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Improvement of asphalt mixture performance with glass macro-fibers

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HIGHLIGHTS

- Use of macrofibers to reinforce asphalt concrete.
- Studied of rutting and fracture performance of mixtures.
- Macrofibers improves the rutting performance.
- Macrofibers improves the asphalt concrete fracture behavior.

GRAPHICAL ABSTRACT

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ABSTRACT

Cracking is a common failure in concrete asphalt mixtures due to fatigue and low temperatures. For centuries fibers have been used to reinforce materials and short and long fibers have extensive use in Portland cement concrete to control cracking and provide residual capacity. In the field of flexural pavements, fibers are commonly used in mixtures like stone mastic asphalt to increase the asphalt content that this mixture requires without binder drain down. Although many works show the reinforcement of asphalt mixtures with short fibers, there is a lack of information about the design and performance of asphalt mixtures incorporating macrofibers. This work explores the use of glass macrofibers in asphalt concrete mixtures. Improvements in fracture behavior at low to medium temperatures were found and macrofibers increased the first peak fracture stress and gave higher residual stress capacity. Additionally, rutting behavior was significantly improved by the addition of fibers reaching up to 50% reduction in permanent deformation with respect to mixtures without fibers.

1. Introduction

Fibers have been used for centuries to reinforce brittle materials and influence the cracking process by increasing toughness, tensile strength and durability. As an example, Fiber Reinforced Concrete (FRC) has been developed. Although asphalt concrete has a viscous elastic behavior at medium to high pavement temperatures, it performs as a brittle material at low temperatures.

In the pavements field, fibers have not been extensively used to reinforce asphalt concretes. Cellulose fibers with a large specific area are commonly used in mixtures like stone mastic asphalt (SMA) or porous asphalts to add a major percentage of asphalt that these mixtures require without binder drain down during the mixing and placement process [1–3].

Mahrez et al. [4] studied an SMA with glass microfibers finding improvements in dynamic modulus and fatigue behavior; they also

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found improvements in the rutting behavior of the mixture. The benefits of fibers in rutting improvement can be due to increases in the consistency of the mastic and lock mechanism between aggregates [5].

An interesting phenomenon was observed by Kutey et al. [6] while performing the Accelerated Loading Facility test. Asphalt concretes with polyester microfibers showed the presence of microcracks, but they do not progress or increase to a level of alligator crack patterns. In this case, as well as in FRC, fibers act like a bridge transferring stresses and limiting the growth of cracks.

Many investigations have reported improvements in behavior of Fiber Reinforced Asphalt Concretes (FRAC) [7–17]. However, all mentioned works refer to short fibers (length <25 mm). To the author's knowledge, no studies incorporating macrofibers (length >35 mm) are available. Additionally, it was observed that no design method exists for this type of FRAC mixture. The fibers are normally used in mortars and Portland cement concretes to control cracking and obtain residual load capacity in cracked states. The action mechanism and improvements of macrofibers in the field of asphalt concrete mixtures are still very much unknown. This work analyses the effects of fiber incorporation on the performance of asphalt mixtures regarding fracture response at low temperatures and rutting at high pavement service temperatures. Results from asphalt mixtures incorporating both micro and macro glass fibers are compared with those obtained on control asphalt concretes without fibers.

2. Experimental

Firstly, as a preliminary study, glass and polyester microfibers were incorporated into conventional asphalt concretes and their effect on the rutting (at 60 °C) and fracture performance (at temperatures <10 °C) was studied. With a novelty approach in a second phase, the same properties were analyzed on similar asphalt concretes where different dosages of glass macrofibers (54 mm in length) were incorporated; in addition, volumetric and mechanical properties of these FRACs were studied.

2.1. Materials and mixtures

The Fiber Reinforced Asphalt Concrete (FRAC) used in this study was developed from a common dense grade asphalt concrete. The base asphalt mixture was made using two fractions of coarse aggregates (6–20 mm and 6–12 mm), crushed sand (0–6 mm) and a conventional asphalt binder (CA30 Argentinian standard IRAM 6835; PG 64-16). Table 1 shows the mixture proportions and the asphalt binder characteristics. Fig. 1 shows the different fibers used in this work, and Table 2, their main properties.

The difference between micro and macro fibers is related to the maximum aggregate size and the interaction inside the asphalt mixture. Glass microfibers have a length shorter than the maximum aggregate size of the asphalt mixture. Its main influence is

Table 1
Base asphalt concrete characteristics.

	Coarse aggregate 16–20 mm	Coarse aggregate 26–12 mm	Crushed sand 0–6 mm	Asphalt binder
Mixture proportions				
Weight %	23.8	10.5	60.9	4.8

	Viscosity at 60 °C [Pa.s]	Penetration [dmm]	Softening point [°C]
Binder properties			
CA-30	335	47	54.8

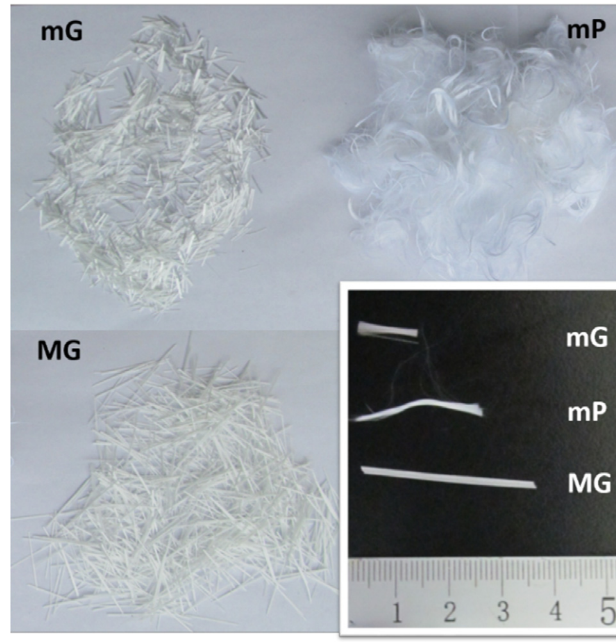

Fig. 1. Micro and macro fibers.

Table 2
Fiber properties.

Fiber		Microglass mG	Micropolyester mP	Macroglass MG
Length	[mm]	12	25	36
Aspect ratio	(l/ø)	58	1250	67
Density	[g/cm^3]	2.68	1.34	2.68
Tensile Strength	[MPa]	1700	300–500	1700
Modulus of elasticity	[GPa]	72	10	72
Softening point	[°C]	860	250	860

to modify mastic behavior. However, the glass macrofibers have a length that is longer than maximum aggregate size and is expected to influence the fracture behavior and crack propagation. The fibers act as a bridge in the cracks and transfer the stress. The polyester microfibers have a length similar to the maximum aggregate size, but because of its shape and rigidity, it is expected to affect the mastic behavior without improving the fracture behavior. In addition, these nomenclatures are the way manufacturers classify the fibers.

In the preliminary study, micro glass and polyester fibers (mG and mP) were incorporated at 0.4% of the weight of the mixture. For the main program, macro glass fibers (MG) were incorporated at different dosages (0.2, 0.4 and 0.6% of the weight of the mixture).

In all cases, the fibers were mixed with the hot aggregates for a minimum of 30 s to enhance fiber dispersion and then the asphalt binder was added while continuing to mix for nearly 2 additional minutes. For instance, Fig. 2 shows the distribution of the macrofibers (MG) during the mixing process.

A control mixture (C) was prepared to compare the performance of the different FRACs studied. The FRACs were labeled according to the type of fiber (mG, mP or MG) and the dosage of fiber (02, 04 or 06).

Asphalt concrete slabs (300 × 300 × 50 mm) were cast in each case to perform wheel tracking and notched beam bending tests as described in the next section. They were compacted with a roller compactor in accordance with the EN 12697-33. Marshall specimens were also produced for FRACs with macrofibers to compare