EVALUATION OF ANTI-REFLECTIVE CRACKING MIXTURES MADE WITH HIGH NFU ASPHALTS

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ABSTRACT*: The world's environmental problems are diverse, among them waste and particularly end-of-life tires (ELTs). The shredding of these tires and their use in construction materials such as asphalt mixtures is one of the techniques with the greatest potential for use. On the other hand, in the search to obtain asphalts with high elastic performance and fatigue responses, in recent years, different asphalt modifiers have been studied and NFUs have been one of them. With the aim of obtaining improvements in the mentioned properties, a greater incorporation of NFU and its application in reflex cracking retardant mixtures has been studied. For this purpose, in the present work, different asphalt mixtures made with asphalt with a high rate of NFU incorporation by wet method have been evaluated. The evaluation of their physical behavior has allowed comparing them and estimating which of them would present the best performance as anti-reflective cracking mixtures.*

KEY WORDS: Tires, asphalt, anti-reflective cracking.

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1. Introduction

Once the tire reaches the end of its useful life, its rubber can be recycled for different uses, such as elements cut directly from it, energy production in cement kilns or also as an addition in the process of modifying asphalts for the production of asphalt mixtures. This elastomer is not virgin, having undergone a change in its response to stress states, with less flexible deformations. Sulfur and fillers such as carbon black increase abrasion resistance. The vulcanization process generates less affinity of rubber with the aromatic fractions of other petroleum derivatives, such as asphalt, generating a product of difficult wetting and microdispersion (1).

Currently, used tires find very different destinations and very diverse uses. Some tons of these wastes are used as fuel in ovens in some countries, they are also deposited in warehouses and open spaces waiting for a "retreading" treatment that does not always arrive. This accumulation leads to the appearance of rodents and insects such as mosquitoes and fires that are difficult to control. On the other hand, if these tires are destined to be disposed of in landfills, this brings inconveniences. Due to their shape and composition, tires cannot be easily compacted, nor do they decompose, and therefore consume considerable amounts of landfill space. With capacity decreasing in most landfills, and with disposal costs for municipal solid waste (MSW) increasing, bulky materials are no longer accepted. In addition, because of their hollow shape, tires can trap air and other gases, which turns them into buoys, and over time, they "float" to the surface, breaking the landfill cover. These openings expose the landfill to rodents, insects and birds, and allow gases to escape, all undesirable processes. These openings also open pathways for rain to enter the landfill, creating unwanted liquids (2).

On the other hand, in the search for asphalts with high elastic performance, different asphalt modifiers have been studied in recent years. End-of-life tires (ELT) have been one of them, with rates of about 8% of the experiences carried out in Argentina. With the objective of obtaining improvements in the mentioned properties, a greater incorporation of NFU and its application in reflex cracking retardant mixtures has been studied. The present research has evaluated the incorporation of 22% NFU in the asphalt binder to provide the base binder with a better elastic performance and to use a greater amount of NFU.

Reflected cracking can be defined as the discontinuity that appears in the asphalt layer laid as reinforcement in an existing pavement, i.e. it results from an upward extension of the crack in the layer below (3).

Reflected cracks are not only an aesthetic problem but fundamentally a possible way for water to enter the lower layers of the pavement, causing degradations that affect the surface regularity and therefore the comfort and safety of traffic; however, it is important to mention that they essentially generate a decrease in the bearing capacity of the lower layers, sub-base and sub-surface, thus significantly reducing the service life of the road (4).

A crack underlying the asphalt layer can act in two independent ways to cause its reflection. One is when there is friction between the reinforcement layer and the existing pavement, which generates a concentration of stresses at low temperature in the region of the crack extremity, which in turn causes the opening of a new crack in the reinforcement layer.

A crack retarding mix should be able to dissipate the stresses generated by deforming without breaking. To achieve this, it is made with more elastic modified asphalt. For this reason, the present research aims to obtain a high viscosity asphalt by incorporating a high NFU content and with this to elaborate a mixture for crack retardation and to evaluate the capacity of this mixture to dissipate the stresses by deforming without breaking. This ability is particularly critical at low temperatures, when the underlying pavement blocks shrink and the bonded reinforcement layer will break if it is not sufficiently elastic.

2. Materials and methods

2.1. Materials

The materials used for the experimental development were rubber powder from end-of-life tires (NFU), conventional asphalt binder, asphalt binder modified with SBS (used as a reference) and aggregates. The NFU has a size obtained through the No. 25 sieve, i.e. 0.7 mm. This size is suitable for its digestion into asphalt binder.

The base binder used to incorporate the NFU was a 50/70 penetration bitumen, this being the classification used in Spain. It would have, as specified by PG3 (6), a penetration between 50-70 [0.1 mm], a softening point between 46-54 [°C]. As for SBS modified bitumen, it would have, according to the same specification mentioned above, a penetration between 45-80 [0.1 mm] and a softening point ≥ 60 [°C].

The aggregates porphyritic nature and sizes used are those shown in the granulometry graphs shown in Figure 3.

2.2. Methods

Asphalt with a high rate of end-of-life tires (ELT) was approached according to previous experiences. It was defined in a proportion of 22% of NFU, with respect to the weight of the base binder, thus obtaining one of high viscosity, such as a BMAVC-1b.

The asphalt with NFU was prepared by first mixing both by hand, see Figure 1. Subsequently, the dispersion was carried out using dispersing equipment, see Figure 2, at a temperature of 185°C and 60 minutes of mixing. The production capacity of this equipment is 0.6 kg per batch. The amount of binder with NFU required for the entire job was 15 kg, so 25 of the above-mentioned bachs had to be made.

Figure 1: Left: NFU; Right: manual pre-mix asphalt-NFU.

Figure 2: NFU dispersion equipment in the binder.

The characterization of the asphalt with NFU was carried out by means of viscosity tests, according to UNE-EN 13302 (8) at different temperatures, penetration according to UNE-EN 1426 (9), softening point according to UNE-EN 1427 (10) and elastic return according to UNE-EN 13398 (11).

In the preparation of the asphalt mixtures, in a first stage, the granulometric curves of three different types of mixtures were composed and adopted, and then evaluated in order to compare them with respect to their performance as retardants of reflex cracking. The particle size curves are shown in Figure 3.

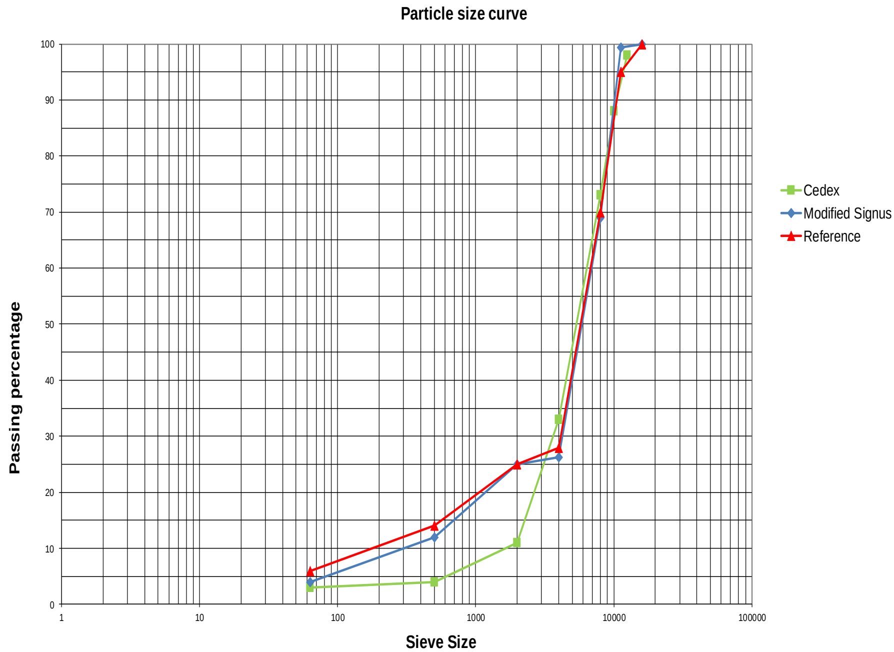

Figure 3: Reference grain size. Source: own.

As for the dosage of the amount of binder to be incorporated, this was established according to the developments and work carried out by the UPM. In a second stage, the preparation of the aggregates was continued, Figure 4. These were separated into fractions by sieving, then washed and conditioned. Thirty-six Marshall-type specimens (Figure 5) and 12 circular specimens of 150 mm in diameter were produced, which, when sawn, became semicircular (Figure 6).


Figure 4: Preparation of aggregates for Marshall specimens.

Figure 5: Mold filling and Marshall compaction.

Figure 6: Production of semicircular specimens.

The bulk density, maximum density and amount of voids were determined according to UNE-EN 12697-5-6-8 (12). These specimens were also used to determine the sensitivity to water according to standard UNE-EN 12697-12 (13), see Figure 7, and the determination of the modulus of rigidity according to standard UNE-EN 12697-26 (14), see Figure 8. The semicircular specimens were manufactured by the rotary compactor using the 150 mm diameter mold, and were cut to obtain 24 semicircular specimens, to test them in flexure at two temperatures, see Figure 9.

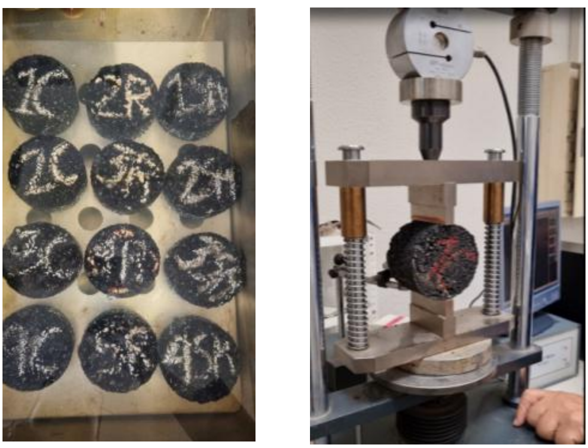

Figure 7: Water sensitivity test: Conditioning and testing.

Figure 8: Modulus of rigidity test**.**

Figure 9: Crack propagation test by bending test of a semicircular specimen.

3. Results

The results of the tests on the base asphalt and the one incorporating NFU can be seen in Table 1.

Table 1: Test results on asphalt binders.

Essay	Units	50/70	BMAVC-1b	PMB 45/80-65
Penetration	0.1 mm	57	33	54
Softening point	ºC	51.4	72.9	67.4
Viscosity at 135 ºC	mPa.s	410	7325	-
Viscosity at 170 ºC	mPa.s	131	1022	-

As for the asphalt mixes, Table 2 shows the test results.

Table 2: Test results on asphalt mixtures.

Essay	Units	Cedex	Signus modified	Reference
Binder in mixture	%	9.0	9.0	5.6
Marshall Density	kg/m3	2.1450	2.3003	2.2860
Maximum density	kg/m3	2.4530	2.3960	2.5330
Voids	%	12.56	4.0	9.75
ITSd	MPa	0.87	1.32	1.60
ITSw	MPa	0.64	1.26	1.42
Sensitivity to water	%	73.5	95.5	88.8
Modulus: 20°C- 2.1 Hz	MPa	1238	2888	3108

On the other hand, continuing with the evaluations on asphalt mixtures, Figures 10 and 11 show the results of the semicircular specimens with crack propagation by flexural test.

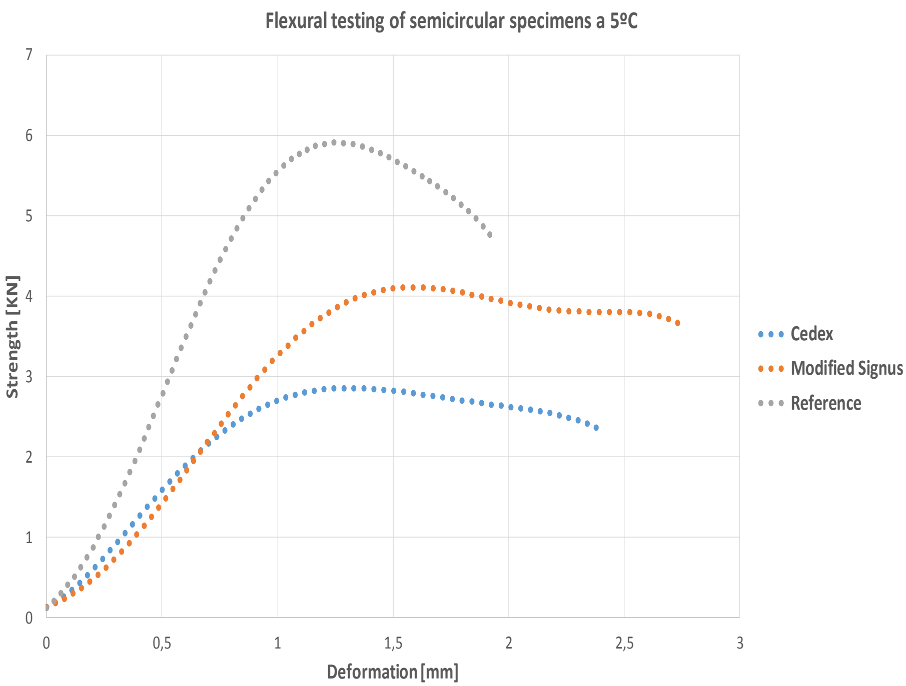

Figure 10: Crack propagation by flexural testing of semicircular specimens. Test temperature: 5°C

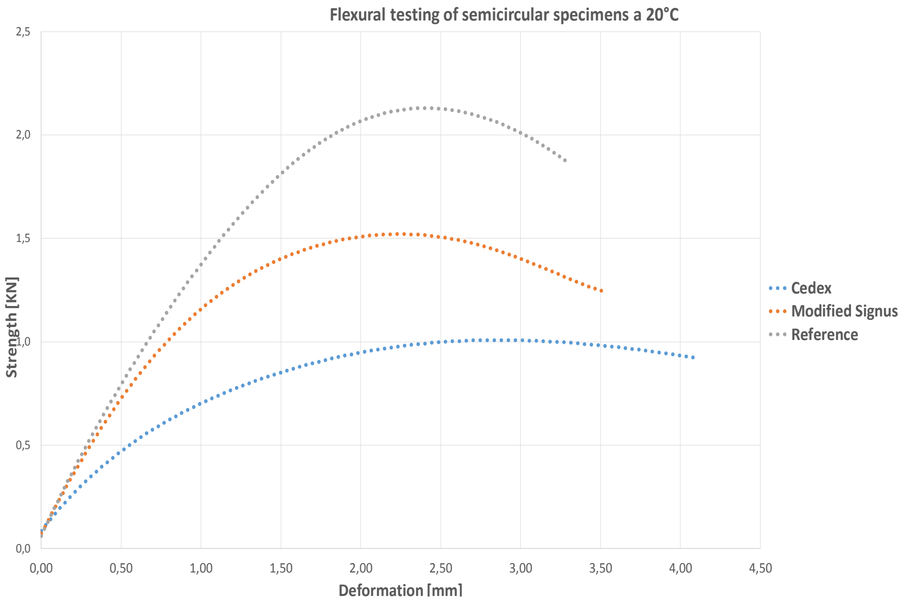

Figure 11: Crack propagation by bending test of a semicircular specimen. Test temperature: 20°C.

4. Discussion of results

Regarding the binders, it is observed that the incorporation of rubber reduces the penetration of the base bitumen, increases its softening point and its viscosity. It is a heavily modified bitumen. On the other hand, PMB 45/80-65 has a lower softening point and softer penetration.

As for the bituminous mixes, both the reference mix (B) and the CEDEX mix (C) have high void contents of 9.75% and 12.65%, respectively. However, the modified signus mix (SM) has a void content of 4%, i.e. it is more impermeable than the other two mixes.

The indirect tensile stress ratio (ITSR) indicates a relationship with void content. The higher the void content, the greater the effect of water attack.

As for the modulus of rigidity, the value in mix R (3108 MPa) is the usual one for mixes with this void content (approx. 3000 MPa). Mix C shows a low modulus of stiffness (1238 MPa), as a result of its high void content and high BMAVC-1b binder content. Mix SM has a higher modulus (2888 MPa), because although it incorporates the same BMAVC-1b, it has few air voids, which generally translates into higher stiffness moduli.

As for the crack progression tests with semi-circular specimens, the curves obtained at 5ºC and 20ºC should be carefully analyzed. If the maximum peak of the rupture curve is taken into account, the reference mix would be the one that offers the best performance, both at 5ºC and at 20ºC. However, the strain (x-axis) corresponding to the peak strength (y-axis), or 80% of the peak downhill, is very descriptive of the performance of overlays on cracked or jointed pavements. Higher deformation indicates a greater ability of the mix to deform without breaking. Accordingly, the most resistant mix at 5°C is mix SM, with an elongation up to 80% of peak strength of 2.75 mm, followed by mix C and R with values of 2.40 mm and 1.90 mm, respectively.

Analyzing the curves at 20ºC, the mixture with the highest rupture deformation is C with 4.10 mm, followed by SM and R with 3.40 mm and 3.30 mm, respectively.

However, the cracking conditions of reinforcements are more critical when the weather conditions are cold. In other words, the analysis of the curves at 5ºC is of interest to predict brittle cracking behavior of the reinforcements. From all this, it is concluded that the bituminous mixture that best resists brittle cracking is the SM. It is also worth mentioning that since it is a more impermeable mix due to its low void content, it is also the most suitable for protecting the existing and cracked pavement from water ingress, which is an additional reason for using it in this type of project.

5. Conclusions

In this work, 3 bituminous mixtures have been studied: (1) The C made with 9% BMAVC-1b binder, giving 12.56 % voids. (2) SM made with 9% BMAVC-1b binder, giving 4.0 % voids. (3) R made with 5.6% PMB 45/80-65 binder, giving 9.75 % voids.

The aim was to compare these three mixtures as reinforcement or surface renewal layers on roads with cracking problems, which in low temperature conditions can lead to reflected cracking.

From the results obtained, it can be deduced that the best performing mix would be the SM mix. The higher deformability before rupture observed at 5ºC can be attributed to both the high content of strongly rubber-modified binder and the low content of air voids.

It should be added that the low void content also translates into impermeability of the layer, and thus into protection of the existing pavement against the entry of rainwater. For both reasons, it seems to be the most suitable layer for surface renovations to prevent water ingress in pavements with cracking problems.

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