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A proposed methodology for the global study of the mechanical properties of cold asphalt mixtures

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ABSTRACT

Despite having been used for decades, the structural performance of emulsion-treated materials has still not been investigated as intensely as in the case of hot-mix asphalt (HMA). Proof of this is the lack of evolution of specific technical tests and standards. Due to this, many studies with cold asphalt mixtures (CAM) are carried out based on HMA specifications. Throughout the present paper, a new methodology is proposed in order to study different mechanical properties of CAM, such as unconfined compression strength (UCS), indirect tensile strength (ITS) and indirect tensile stiffness modulus (ITSM) not only in an independent way but also by giving a global approach. The consistency and applicability of the method is discussed and from its application to a practical case study with two very different CAM, new conclusions about their performance are laid down.

1. Introduction

Cold asphalt mixes (CAM) have been considered inferior to hot-mix asphalt (HMA) over the last decades due to the high air-void content of the compacted mixtures, weak early life strength and long curing times required to achieve an optimal performance [1]. However, in general terms, CAM tend to be better in certain aspects, such as production and implementation costs, ecology and sustainability, safety and the health of workers and even regarding some mechanical properties (i.e. flexibility). Furthermore, day by day new improvements come to light, which have already allowed producers to obtain high quality CAM, which in many cases are more suitable for certain applications than HMA. It is no wonder then that over the last years the production of CAM has been increasing in many countries, reaching annual productions of 1.5 million tones in France or 2 million tones in Turkey [2].

However, the structural performance of emulsion-treated materials has not been investigated in detail although they have been used with great success for a number of years [3]. In fact, from the point of view of the laboratory tests, the specific tests for CAM have barely been developed in decades, so there is a problem that still has not been solved. On the one hand, there are tests which take into account the need of cold mixes to be subjected to a higher energy compaction than the hot mixes, in order to drain out the water and cause the setting of the emulsion while the residual bitumen flows through interstitial voids getting in this way a suitable coating of the aggregates. Examples include immersion-compression and simple compression tests governed by the Spanish Standards NLT-161 [4] and NLT-162 [4] (somehow heirs from the French *Duriez* test, NF P98-251 [5]), which explicitly required a static compaction.

On the other hand, there are numerous properties which do not have a specific test standard for CAM and that is why, for analysis, many authors resort to compaction methods more suitable for HMA (like the Marshall hammer) or granular materials (such as vibrating hammer) [6] which fail to achieve the desired effect, resulting in fragile, not very resistant and with consequent detachment of material specimens.

To some extent, even using a compaction method unsuitable for CAM, as long as it is kept the same for all tests, the results could be comparable, though probably far from reality. The problem, as mentioned, is that this does not happen from a normative point of view.

Therefore, in this research, the method that the authors have followed when analyzing the different properties of CAM, not only separately, but also analyzing the relationship between pairs of them in a faithful and true way is set out.

Finally, the results of application examples conducted on CAM made with two very different types of aggregates, in which the consistency and wide applicability of the proposed process is reflected, are presented.

2. Materials used

In order to show the wide applicability of the proposed method, two very different aggregates were used obtaining CAM whose

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Table 1
Components of recycled aggregate (% of total dry weight).

Material	% in coarse aggregate	% in medium aggregate
Concrete and mortar	70	55
Natural aggregates	25	40
Ceramics and masonry materials	3.7	4.1
Concrete with metal pieces	1.121	<0.001
Concrete with textile fibers	0.146	0.042
Plaster/gypsum	0.103	0.012
Plastics	0.015	0.0
Metal	0.002	0.029
Light materials (paper, plastics)	0.001	0.002
Asphalt materials	<0.001	<0.001
Glass	<0.001	<0.001
Other no identifiable	<0.001	0.008

Table 2
Characterization of recycled and natural aggregates.

Property	Recycled aggregate	Natural aggregate
Flakiness Index (UNE EN 933-3 [9])	4.5%	19.8%
Crushed particles (UNE EN 933-5 [10])	89%	94%
Sand equivalent (UNE EN 933-8 [11])	77	78
Los Angeles coefficient (UNE EN 1097-2 [12])	38	14
Bulk specific gravity (UNE EN 1097-6 [13])	2.64 t/m^3	2.78 t/m^3
Dry specific gravity (UNE EN 1097-6 [13])	2.23 t/m^3	2.74 t/m^3
SSD specific gravity (UNE EN 1097-6 [13])	2.39 t/m^3	2.75 t/m^3
Absorption (UNE EN 1097-6 [13])	7.0%	0.5%

properties can be compared. On the one hand, a hornfels, a metamorphic siliceous aggregate from a natural quarry (hereafter, natural aggregate or NA) and on the other hand, a 100% recycled aggregate from Construction and Demolition Waste (hereafter construction and demolition waste aggregate or CDWA) whose composition is given in Table 1 for the received coarse and medium fractions. Most of this aggregate was concrete and natural stone but impurities, such as asphalt materials, plaster, aerated concrete or limestone were found which, in some cases, needed the use of an X-Ray diffractogram to truly define their source. This aggregate has very different properties compared to a NA but it is suitable for use in both cold and hot asphalt mixes according to other investigations [7,8].

Table 2 shows the different properties of both natural and recycled aggregates such as a poor Los Angeles coefficient, Flakiness Index and Crushed Particles Percentage of CDWA. However, the most characteristic feature is its low specific gravity and the huge water absorption which will clearly affect the mechanical and rheological properties of the bituminous mixtures made from them.

The adopted aggregate gradations were based on the recommendations given by the Spanish Technical Association of Bituminous Emulsions (ATEB) for GE1 grave-emulsions but slightly modified in order to keep it within the upper and lower limits after compaction since the gradation of recycled aggregate tended to get modified as observed and shown in Fig. 1 and Table 3.

The binder used was a cationic bitumen emulsion (60% bitumen content) with 100 pen. grade base bitumen.

3. Method

3.1. Specimen production

As explained, there is not a standardized production and compaction method generally adopted by diverse test standards. This

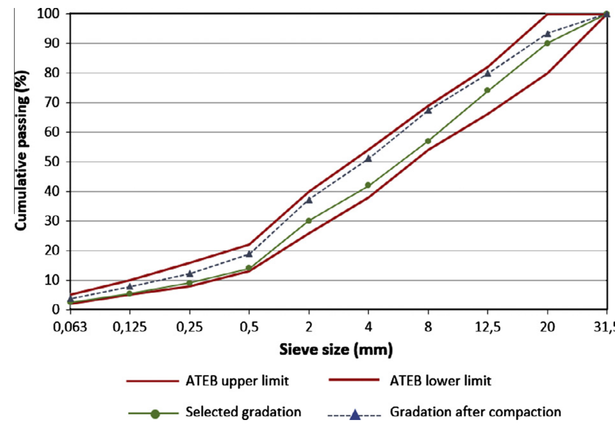

Fig. 1. Aggregate gradation of CDWA before and after compaction compared with ATEB recommendations.

Table 3
Cumulative passing values of CDWA before and after compaction compared with ATEB recommendations.

Sieve size (mm)	ATEB upper limit	ATEB lower limit	Selected gradation	Gradation after compaction
40	–	–	0	0
31.5	100	100	100	100
20	100	80	90	93.4
12.5	82	66	74	79.9
8	69	54	57	67.3
4	54	38	42	51.2
2	40	26	30	37.2
0.5	22	13	14	18.9
0.25	16	8	9	12.2
0.125	10	5	5.5	7.8
0.063	5	2	2.5	3.8

way, for instance, the specimens made to be subjected to an unconfined compression strength (UCS) test could have different properties than others made to be subjected to an indirect tensile strength (ITS) test. As a consequence, both results could not be comparable to each other. Due to this, the aim of this research was to standardize a method which allows to get specimens of different sizes but with identical intrinsic properties, such as specific gravity, voids, moisture, aggregates degradation after compaction etc. in order to test them in different ways and to relate the results with a complete reliance. That is, if two series of results, such as UCS and ITS show no relationship to each other, at least the fact that this happens because the production of the specimens was performed with different methods can be rejected and therefore, the test samples might not be equal either.

The specific for CAM Immersion-Compression test (NLT-162 [4]) and unconfined compressive strength test (NLT-161 [4]) contained a standard procedure by means of which 101.6 mm diameter by 101.6 mm height cylindrical specimens are obtained. The compaction process involves the application of the following steps (Fig. 2 was collected by the monitoring equipment of the authors during the development of this research):

- 1-min loading ramp to reach a 1 MPa preload (8.11 kN for 101.6 mm diameter specimens).
- Maintain the preload for 1 min.
- 2-min loading ramp up to the 21 MPa peak load (170 kN for 101.6 mm diameter specimens).
- Maintain the peak load for 2 min.
- 1-min downloading ramp.