aggregate combined with three types of bitumen, a grade pen 35/50 (conventional), a polymer modified bitumen and a bitumen especially modified for fuel resistance. The resistance to fuel was determined for three different types of fuels: gasoline 95, diesel and Jet A1. This paper will present the results obtained up to now in the study.

2. WORK PROGRAM

Taking into account the objectives of the study, the following activities were developed:
• Manufacture and compaction of asphalt mixtures with the different types of bitumen selected for the study;
• Evaluation of resistance to fuel on asphalt specimens, according to EN 12697-43:2005;
• Complementary laboratory tests to assess the asphalt mixtures performance related - modulus, fatigue and permanent deformation - according to EN 12697-26:2004, EN 12697-24:2004 + A1: 2007 and EN 12697 -22:2003 + A1: 2007, respectively;
• Complementary tests for assessing the water sensitivity of bituminous specimens, according to EN 12697-12:2008.
The determination of resistance to permanent deformation, the stiffness modulus and the assessment of the fatigue behaviour of the three bituminous mixtures is carried out on prismatic specimens compacted in the laboratory as recommended in EN 12697-33:2004 + A1: 2007, using the roller compactor (5.3 of the standard test specification).
The specimens for testing (4 point bending) were obtained by sawing the slabs. These tests are still going on.

3. BITUMINOUS MIXTURES COMPOSITION

The manufacture of the bituminous mixtures used in the study included 10/14, 6/12 and 0/4 fractions, obtained from crushed granite rock, from the Secil Britas quarry in Penafiel. The added filler used was provided by Eurocálcio. These materials were used in the following proportions:

- Aggregate 10/14 – 19.0%
- Aggregate 6/12 – 30.4%
- Aggregate 0/4 – 42.7%
- Filler – 2.9%
- Bitumen – 5.0%

The three different types of bitumens used in the manufacture of the asphalt mixtures were supplied by Petrogal:

- Penetration grade bitumen 35/50 (Galp 35/50)
- Polymer modified bitumen PB 1,5 with a penetration grade 35/50 (Galp PB 1,5 (35/50))
- Kero bitumen, resistant to fuel, with 35/50 penetration grade (Galp Kero (35/50))

The corresponding asphalt mixtures are identified as MB 35/50, MB PB 1,5 and MB Kero.

4. PRESENTATION AND ANALYSIS OF RESULTS

4.1 Resistance to fuel

The resistance to fuel was evaluated according to EN 12697-43:2005, for the three types of bituminous mixtures and the three types of fuel. The test method recommended in this standard comprises two distinct and selective phases. In the first stage the specimen is partially immersed in fuel and its loss of mass is measured afterwards. If the mass loss is greater than 5%, the test will be finished and the specimen is awarded a "low resistance" to fuel. If mass loss is lower than 5% the sample undergoes a brushing procedure made with a wire brush, which constitutes the second phase of the test. The classification of the resistance to fuel is performed on the basis of the average loss in mass (B), during the second phase, and the average value (A) obtained in the first stage:

a) good resistance to fuel if A ≤ 5% and B < 1%
b) moderate resistance to fuel if A ≤ 5% and 1% ≤ B < 5%
c) poor resistance to fuel if A > 5% or B > 5%

EN 12697-43 recommends that the period of immersion in fuel is 24 hours ± 30 min. at room temperature (between 18°C and 25ºC). In the case of polymer modified bitumen, the recommended immersion period is 72 hours ± 30 min.
Since this is a comparative study of penetration grade bitumens and polymer modified bitumen, the selected immersion time in fuel was 24 hours ± 30 min for all samples, as recommended in the standard. Figure 1(a) and (b) shows the residue resulting from the immersion of a sample of 35/50 MB in 95 gasoline, as well as the appearance of three pieces of the mixture MB PB1 after immersion in fuel for 24 h. Figure 1(c) shows the pieces of PB 1.5 MB after immersion in fuel (gasoline 95) and washing.

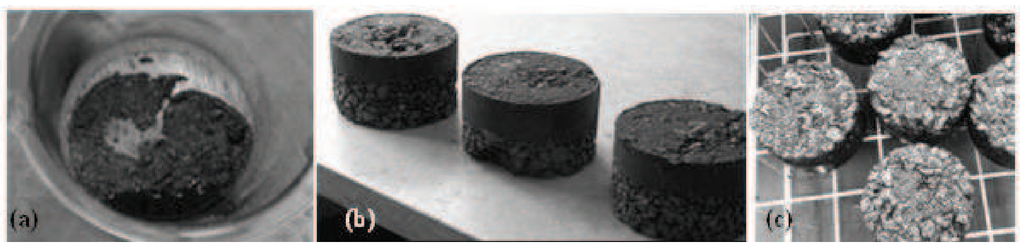

Figure 1. After soaking in fuel (gasoline 95): (a) mixture residue MB 35/50; (b) specimens of MB PB 1,5; (c) MB PB 1,5 after immersion and washing

Figure 2 demonstrates the various stages of the brushing process the samples obtained after immersion in fuel and washing undergo.

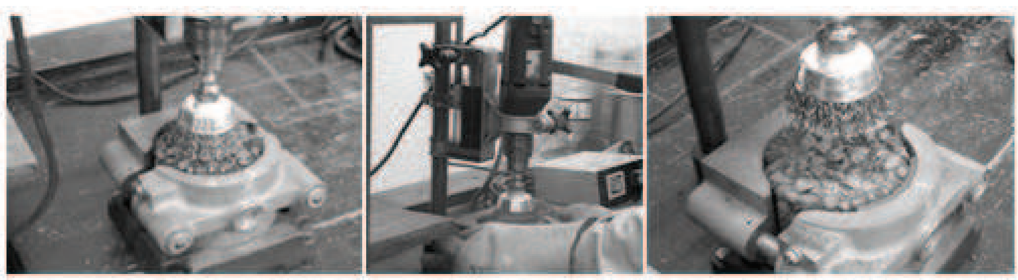

Figure 2. Brushing test of bituminous specimens

It could be argued that in the test procedures during the first stage and second stage are of a very extreme nature, and therefore they are not realistic with respect to their service conditions for asphalt mixtures applied on wearing courses of pavements or airports where there is leakage fuel.
However, when two or more types of asphalt mixtures are tested, the application of this test method will allow for a comparative analysis of its resistance.
Table 1 shows the results obtained in the study of resistance to fuel of the three asphalt samples here.
The analysis of the results presented in Table 1 lead to the following considerations:
• For the three bituminous mixtures under study, 95 gasoline led to the highest mass loss after immersion; diesel was the fuel that caused the lowest mass losses;
• The asphalt mixtures 35/50 MB and 1.5 MB PB had a poor resistance to fuel, with mass losses after immersion higher than 5%, without brushing, when exposed to gasoline 95;
• MB Kero presented the best behaviour when subjected to the brushing, but the same values of mass loss on immersion than those of other bituminous mixtures. Therefore has a better resistance to the action fuel than the remaining mixtures.
Note that, although normally diesel is considered the most aggressive fuel, this was not the case for the test results. In fact, in

the test procedure specimens were immersed in different fuels for equal periods of time.
In a normal situation in service, the pavement surface will be more exposed when diesel is spilled, because this type of fuel will remain on the surface for along period.

Table 1. Resistance to fuel (EN 12697-43)

Asphalt mixture	FUEL								
	JET A1			DIESEL			GASOLINE 95		
	1st phase (soaking in fuel)	2nd phase (brushing)	Classification	1st phase (soaking in fuel)	2nd phase (brushing)	Classification	1st phase (soaking in fuel)	2nd phase (brushing)	Classification
MB 35/50	A_i = 2,7 A_i = 1,5 A_i = 2,7	B_i = 3,0 B_i = 1,2 B_i = 3,3	-	A_i = 1,5 A_i = 1,8 A_i = 1,3	B_i = 2,8 B_i = 1,6 B_i = 1,9	-	A_i = 3,5 A_i = 9,0 A_i = 6,2	B_i = 2,7	-
	A = 2	B = 3	**RM**	A = 2	B = 2	**RM**	A = 6	B = 3	**RF**
MB PB 1,5	A_i = 2,7 A_i = 3,8 A_i = 2,4	B_i = 1,4 B_i = 3,6 B_i = 2,5	-	A_i = 1,4 A_i = 1,7 A_i = 1,7	B_i = 1,6 B_i = 1,2 B_i = 1,9	-	A_i = 6,4 A_i = 6,9 A_i = 5,5	---	-
	A = 3	B = 3	**RM**	A = 2	B = 2	**RM**	A = 6	---	**RF**
MB Kero	A_i = 3,0 A_i = 4,2 A_i = 3,0	B_i = 1,4 B_i = 1,5 B_i = 1,1	-	A_i = 2,1 A_i = 2,9 A_i = 3,1	B_i = 0,9 B_i = 1,2 B_i = 1,2	-	A_i = 3,8 A_i = 3,9 A_i = 4,3	B_i = 1,0 B_i = 1,1 B_i = 1,5	-
	A = 3	B = 1	**RM**	A = 3	B = 1	**RM**	A = 4	B = 1	**RM**

LEGENDA:
Ai – Individual values of the loss of mass after soaking in fuel;
Bi – Individual values of the loss of mass after the brush test;
A – Mean value of the loss of mass after soaking in fuel;
B – Mean value of the loss of mass after the brush test;
RM – Moderate resistance;
RF – Poor resistance.

5. PERMANENT DEFORMATION BEHAVIOUR

For each of the three types of bituminous mixtures in the study, two slabs were prepared in laboratory using the roller compactor as recommended in EN 12697-33:2004 + A1: 2007, which after sawing and correction possible to obtain prismatic specimens for testing.
The assessment of resistance to permanent deformation was carried out according to EN 12697-22:2003 + A1: 2007, using small size device, according to procedure B, on air. The specimen submitted for testing had a thickness of 50 mm.
The elapsed time between the preparation of specimens and the start of the test was over 4 hours and less than 24 hours. The wheel tracking tests were carried out in accordance with the reference standard, at a temperature of 60 º C.
The values of bulk density of the samples, obtained as stated in EN 12697-6:2003 + A1: 2007 (method B), and the results obtained in the wheel tracking test for the two specimens of each type of mixture, are presented in Table 2.

Table 2. Wheel tracking test results (EN 12697-22)

Parameter	MB 35/50		MB PB1,5		MB Kero	
	Specimen 1	Specimen 2	Specimen 1	Specimen 2	Specimen 1	Specimen 2
Bulk density (kg/m^3)	2396	2398	2392	2396	2390	2388
Maximum deformation (mm)	4,71	6,70	3,98	5,54	1,62	1,71
Mean rut depth at 10000 cycles (mm) (RD_{AIR})	5,7		4,8		1,7	
Wheel-tracking slope in air (mm/10^3 cycles)	0,26	0,35	0,17	0,22	0,03	0,04
Mean wheel-tracking slope in air (mm/10^3 cycles) (WTS_{AIR})	0,30		0,20		0,04	
Rut proportional depth at 10000 cycles (%)	9,4	13,4	8,0	11,1	3,2	3,4
Mean proportional rut depth (%) (PRD_{AIR})	11,4		9,5		3,3	

The results in Table 2 show that the three mixtures tested with different types of bitumen had distinct performances. Kero MB mixture presented the best resistance to permanent deformation, with values of maximum deformation of about one third of those obtained for the other mixtures.

6. WATER SENSITIVITY

In addition to the tests characterization of resistance to permanent deformation the water sensitivity of asphalt mixtures was evaluated, according to test method EN 12697-12:2008 - "Bituminous mixtures - Test method for hot mix asphalt. Part. 12 - Determination of the water sensitivity of bituminous specimens.
In accordance with the methodology recommended in the European standard, a total of 6 cylindrical specimens of each type of asphalt mixture were prepared. For each type of mixture 3 specimens with similar characteristics according to their height and bulk density were assigned to two groups. All specimens were compacted within the same week, and thereby had similar ages when tested, as required in the standard.
One of the test group was conditioned in air at a temperature of 20ºC. The specimens from the other group were immersed in water at 20°C and subjected to vacuum, so that the water penetrated into every pore. They were subsequently kept in a water bath at 40 ° C, for a period of 68 to 72 h. After conditioning, the specimens were tested to determine the indirect tensile strength at a temperature of 15°C, as recommended in EN 13108-20.
Table 3 presents the average values of bulk density for each group of specimens and the indirect tensile strength of the two sets of specimens – wet and dry - as well as the value of the retained strength (ITSR) obtained for the three mixtures in question.

Table 3. Water sensitivity test results (EN 12697-12)

Bituminous mixtures	Quantities	Dry specimens	Wet specimens
MB 35/50	Mean bulk density (SSD) (kg/m^3)	2397	2399
	ITS (kPa)	1259	1123
	ITSR (%)	89	
MB PB 1,5	Mean wet bulk density (kg/m^3)	2390	2396
	ITS (kPa)	1498	1074
	ITSR (%)	72	
MB Kero	Mean wet bulk density (kg/m^3)	2401	2397
	ITS (kPa)	1378	1289
	ITSR (%)	94	

The set of values indicates, in general, a good performance of mixtures with respect to water sensitivity.

The values of water sensitivity presented in Table 3 show a better performance of the mixture MB Kero expressed by the ITSR when compared with those obtained for the other mixtures. The experience gained so far with this test has shown some variability of results (Batista, F, Antunes, ML (2009)).

7. FINAL REMARKS

The use of modified bitumen specially developed to improve resistance to fuel allow for the use of asphalt mixtures in areas where fuel spillage is likely to occur. The resistance to fuel spillage of these mixtures was evaluated with EN 12697-43 test method, where 3 asphalt mixtures with different bituminous binders were compared. The improvement of resistance to fuel was more significant in the second test phase – the brushing phase - which simulates the abrasive effect of traffic on the surface of the pavement layers subjected to the action of fuel.

The results obtained from complementary tests showed that the use of this type of bitumen does not compromise other performance characteristics, such as permanent deformation performance or water sensitivity. In fact, MB Kero presented a better behaviour than the asphalt mixtures made with conventional bitumen or with the PB 1.5 modified bitumen.

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