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Experimental characterization of high-performance fiber-reinforced cold mix asphalt mixtures

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HIGHLIGHTS

- Cold mix asphalt (CMA) mixture performance generally increase with curing time.
- The proper type and content of fibers can improve CMA performance.
- The research provides the validation of a laboratory approach for the performance study of CMA mixtures.

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ABSTRACT

Maintenance of existing road pavements assumes increasing interest as the traffic growing produces a faster deterioration of road infrastructures compromising safety and pavement serviceability. In order to guarantee long-lasting pavement repairs, maintenance activities and products must be optimized in terms of both achieved performance and curing times to reach a proper pavement serviceability. This research project focuses on the experimental characterization of a high-performance cold mix asphalt mixture reinforced with three types of fibers (cellulose, glass–cellulose, nylon–polyester–cellulose) dosed at two different contents (0.15% and 0.30% by the aggregate weight). Such materials were investigated at different curing times (1, 7, 14, 28 days) and conditions (dry and wet). Laboratory tests (Marshall, Indirect Tensile, Abrasion and Compactability) usually employed for hot mix asphalts were considered, adjusting the testing procedures taking into account the specific characteristics of cold mixes. Results showed that the mix with 0.15% cellulose fibers provides similar (for curing times of 14 and 28 days) or even higher performance (for curing times within 7 days) than the standard mixture (without fibers). Finally, the last two mixtures were compared with two cold mix asphalt mixes available on the market. The cellulose-fiber-reinforced material and the standard one showed enhanced performance, allowing the conclusion that they can be more successfully used in maintenance activities.

1. Introduction

The progressive deterioration of road pavements is mainly due to water action, freeze/thaw cycles, heavy traffic and combinations of these factors. The main goal of maintenance is the preservation of both structural integrity and proper service life of road infrastructures, restoring pavement conditions and retarding future deteriorations. However, even if the overall pavement structure is still able to guarantee a proper service life, localized distresses can cause numerous car accidents [1] and bicycle injury events [2], seriously reducing user safety. Since effectiveness of maintenance activities is maximized when the optimal timing is chosen allowing the achievement of the greatest improvement in performance at the lowest cost [3], localized-hazardous failures such as potholes and depressions should be repaired as soon as they occur [4].

The maintenance procedures and the corresponding materials used strongly influence repair durability [5–7]. It has been shown that rigorous procedures (cut, clean and compact) to repair potholes, combined with more performing materials, are more cost-effective than faster methods such as *throw-and-go* and *throw-and-roll* which have a lower durability [8,9]. In fact, material costs are a small percentage of the total cost for pothole repair, making attractive the employment of more performing and expensive materials which can provide high short-term performance and extended durability.

Emergency repair and routine maintenance can be carry out through hot mix asphalt (HMA) or cold mix asphalt (CMA) mixtures. Although HMA provide higher performance than CMA [10],

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HMAs are rarely used for localized distresses maintenance due to practical and operating reasons. Therefore the regular employment of CMA mixtures makes necessary the investigation of their performance, taking into account that internationally recognized standard tests are not available for these materials at present. Since the eighties, many research projects [4,5,9,11–13] investigated CMA mixture performance through laboratory tests originally designed for HMA materials and properly adjusted in order to take into account the specific characteristics of cold mixes. Obviously these laboratory tests are not able to perfectly reproduce field conditions such as sequence of climatic conditions and loading but they provide an indication of the material characteristics as performance lack in laboratory tests usually means early failure in the field.

Strength, bonding and durability of HMA mixtures can be improved with the addition of fibers [14,15], as usually occurs for open graded [16] and stone mastic asphalt (SMA) mixes. The fiber-reinforced mixture performance are strongly influenced by fiber type and content [14,15,17] and by fiber diameter, length and surface texture [18]. These parameters (fiber type, content and length) should be also considered when fibers are added to a CMA, as investigated by de S. Bueno et al. [19], who showed that a fiber content of 0.10–0.25% by the aggregate weight is enough to improve material performance.

The overall objective of this study is the laboratory investigation of the performance provided by a CMA mixture containing different types and amounts of fibers. These fiber-reinforced CMA mixtures were then compared with the high-performance standard CMA (without fibers) and with two commercialized high-performance cold mixes, usually employed in maintenance activities. The laboratory tests were carried out following a specific testing protocol able to characterize cold mixes through parameters usually employed to investigate HMA performance.

2. Testing program and procedures

The testing program was divided in two phases. In the first one, different fiber-reinforced materials were investigated in order to determine the optimized fiber type and content. In the second one, the high-performance standard mixture and the optimized fiber-reinforced cold mix were compared with two high-performance CMA mixtures available on the market.

Due to the lack in terms of internationally recognized specifications for CMA mixtures, laboratory tests usually employed to characterize HMA were considered: Marshall Stability, Indirect Tensile Strength, Abrasion Resistance and Compactability. However, due to the peculiar mechanical properties of CMAs, a preliminary study was carried out in order to define reliable specimen preparation procedure and test protocols for the investigation of the performance of cold mixtures. Results showed that the compaction at ambient temperature (about 20 °C), avoiding any high-temperature conditioning, and the testing after at least a 1-day-curing time were appropriate for studying the high-performance CMA mixtures considered. It is worth noting that this specimen preparation procedure is different from the protocol used in other research projects [9,12] where the CMA mixtures needed a preliminary aging in the oven before compaction in order to confer stability to the material as several samples prepared without heating collapsed soon after extrusion and prior to testing.

2.1. First phase

In the first phase, Marshall Stability (EN 12697-34), Indirect Tensile Strength (EN 12697-23) and Abrasion Resistance (EN 12697-17) were evaluated according to the experimental program summarized in Table 1, considering the following test parameters:

- three fiber types (cellulose [CEL], glass–cellulose [GCF], nylon-polyester-cellulose [NPC]);
- two fiber contents (0.15% and 0.30% by the aggregate weight);
- four curing times (from 1 to 28 days), for studying the variation of the material strength as a function of time;
- two curing conditions (in air and in water), for the simulation of different weather situations. Conditioning was performed at 25 °C, both in air and in water.

The same experimental tests were also carried out on the high performance standard mixture (STD), considered as reference material.

Table 1
Testing program – first phase.

Mixture type	Fiber type	Fiber content (by aggregate weight)	Curing time	Testing repetitions		
				Marshall Stability @25 °C	Indirect Tensile @25 °C	Abrasion Resistance @25 °C
Standard (STD)	No. fibers	0%	1 day in air	2	2	
			7 days in air	2	2	
			14 days in air	2	2	
			28 days in air	2	2	2
			28 days in air + 2 days in water	2	2	
STD + cellulose (CEL)	Cellulose	0.15%; 0.30%	1 day in air	2	2	
			7 days in air	2	2	
			14 days in air	2	2	
			28 days in air	2	2	2
			28 days in air + 2 days in water	2	2	
STD + glass–cellulose (GCF)	Glass–cellulose	0.15%; 0.30%	1 day in air	2	2	
			7 days in air	2	2	
			14 days in air	2	2	
			28 days in air	2	2	2
			28 days in air + 2 days in water	2	2	
STD + nylon–polyester–cellulose (NPC)	Nylon–polyester–cellulose	0.15%; 0.30%	1 day in air	2	2	
			7 days in air	2	2	
			14 days in air	2	2	
			28 days in air	2	2	2
			28 days in air + 2 days in water	2	2	