STRENGTH TESTS ON ASPHALT MIXES ATTACKED BY MOTOR FUELS. RECOMMENDATIONS ON BATH IMMERSION TIMES.

by

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ABSTRACT

One of the limitations of asphalt mixes as pavement materials is their poor resistance to attack from crude oil-based motor fuels.

Several procedures exist for determining the resistance of asphalt materials to motor fuel action. Different test standards can be found for fillers and surface dressings in both the US and European series. However, where the assessment of asphalt mixes themselves are concerned, there is a considerable lack of standardisation.

This paper reports on laboratory studies on certain essential aspects of the procedures for assessing the strength of asphalt mixes in respect of motor fuel attack, chiefly the time the mix is exposed to the fuel.

Based on the research results, the paper makes some good-practice recommendations for weight-loss procedures after immersion in motor fuel, with or without subsequent brushing, and in respect of the Marshall stability preserved after immersion.

In relation to the immersion period and in view of the laboratory findings and their subsequent statistical processing, one of the factors with the greatest influence is the recommendation that the immersion period should be 24 hours, except in the weight-loss test subsequent to immersion without any brushing where the results obtained prove to be more significant if the immersion period is seven days.

INTRODUCTION

One of the limitations of asphalt mixes as paving materials is their lack of resistance to attack from crude-oil based motor fuels. The very asphaltic nature of asphalt mixes means that crude-based motor oils contain soluble components and over the short or medium term this can lead to a deterioration of asphalt road pavements subjected to accidental motor fuel spills.

Fortunately, this exposure to motor fuels only occurs with any degree of intensity in the forecourts of filling stations (Fig. 1), particularly in the filling pump area, on parking areas for trucks and buses and on some airport surfaces.

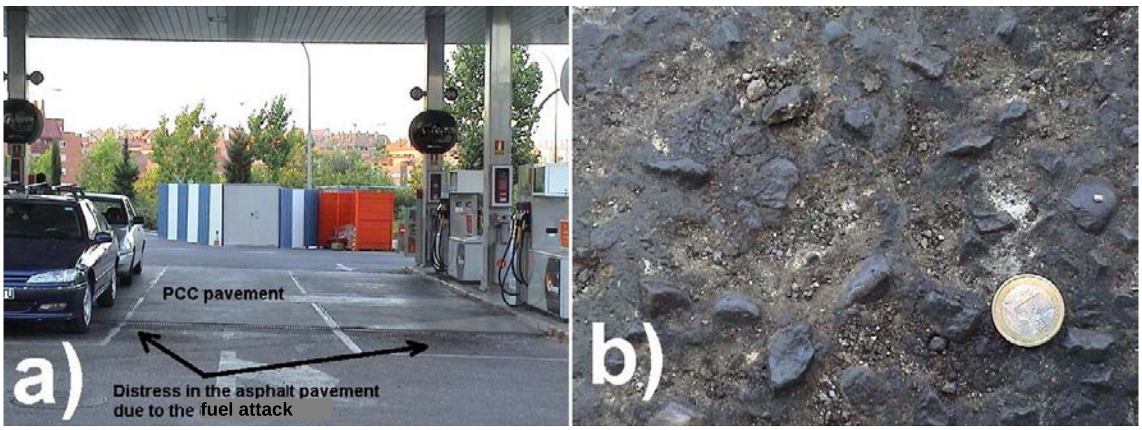

FIGURE 1.a) Asphalt pavement affected by fuel spills. b) Pavement stress detail

Traditionally, this limitation has not been directly tackled but concrete pavements have frequently been used instead as they do not suffer this limitation in respect of motor fuels. Another solution consisting of the use of tar-based binders has been totally abandoned owing to the carcinogenic effect of tar.

Recently, some binder manufacturers have launched so-called "motor-fuel resistant" asphalt binders on the market. This property is justified by tests differing from one firm to another and that consequently do not allow these allegedly fuel-resistant products to be properly compared.

There is a general lack of standardisation of the procedure for assessing the resistance of asphalt mixes to accidental motor fuel spills, which is the first step to setting up specifications.

This paper reviews the different procedures used for assessing the resistance of asphalt mixes to motor fuels and sets out an experiment to determine which parameters should comprise some of the parameters for a standard test for this purpose, essentially the exposure time to motor fuel prior to determining the aggression this has caused to the asphalt mix.

METHODS FOR ASSESSING THE MOTOR FUEL RESISTANCE OF ASPHALT MIXES

According to Paez et al. (1), the methods for assessing the resistance of asphalt mixes to motor fuel attack can initially be divided into three groups.

A) Binder Studies:

A1) Assessment of surface dressings (visual assessment)

- Ring Filled Test, ASTM D2939-03 (Standard Test Methods for Emulsified Bitumens Used as Protective Coatings)
- Panels Test, ASTM D2792-04 (Standard Test Method for Solvent and Fuel Resistance of Traffic Paint)

A2) Assessment of the mass product

- mass variation after immersion
- variation of the cone penetration after immersion
- solubility in toluene
- softening point variation after immersion
- complex modulus variation (rheometer).

Immersion can be in the form of the binder being directly immersed into a bath of motor fuel or else by immersing the asphalt mix and subsequently recovering its binder with solvents and testing it. In the latter case, the asphalt mixes are usually porous in order to increase the exposure of the binder to the motor fuel action.

B) Studies on the Asphalt Mix:

B1) Mass variation after immersion

B2) Mass variation after immersion and mechanical action

- Rolling Flash Rotating Test (simultaneous)
- Brush Test, EN 12697-43 (Bituminous mixtures - Test methods for hot mix asphalt - Part 43: Resistance to fuel)

B3) Variation of mechanical properties after immersion

- Marshall Stability Test
- Dynamic or Resilient Modulus Test
- Wheel Tracking Test

C) In situ studies: monitoring pavement performance.

The main disadvantage with the first group of methods, binder studies, is that the asphalt mix as a whole is not assessed, just the binder only. In addition, when binders recovered from asphalts that have been immersed in motor fuel are studied, the actual drying procedure and subsequent binder recovery using solvents can affect the characteristics of the binder recovered, whereby part of the change in its properties may be due to the recovery process and not to motor fuel action.

The second group of methods, however, permits a joint study of the binder-filler- aggregate system. Furthermore, the dissolving action produced by the motor fuel (Group B1) can be reinforced by some form of mechanical action (Group B2). In any event, weight loss is produced in the asphalt mix specimens under test, a loss that can constitute a scale of resistance to the motor fuels. Group B3 consists of methods assessing the variation of the mechanical properties of the asphalt mix, namely Marshall stability, resilient modulus and resistance to permanent deformation. Consequently, they do not assess a more or less superficial phenomenon but attempt to measure the extent to which the motor fuel has affected the asphalt mix as a whole, not just its surface.

If it is admitted that a laboratory test for measuring a particular property ought to represent in the best possible manner the actions a material suffers during the course of its service life, in the case of the motor fuel resistance of asphalt mixes, the test should comprise the following conditions:

1. being run on the asphalt mix and not on its binder;
2. given that the larger the attack surface offered by the asphalt mix to the motor fuel, the greater the damage it will suffer, in pavements exposed to this risk the mixes generally used are dense graded, consequently, the mix to be tested should be dense and with a low voids ratio;
3. the actions for laboratory subjecting the asphalt mix will be direct contact with the motor fuel and any mechanical action imitating the action of vehicle tires on the pavement and any possible mechanical or water jet sweeping, etc.;
4. the scale of the resistance to motor fuel action is set up on the basis of the material lost, an effect seen in pavements affected by the accidental spillage of motor fuels (Figure 1b) or by the weakening of the asphalt mix, making it susceptible to losing material.

Bearing in mind these considerations, the most suitable tests would be those in Group B. This is the reason why the study being reported here concentrated on simple tests belonging to this group while the tests on binders - original or recovered - and the in situ tests monitoring pavements in service are not covered in this paper.

LABORATORY TESTS UNDER STUDY

The motor fuel resistance tests carried out are simple enough to be performed in any laboratory or, thanks to the general principle on which they are based, provide conclusions and recommendations for carrying out other more complex tests based on the same general principle.

The study tests used were:

- weight loss as a result of immersion in motor fuel
- weight loss as a result of the combined action of immersion in motor fuel and vigorous brushing with a Steel Toothed Brush and
- Marshall stability preserved after immersion.

Weight Loss as a Result of Immersion in Motor Fuel

As performed in this study, this test consists of placing a Marshall type specimen in a metal basket (Fig. 2) enabling it to be immersed in motor fuel (automotive diesel in this case) and subsequently removing it from the bath, affecting the specimen as little as possible during the removal process. In short, use of the basket makes it easier to handle the specimen and limits the loss of mass through handling, loss that can be confused with the loss caused exclusively by the dissolving action of the motor fuel.

The temperature in the bath was 25±1 ºC and the proportion of motor fuel volume to specimen volume was 4:1. The following procedure was applied.

Weigh the Marshall specimen dry to obtain a Wd weight, place it in the basket and lower it into the bath for five minutes to allow the accessible voids to be saturated. Next, take it out of the bath and leave it to drain for 15 minutes, at the end of which time, weigh the specimen and basket assembly to obtain an initial SB_0 weight representing the weight of the basket plus that of the specimen with all its accessible voids saturated. Next, immerse it in the bath for the desired immersion period, t. When this period has transpired, remove the basket containing the specimen from the bath and leave it to drain for 15 minutes before obtaining its SB_t weight. Calculate the loss in weight of the specimen compared to its original dry weight using the expression [1]:

$$LW_t = \frac{SB_0 - SB_t}{Wd} \times 100 \qquad [1]$$

Three specimens were used in the test being reported and the result was the average loss value in the three specimens tested. The procedure was applied with t periods varying between 24 hours and seven days in duration.

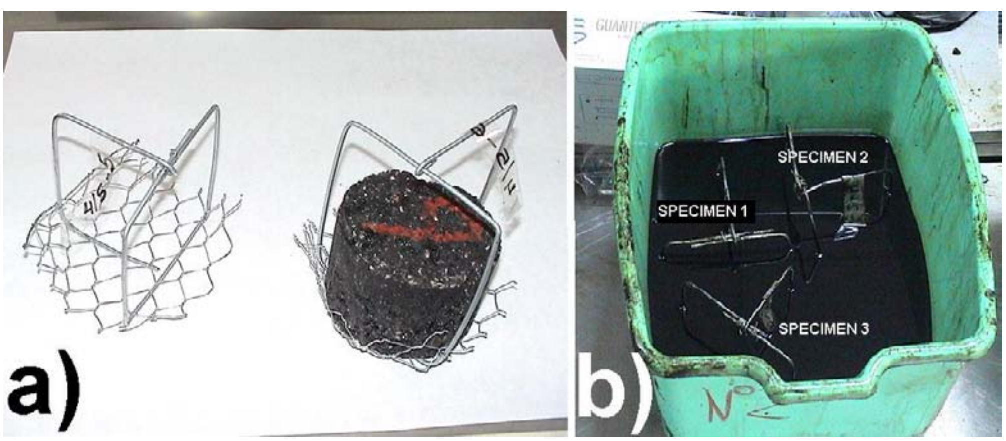

FIGURE 2. a) Metal basket and specimen inside the basket. b) Three specimens in the fuel bath.

An additional comment is required here concerning the observation made that the upper face of the specimens suffered less loss of material than the bottom, attributable to the fact that the material on the bottom face - and on the side – sloughed off by gravity whereas it stayed in place on the upper face (Fig. 3). This observation gives rise to the recommendation to turn over the position of the specimen in the basket on a regular basis during long immersion periods so that the loss of material is similar on both faces of the specimen. Similarly, the size of the mesh in the bottom of the basket needs to be sufficiently big to allow the mineral particles coming away during the immersion process to pass through and settle in the bottom of the bath. It is recommended a 25 mm mesh.

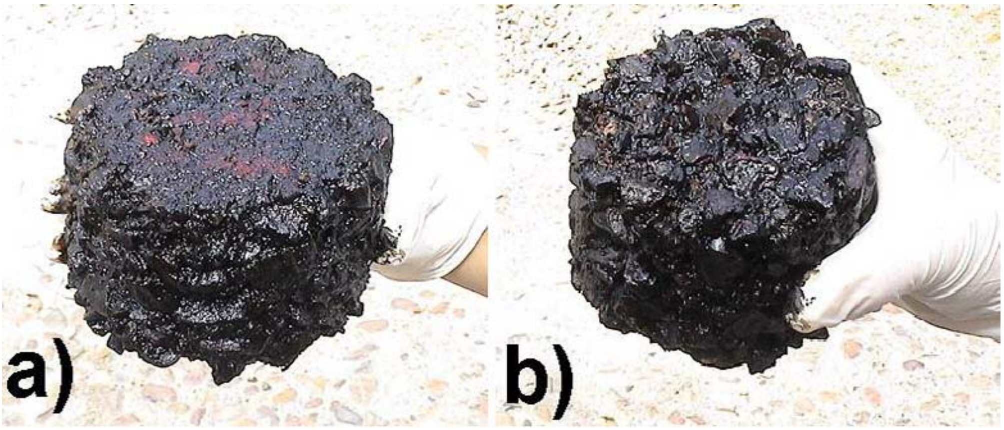

FIGURE 3. Loss of material in the upper face (a) and in the bottom face (b) of the specimen after immersion in motor fuel for seven days.

Weight Loss as a Result of the Combined Action of Immersion in Motor Fuel and Vigorous Brushing with a Steel Toothed Brush

This is the same test as described in the paragraph above but before the specimen is weighed, it is brushed vigorously with a Steel Toothed Brush (Fig. 4b) for 60 seconds so that all the soft material on all the specimen surface is removed. The following procedure was applied.

Once the specimen, of the same Marshall type as in the previous test, has been brushed, plunge it three times, one after the other, into the motor fuel for the space of two or three seconds for the sole purpose of rinsing the surface and washing off any loose particles by the motor fuel so that the weight of the specimen does not include any loose particles on its surface. Before weighing the basket-specimen assembly, leave it for 15 minutes to drain off the motor fuel from its surface.

Calculate the weight loss using the expression [1]. It is advisable to clarify that, although the study period can be 24 hours, 48 hours or several days, etc., the specimen needs to be removed and brushed every 24 hours of immersion to facilitate the motor fuel attack over the following 24 hours.

The procedure involves the use of three specimens and the result is the average loss recorded in the three. More material is lost with this method than with immersion without brushing (Fig. 4a,b).

FIGURE 4. a) Specimen after immersion. b) Metal brush. c) The same specimen after brushing.

Marshall Stability Preserved After Immersion

The procedure consists of producing six specimens, three of which are introduced into the motor fuel bath for the desired period of time. The bath temperature is 25±1 ºC and the proportion of motor fuel volume to specimen volume is 4:1.

With the immersion period over, the average Marshall stability of the three submerged specimens is obtained (S_t) and the of the three unsubmerged specimens (S_0). The stability preserved after immersion in motor fuel (RS_t) for a period of time, t, is given by the expression [2]:

$$RS_t = \frac{S_t}{S_0} \times 100 \qquad [2]$$

The Marshall Rupture Test is performed as is customary at 60 ºC to which end the specimens are put into a thermostatic water bath for at least 30 minutes prior to being broken up in the press.

EXPERIMENTAL STUDY CARRIED OUT

In order to determine the aptness of each of these tests for assessing the resistance to motor fuel action, several asphalt mixes were produced, having the same grading and aggregates but with different binders. One of the binders, according to its maker's indications, is resistant to motor fuel action. The other binders, two of which conventional and the other one polymer-modified, should in principle show different resistance rates to motor fuel action. The capacity to distinguish the motor fuel resistance of these asphalt mixes would be the criterion for determining the aptness of the laboratory tests under study.

Materials Used

Aggregates

A fine fraction of limestone aggregate was used and a coarse fraction of siliceous aggregate. The grading used is shown in Table 1. This was a dense grading giving rise to asphalt mixes with a voids content of approximately 4-5%.

TABLE 1. Asphalt Mix Grading under Study

Sieve (mm)	20	10	8	4	2	0.5	0.063
% Passing	10	85	64	36	25	14	5

Binders

Four binders were used: one "motor fuel resistant" binder, referred to from here onwards as FR asphalt, two conventional bitumens with a 40/50 and 60/70 penetration rate made from different crude-oils, and one bitumen modified with an SBS polymer, referred to from here onwards as SBS asphalt.

Motor Fuel Utilised for Submerging the Specimens

The motor fuel utilised in the immersion baths was automotive diesel.

Characteristics of the Asphalt Mixes Produced

The voids in mix were 5,9% for all the mixes but for B 40/50 that was 5,7%. The four mixes were fairly similar, facilitating the comparison of results in the subsequent tests on motor fuel resistance.

Tests Performed

The tests were run are listed below.

- Weight loss after immersion at 1, 2, 3, 4, 5, 6 and 7 days. The same specimens were used throughout the process as the procedure allows the loss suffered by each specimen to be measured on a day by day basis as they progressively deteriorate. The four asphalt mixes under study were all tested.
- Weight loss after immersion plus brushing at 1, 2, 3, 4, 5, 6 and 7 days. As in the previous case, the specimens were the same throughout the entire process as the intention was to measure the progressive weight loss as from the initial specimen weight. Two mixes were tested, the one containing the FR asphalt and the one containing the B 40/50 binder.
- The Marshall stability preserved after immersion. The loss at seven days was measured in all four mixes under study and at 24 hours in the mixes made with FR asphalt and B 40/50 binder.

Two replicas were carried out of all the tests described to enable a subsequent variance study to be carried out, beyond the analysis of the results average, in order to estimate whether the results were statistically significant or not.

TEST RESULTS

Weight Loss as a Result of Immersion in Motor Fuel

Table 1 and Figure 5 give the results obtained for the four mixes under study. The most resistant mix was seen to be the one made with the FR binder, followed by the one made with the B 40/50 binder, next the one with the 60/70 binder and finally, the one with the SBS binder.

This ranking for resistance to the attack of diesel automotive fuel was preserved over all seven days that the mixes were under study. Consequently, in principle, whatever the immersion period chosen, between one and seven days, the relative ranking does not vary between the binders, which could lead engineers to think that it would be recommendable for this type of test to be carried out with a standard 24-hour immersion period on the grounds of convenience and time saving.

TABLE 2. Weight Loss after Immersion and Immersion Plus Brushing. F Statistic Values.

IMMERSION PERIOD		LOSS OF WEIGHT AFTER IMMERSION (%)					
		FR Asphalt	B 40/50 Asphalt	B 60/70 Asphalt	SBS Asphalt	F Statistic 4 Mixes [(1)]	F Statistic 2 Mixes[(2)]
24 h	Replication #1	0.59	0.64	1.56	3.17	24.48	2.9
	Replication #2	0.48	0.88	1.97	4.30		
	Average	0.54	0.76	1.77	3.74		
48 h	Replication #1	0.63	1.1	2.07	4.21	37.93	16.1
	Replication #2	0.61	1.41	2.20	5.35		
	Average	0.62	1.26	2.14	4.78		
72 h	Replication #1	0.83	3.03	2.76	5.11	27.10	6.14
	Replication #2	0.69	1.73	2.90	5.65		
	Average	0.76	2.38	2.83	5.38		
96 h	Replication #1	0.92	3.27	3.00	5.55	8.86	8.80
	Replication #2	0.74	2.05	5.55	6.43		
	Average	0.83	2.66	4.27	5.99		
120 h	Replication #1	1.02	4.32	3.23	6.04	5.58	34.48
	Replication #2	0.93	3.35	7.16	7.70		
	Average	0.98	3.84	5.20	6.87		
144 h	Replication #1	1.18	5.19	4.38	6.92	5.23	70.94
	Replication #2	1.19	4.34	9.05	8.89		
	Average	1.19	4.77	6.72	7.91		
168 h	Replication #1	1.71	6.20	6.44	8.49	7.15	45.01
	Replication #2	1.40	5.03	11.48	10.21		
	Average	1.56	5.62	8.98	9.35		
		LOSS OF WEIGHT AFTER IMMERSION PLUS BRUSHING (%)					
		FR Asphalt	B 40/50 Asphalt	-	-	-	F Statistic 2 Mixes[(2)]
24 h	Replication #1	5.11	7.15				119.18
	Replication #2	5.21	6.83				
	Average	5.16	6.99				
48 h	Replication #1	10.44	12.64				91.26
	Replication #2	9.86	12.01				
	Average	10.15	12.32				
72 h	Replication #1	14.12	17.81				16.75
	Replication #2	12.50	16.76				
	Average	13.31	17.29				
96 h	Replication #1	17.37	23.63				42.69
	Replication #2	15.88	22.37				
	Average	16.62	23.00				
120 h	Replication #1	21.39	31.49				29.05
	Replication #2	18.74	28.84				
	Average	20.07	30.17				
144 h	Replication #1	24.59	36.37				52.93
	Replication #2	22.16	34.18				
	Average	23.37	35.28				
168 h	Replication #1	27.64	42.85				42.54
	Replication #2	25.54	38.99				
	Average	26.59	40.92				

[(1)] F Statistic for the four mixes under study. Values higher than 6.59 ($F_{3,4,\ 0.5}$ in the Fisher-Snedecor Distribution) mean that the results are statistically significant.
[(2)] F Statistic for the results of the FR Asphalt and the B 40/50 Asphalt mixes. Values higher than 18.51 ($F_{1,2,\ 0.5}$ in the Fisher-Snedecor Distribution) mean that the results are statistically significant.

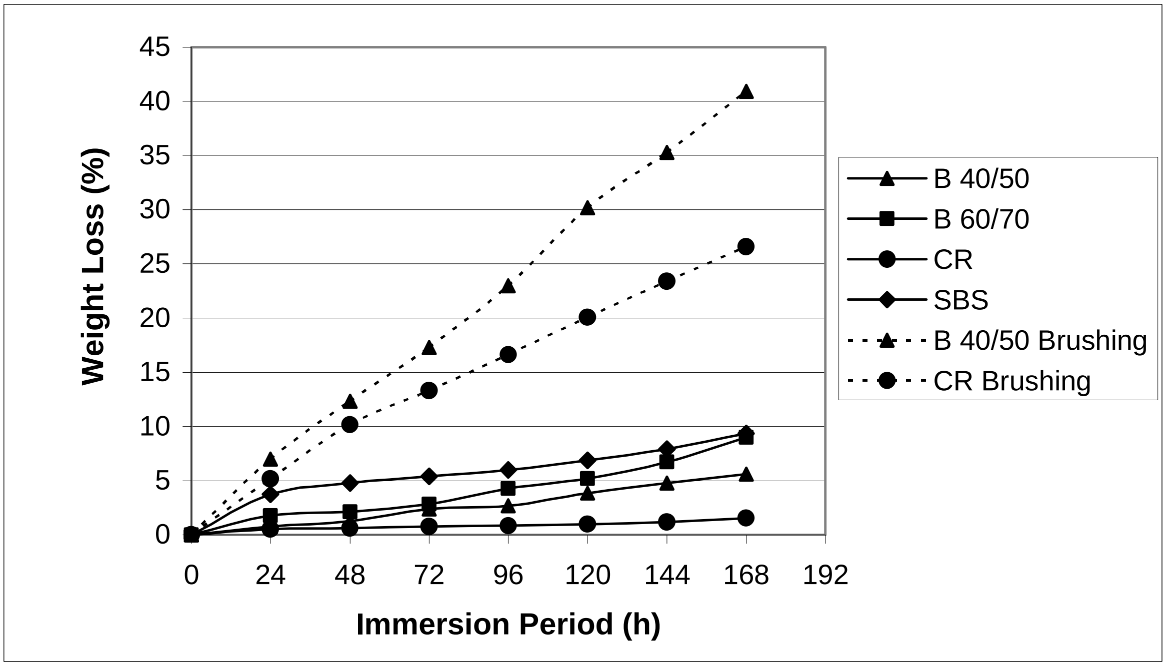

FIGURE 5. Weight Loss after Immersion and Immersion + Brushing

Weight Loss as a Result of the Combined Action of Immersion in Motor Fuel and Vigorous Brushing with a Steel Toothed Brush

As already stated, the two materials that in the weight loss without brushing test showed the greatest motor fuel resistance were selected for this test, i.e., the asphalt mix made with FR asphalt and the one made with B 40/50 binder. The results obtained for both mixes in the test incorporating brushing are given in Table 2 and Figure 5.

As happened in the immersion test, the ranking of the resistance to automotive diesel remained the same regardless of the study period observed, between one and seven days. The FR asphalt mix was more resistant than the B 40/50 penetration mix. This could therefore indicate that, in order to save time and resources, the tests on weight loss as a result of immersion incorporating brushing could be carried out with a standard 24-hour duration since extending the test period does not seem to provide any advantage at all.

Marshall Stability Preserved After Immersion

As reported above, the preserved Marshall stability was studied after seven days of immersion in automotive diesel. The results obtained are given in Table 3. It can be seen that the values obtained are roughly coherent with those obtained in the earlier weight loss tests after immersion or after immersion plus brushing.

As in the case of the weight loss with immersion plus brushing, it was decided to repeat the procedure with a 24-hour immersion period in order to determine whether the immersion period could be reduced with the consequent savings in time and resources that would provide, without altering the conclusions on the motor fuel resistance of the mixes under study. The experiment was only carried out on the two most resistant mixes, i.e., the mix with the FR asphalt binder and the mix with the B 40/50 asphalt. Table 3 gives the results.

TABLE 3. Marshall Stability Preserved after Immersion. F Statistic.

IMMERSION PERIOD		MARSHALL STABILITY PRESERVED AFTER IMMERSION (%)					
		FR Asphalt	B 40/50 Asphalt	B 60/70 Asphalt	SBS Asphalt	F Statistic 4 Mixes(1)	F Statistic 2 Mixes(2)
24 h	Replication #1	90.70	65.60	-	-		
	Replication #2	89.20	71.30			-	53.22
	Average	89.95	68.45				
168 h	Replication #1	60.10	46.80	31.20	38.50		
	Replication #2	60.10	42.80	32.40	42.70	63.82	58.52
	Average	60.10	44.80	31.80	40.60		

(1) F Statistic for the four mixes under study. Values higher than 6.59 ($F_{3,4,\ 0.5}$ in the Fisher-Snedecor Distribution) mean that the results are statistically significant.

(2) F Statistic for the results of the FR Asphalt and the B 40/50 Asphalt mixes. Values higher than 18,51 ($F_{1,2,\ 0.5}$ in the Fisher-Snedecor Distribution) mean that the results are statistically significant.

It was observed that the ranking between the two mixes in the 24-hour study was the same as in the seven-day study whereby, in principle, it could be recommended that this type of test is carried out over 24 hours.

DISCUSSION OF THE RESULTS.

In the light of the above results, it would seem plausible to recommend carrying out the motor fuel resistance tests with 24-hour immersion periods as, in line with the results reported so far, the tests involving longer immersion periods did not alter the consideration of the mixes studied in this case.

It should also be clarified that, extending the immersion period increases the loss of weight or preserved Marshall stability, meaning that, with a view to drawing up specifications for motor fuel resistant mixes, the admissible limits for weight loss or preserved Marshall stability should be a function of whatever immersion period is decided to be used in the standard laboratory tests.

Notwithstanding, an essential aspect at the time of assessing the reliability of laboratory results has not yet been reported here. It was particularly necessary to estimate whether the results obtained and reported above are significant from a statistical point of view.

To be able to make this estimation, all the tests reported here were carried out with two replicas in order to be able to run a variance study allowing a statistical calculation to be made to determine whether they are statistically significant or whether, on the contrary, the dispersion of the results cancels out their validity.

Variance Analysis in the Tests for Weight Loss as a Result of Immersion in Motor Fuel

Figure 6a shows the evolution of the F statistic obtained in the test on the four asphalt mixes. The F statistic was seen to have high values when the tests were run over 24, 48 or 72 hours, while this value subsequently fell, even to less than 6.59, for $F_{3,4,\ 0,05}$ in the Fisher-Snedecor F distribution, a situation in which the results are not significant with a 95% confidence interval. This unfavourable scenario may be due to the fact that during the first immersion days the material sloughing off from the specimen was essentially asphalt and fine aggregate, whereas from Day 3 of immersion onwards mineral particles of a certain size begin to come away, introducing a significant dispersion factor, lowering the degree of statistical significance of the results obtained.

Consequently, these results appear to support the above recommendation for carrying out immersion loss tests over 24 hours. The following argument would nevertheless be relevant, namely that a test to determine whether a mix is resistant or not to motor fuels ought to be designed to assess mixes that are fairly resistant and a test that is applicable to mixes that are very far from being motor fuel resistant is of less interest.

With this approach in mind, the F statistic and its evolution was determined once more, obtained in this case taking into account only the results obtained in relation to the mixes containing FR asphalt and B40/50 asphalt. The variation in the F statistic in the variance analysis is given in Figure 6b. It can be seen that the F statistic generally showed a rising trend and that up to Day 5 of immersion it did not go above 18.513 corresponding to $F_{1,2,0,0.5}$ in the Fisher-Snedecor F distribution. Therefore, considering this graph, it should be recommended that the test on weight loss as a result of immersion is carried out with seven days of immersion. This would not alter the motor fuel resistance ranking but improves the statistical significance of the results.

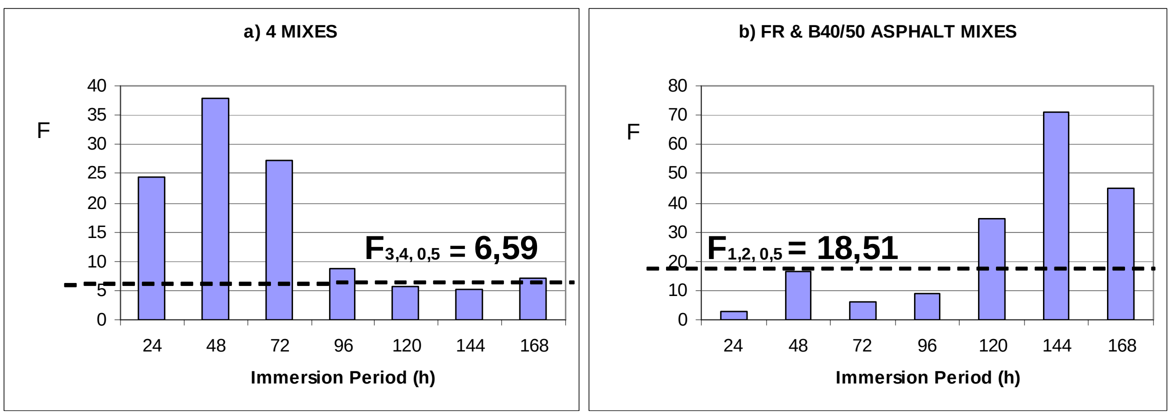

FIGURE 6. Weight Loss after immersion: evolution of the F statistic for (a) the four mixes under study and (b) the FR and the B40/50 asphalt mixes.

The seven-day period recommended is half way between the one used by Garnica et al. (2), who employed 1, 7, 14 and 28 days. In this case, no statistical study was reported on the data, simply the successive loss was assessed and compared with the amount suffered by the same type of specimen when the motor fuel was gasoline. However, no conclusion was drawn as to the most adequate immersion period for each motor fuel.

Cruz et al. (3) monitor the weight loss of two asphalt mixes over ten days but do not indicate the most adequate immersion period with a view, for example, to drawing up a compulsory specification for this type of motor fuel resistant products.

Finally, Van Roijen et al. (4) indicate that the first time a specification on jet fuel resistance was used in airports dates back to 1995, in the construction of the new Kuala-Lumpur Airport in Malaysia. It was specified that the weight loss after 24 hours of immersion in jet fuel should not exceed 1%. In this respect and pointing out that the laboratory tests described in this paper involved automotive diesel, both the mix made with FR asphalt and the one made from B 40/50 asphalt met that requirement.

However, after seven days in immersion, the weight loss in the mix containing B 40/50 asphalt was three or four times greater than in the mix containing FR asphalt. This supports the proposal made in this paper that the immersion period for measuring weight loss on which motor fuel resistance specifications should be based ought to be seven days.

Analysis of the Variance in the Tests on Weight Loss as a Result of the Combined Action of Immersion in Motor Fuel and Vigorous Brushing

As reported above, this test was applied to mixes containing FR asphalt and B 40/50 asphalt. Figure 7 presents the evolution of the F statistic. Throughout the seven test days, the F factor remained above the 18.51 value corresponding to $F_{1,2,0,0.5}$ in the Fisher-Snedecor F distribution. Consequently, in view of the variance analysis of the results, the above recommendation stands that this type of tests are carried out using a 24-hour immersion period as there is no advantage whatsoever to be gained by extending this period.

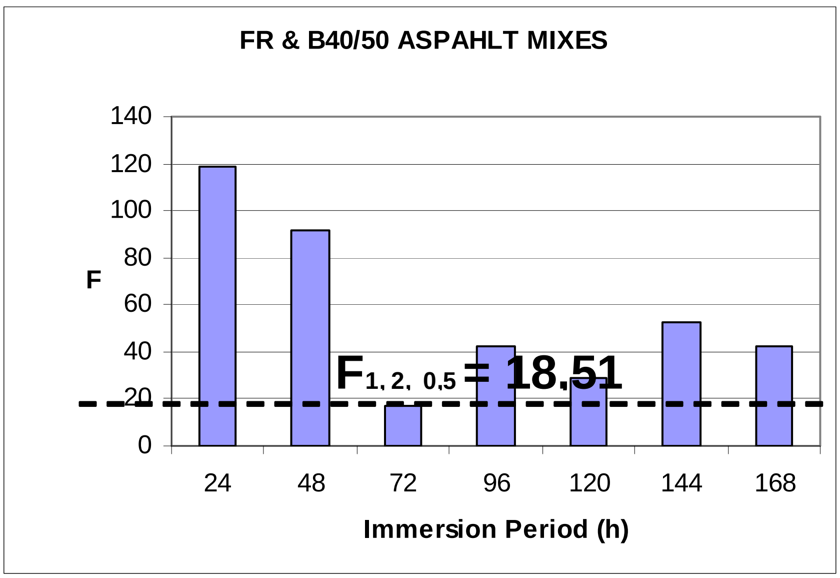

FIGURE 7. Weight Loss after Immersion and Brushing. Evolution of the F Statistic

The EN 12697-43 Standard, which employs a standardised brushing procedure, indicates that the immersion period of the mix, prior to the brushing process, should be 24 hours when the asphalt mix is made with conventional bitumens and 72 hours when the mixes incorporate polymer-modified binders. In view of the results obtained in the research reported here, the authors fail to understand fully the reason for extending the exposure period when polymer-modified bitumens are involved. In fact, the SBS asphalt reported in this paper showed poor performance, detected already after the first 24 hours of immersion in diesel. It is possible, however, that the asphalt mixes incorporating other polymer-modified binders do require a 72-hour period to manifest their lack of motor fuel resistance. In any event, the Standard does not extend immersion to any further days (up to seven for instance), in line with the conclusions of this paper.

Variance Analysis on the Preserved Marshall Stability After Immersion

Table 3 presents the values for the F statistic for three scenarios, namely the seven-day study of four mixes, the seven-day study of two mixes and the 24-hour study of two mixes. In all cases, the F value was high, proving that the results are statistically significant and consequently reliable. By way of conclusion, the recommendation can stand for carrying out the preserved Marshall stability test after immersion in motor fuels in a soaking period of only 24 hours.

In general, the authors consulted (1), (4), use or recommend – but do not justify – the 24-hour immersion period. In this respect, this paper contributes the technical justification for continuing to utilise this period.

CONCLUSIONS

The following conclusions can be drawn from the foregoing report:

- the three procedures studied prove to be valid for assessing the resistance of asphalt mixes to motor fuel attack
- the simplest laboratory procedure is the evaluation of the weight loss after a period of immersion – it is advisable to adopt a seven-day immersion period for this; the specimen has to be turned over inside the basket every 24 hours so that the loss of material is similar on both faces of the specimen.
- if a specimen brushing is added to the motor fuel action during the immersion time, a 24-hour immersion period is sufficient as any longer exposure time does not appear to provide any additional advantages;
- when the laboratory procedure consists of measuring the Marshall stability preserved after immersion, there is no improvement either in the validity of the results on extending immersion time, whereby a 24-hour immersion period is recommended.

These recommendations were made in relation to Marshall type specimens, so that with the use of different types of specimen with a different weight to exposed-surface ratio, the recommendations could vary as well as with other aggregate grading than the dense-graded one used here. Equally, during the experiments reported, the motor fuel utilised in the immersion baths was diesel. It would be interesting to repeat the experiment using gasoline or aviation fuel.

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