

2ND INTERNATIONAL WARM-MIX CONFERENCE



Laboratory and Field Study of a WMA Mixture Produced with a New Temperature Reduction Additive

Joel Oliveira, Hugo Silva, Paulo Fonseca, Yongjoo Kim, Sungdo Hwang,
Joonbum Pyun, Hosin "David" Lee



University of Minho
School of Engineering

Portugal



MonteAdriano,
Engenharia e Construção, S.A.

Portugal



Korea Institute of
Construction Technology

Korea



Kumho
Petrochemical Co., Ltd

Korea



University of Iowa
College of Engineering

USA



CONTENTS

1. Introduction

2. Laboratory Performance of WMA Mixtures

Mix Design – HMA and WMA

Performance of Studied Mixtures – Rut, Stiffness, Fatigue

3. WMA Pavement Trial Section in Portugal

Production and Application of Studied Mixtures

Thermographic Analysis of the Pavement Trial

4. Comparison Between Laboratory and Field Mixtures

Performance of WMA and HMA Mixtures

5. Conclusions



1. Introduction

- 1) Lowering the production and application temperatures reduces energy consumption, emissions, and odors in a cooler work environment.
- 2) However, it is essential that the overall performance of WMA is truly as good as HMA.
- 3) In Korea, the Korea Institute of Construction Technology (KICT) and Kumho Petrochemical Co. LTD. have jointly developed a new WMA additive which is named as low energy and low carbon-dioxide asphalt pavement (LEADCAP).
- 4) In this study, both lab and field mixtures using LEADCAP were tested to assess performance, in comparison to a conventional HMA.



A. LEADCAP



- 1) LEADCAP is an organic WMA additive, with a wax-based composition including a crystal controller and an adhesion promoter.
- 2) The crystal controller adjusts the wax crystallization at the low temperature to improve crack resistance at low temperature.
- 3) The adhesion promoter acts as an effective bonding agent between aggregates and asphalt binder to enhance the moisture susceptibility of WMA mixtures.



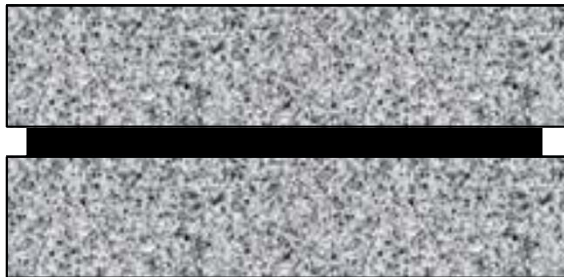
2ND INTERNATIONAL WARM-MIX CONFERENCE

Wax Based Composition

Reduce viscosity of asphalt binder with a lubricant effect



LEADCAP asphalt mixture can be mixed and compacted at lower temperature

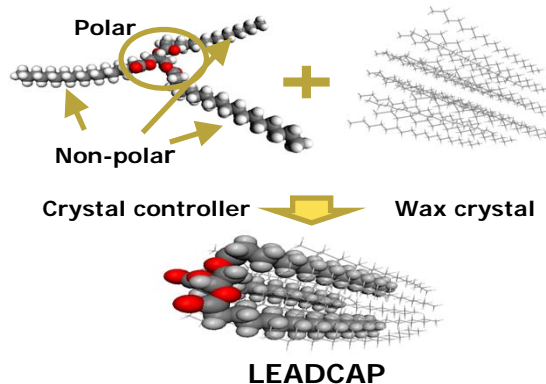


Crystal Controller

Typical wax-based WMA additives has a high degree of crystallinity resulting in low temperature cracking



LEADCAP contains Crystal controller.

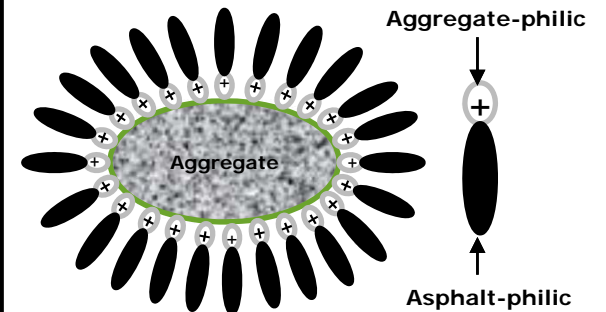


Adhesion Promoter

Most WMA additives are susceptible to moisture resulting in stripping between aggregate and asphalt



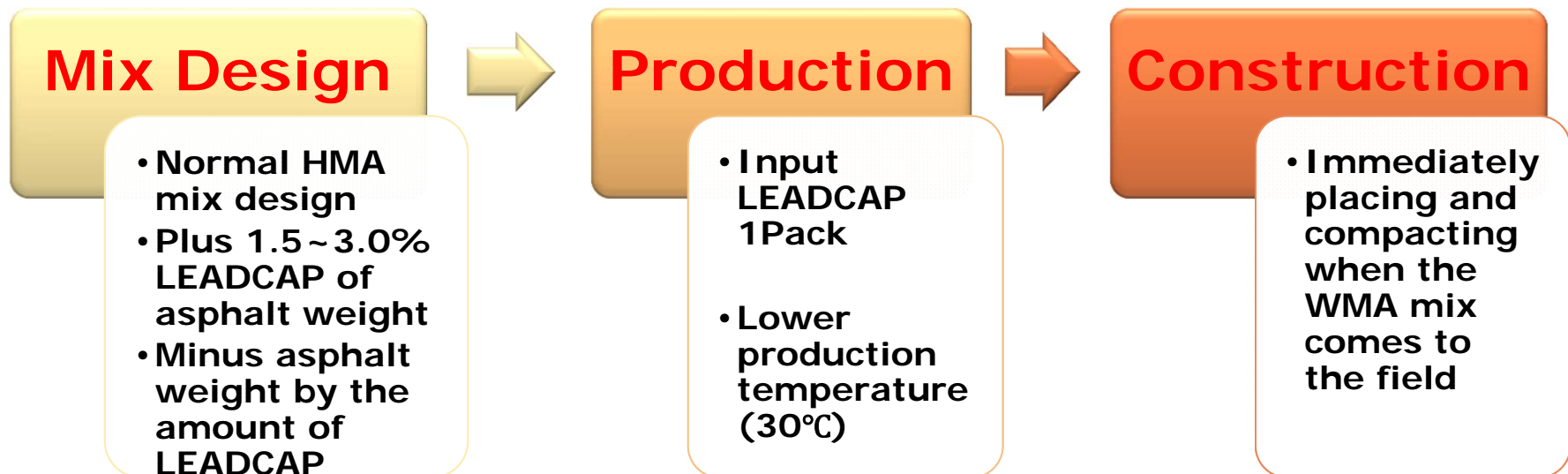
LEADCAP contains Adhesion promoter





B. LEADCAP Application Procedure

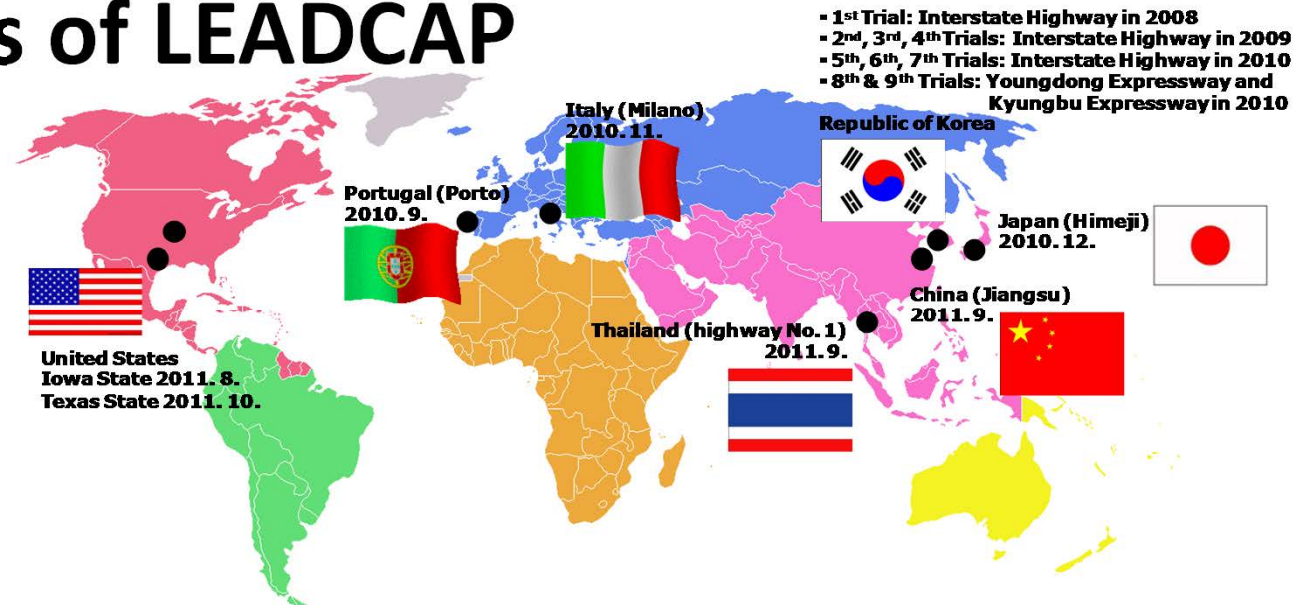
- 1) Add the LEADCAP additive to aggregate stream at plant mixer (plant-mixed type) or to asphalt tank (pre-mixed type)
- 2) Use the same paving method and conventional paving equipment
- 3) Application: Surface, Intermediate, and Base Courses





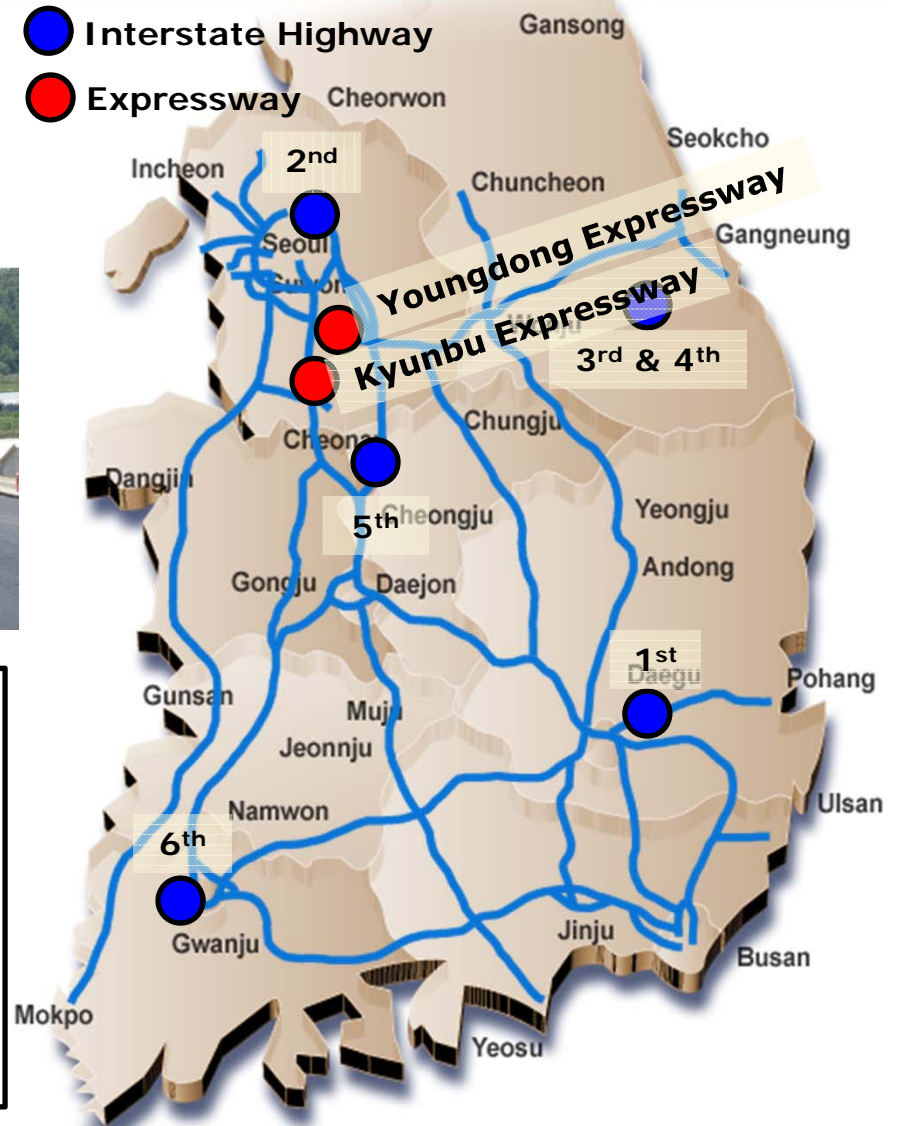
2ND INTERNATIONAL WARM-MIX CONFERENCE

C. Field Trials of LEADCAP



- 1) Several field trials using LEADCAP were successfully constructed in Korea, Japan, China, Thailand, Portugal, Italy and United States.
- 2) This paper presents in more detail the results obtained in the Portuguese trial.

Field Trials in Korea



Production of HMA vs. WMA





2ND INTERNATIONAL WARM-MIX CONFERENCE

Field Trial in Iowa City (USA)



Laboratory and Field Study of a WMA Mixture Produced with a New Temperature Reduction Additive

D. Emissions and Fuel Consumption

- Emissions and fuel consumption during the production of WMA and HMA mixtures in the plant (from the field trial in Korea)

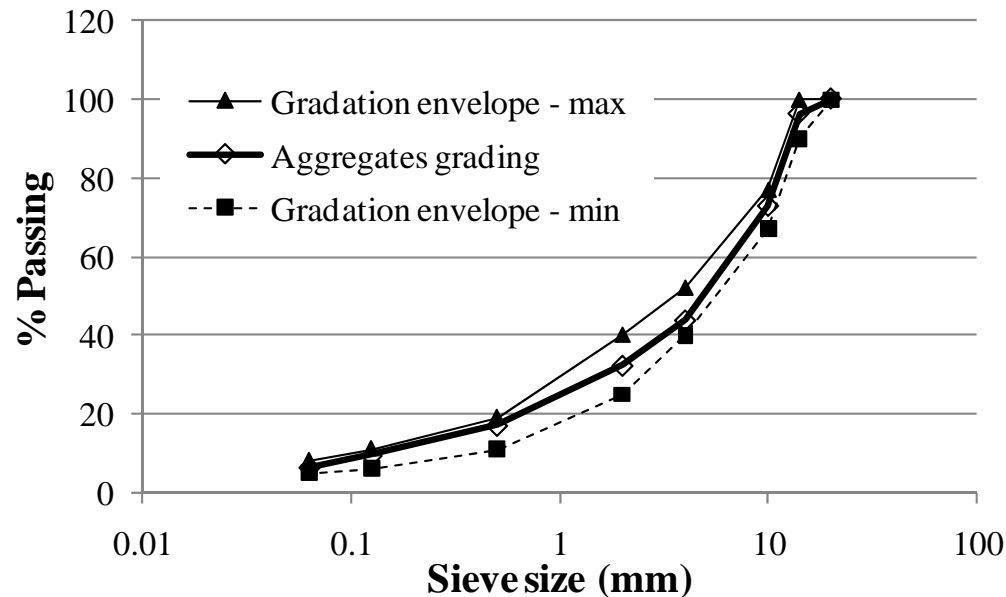
Content	Asphalt Mixture		Reduction Ratio
	WMA with LEADCAP	Control HMA	
Fuel use (liter/ton)	6.3	9.3	32%
CO ₂ (kg/ton)	19	28	32%
CO (ppm)	850	1040	18%
SO ₂ (ppm)	160	210	24%
NO _x (ppm)	20	30	33%



2. Laboratory Performance of Mixtures

A. Mix Design - HMA

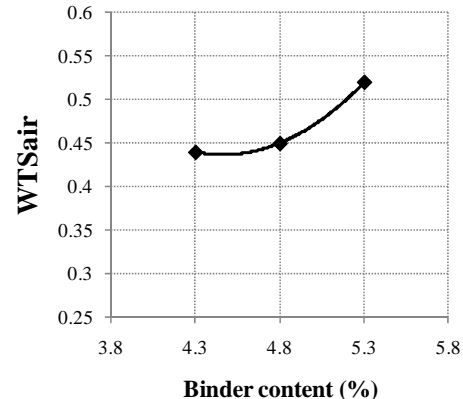
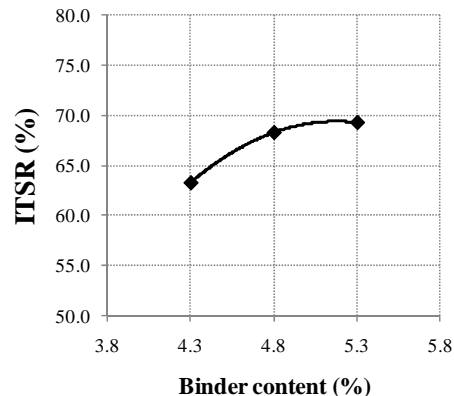
- 1) The mix design of the conventional HMA mixture was carried out according to the Marshall Mix Design Method.



a surface course
mixture was used in
the study (European
Designation:
AC 14 Surf 35/50)

Gradation of the aggregate used in the conventional HMA and WMA mixtures

- 2) The characteristics of the designed mixture were in conformity with the Portuguese Specifications and the optimum binder content (OBC) obtained was 4.8%.
- 3) An additional study was carried out to validate the mix design.
 - water sensitivity tests (Indirect Tensile Strength Ratio, ITSR, according to EN 12697-12)
 - wheel tracking tests (Wheel Tracking Slope, WTS_{air} , according to EN 12697-22)
- 4) Tests performed on three sets of specimens (OBC - 0.5%; OBC; OBC + 0.5%)



The results obtained in this study, confirm the previous OBC of 4.8%



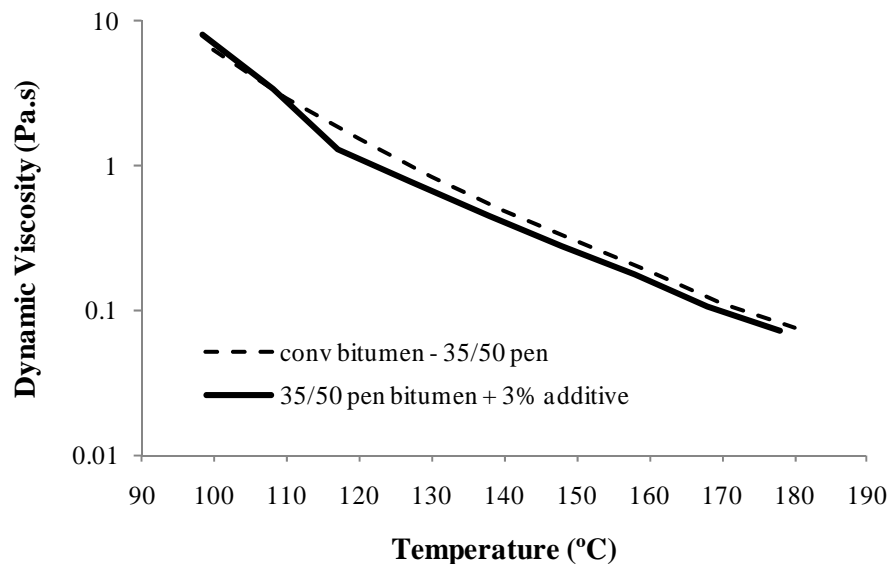
2ND INTERNATIONAL WARM-MIX CONFERENCE

- 5) For this project, the rate of 3.0% additive by weight of asphalt binder was selected to produce an asphalt binder equivalent to a PG 70-22 that was used in the laboratory and field mixtures;
- 6) No separate mix design procedure was carried out for the WMA. The bitumen content, aggregate type and gradation were the same used for the HMA, for comparison purposes;
- 7) The production temperature of the HMA mixture was 165°C (based on the recommendations of EN 12697-35 for a 35/50 penetration grade bitumen);
- 8) The temperature reduction for the WMA mixture was determined by dynamic viscosity (EN 13302), and compactability tests (EN 12697-10)



B. Mix Design - WMA

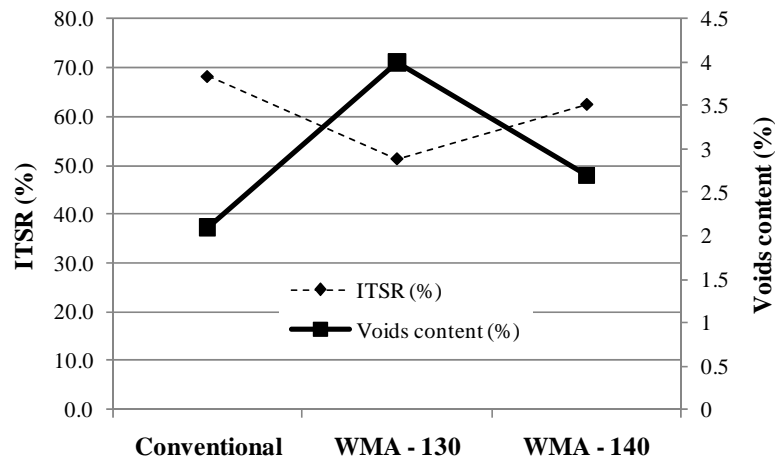
- 1) The viscosity test results were almost inconclusive (very similar results); this is also confirmed by the penetration and softening point test results



Penetration and Softening Point of studied binders

Binder	Penetration (0.1 mm)	R&B (°C)
Conventional	37.3	53.1
Modified with 3% LEADCAP	37.2	55.9
Difference	-0.1	2.8

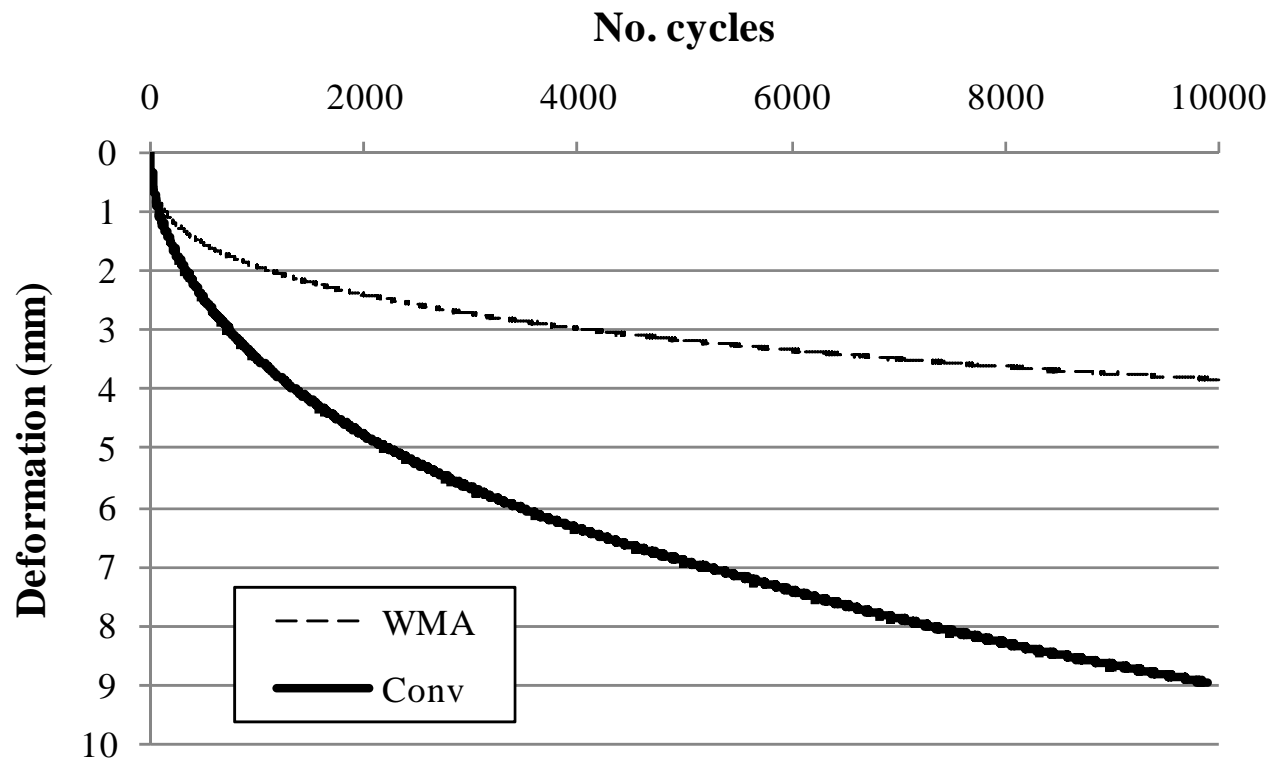
2) The temperature reduction was defined according to the compactability test results; tests were carried out on WMA mixtures produced at 140 °C and 130 °C (25 °C and 35 °C below the HMA temperature) in order to compare the voids content and the water sensitivity of the WMAs and the HMA.



- 130 °C is not adequate to assure a performance equivalent to HMA;
- a more conservative reduction (25 °C) was used for the WMA (production temperature of 140 °C).



C. Rut Resistance



WMA additive has significantly improved the rut resistance of the mixture:

$WTS_{air} (WMA) = 0.13$ mm per 10^3 cycles (less than half of HMA result)

$WTS_{air} (HMA) = 0.45$ mm per 10^3 cycles

Wheel tracking test results of studied mixtures (60°C)

Specimens after the Wheel Tracking test

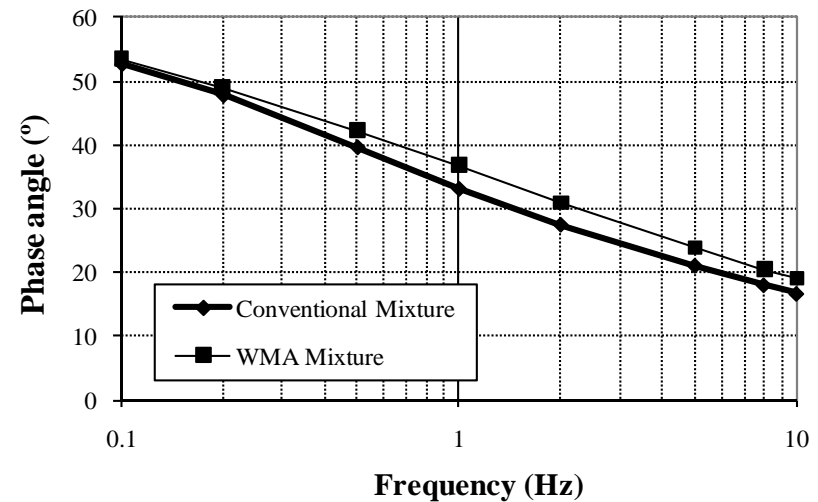
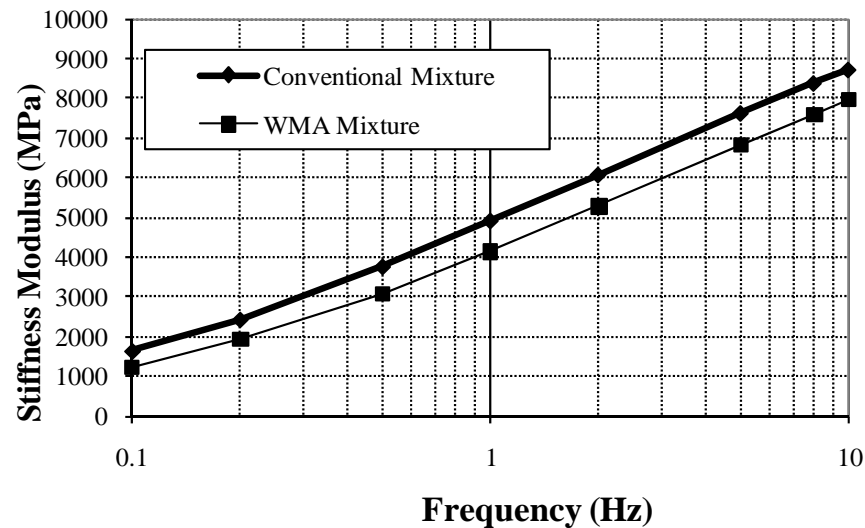


HMA

WMA



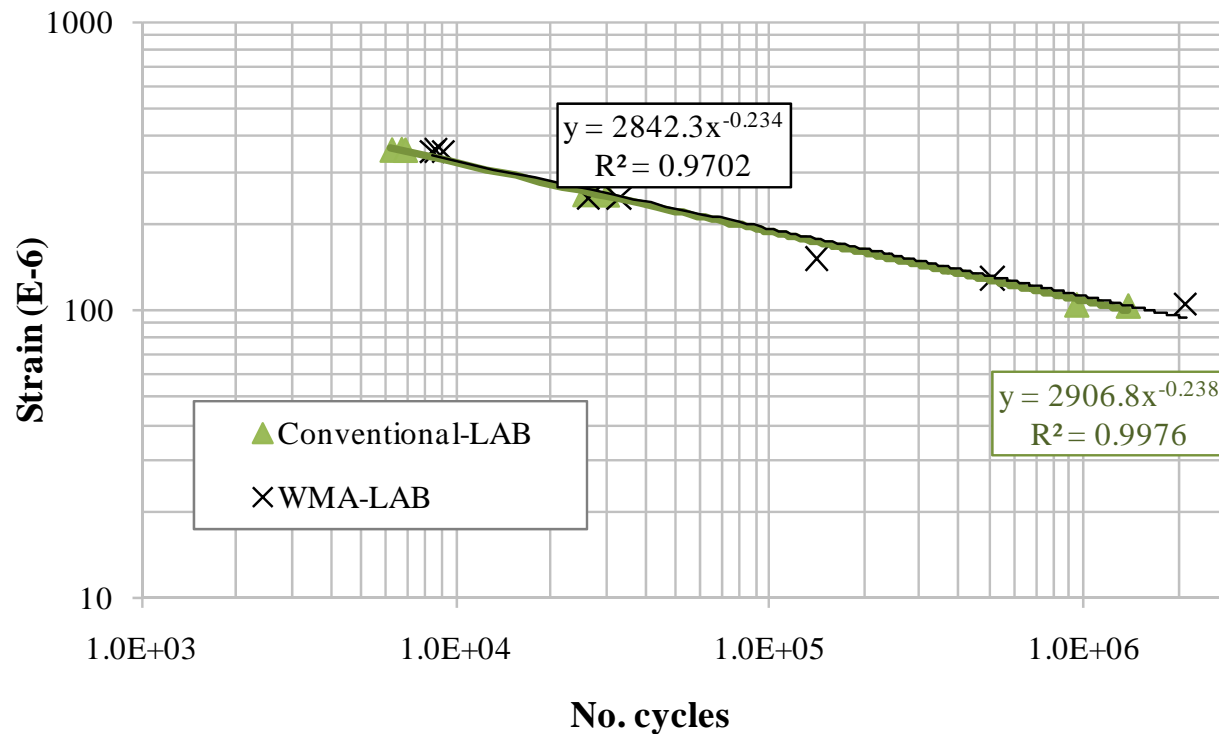
D. Stiffness Modulus (20 °C)



Slight softening effect of the additive on the WMA mixture, which can be observed by the reduction on the stiffness modulus and by the small increase on the phase angle



E. Fatigue Resistance



Similar fatigue performance of both mixtures

Four point bending fatigue test results of studied mixtures (20 °C)



3. Pavement Trial Section

A. Production and Application of Studied Mixtures

- 1) The additive was introduced in the bitumen tank and left under circulation for a period of about four hours in order to obtain a homogeneous blend;
- 2) a visual inspection detected some agglomeration of additive at the top of the bitumen; after manual agitation, it was subjected to an extra two hours of circulation;
- 3) After satisfactory blend, some binder samples were collected and the mixture started to be produced at 140 °C;
- 4) Further samples were collected during the production stage to check variability.



Binder	Penetration (0.1 mm)	R&B (°C)
Conventional	39.6	50.4
Modified with 3% WMA additive	39.8 (± 1.3)	52.8 (± 1.0)
Difference	0.2	2.4

Penetration and Softening Point of binders used in the trial section

- 5) The difference observed between both types of binder is similar to that obtained in the laboratory, which demonstrates the efficacy of the modification process

- 6) As expected, a significant reduction on the amount of fumes emitting from the WMA mixture was observed, in comparison with the HMA mixture, during the discharge of the mixture to the truck



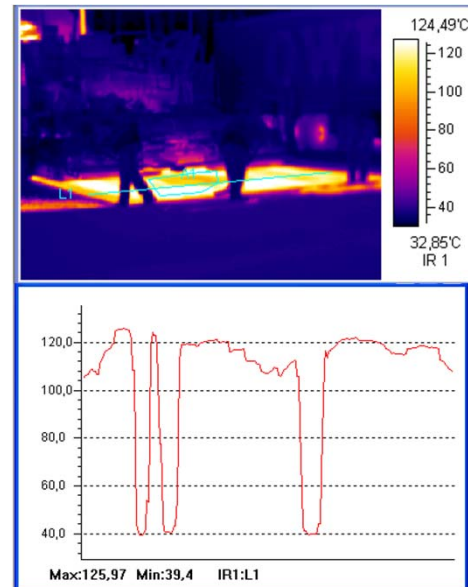
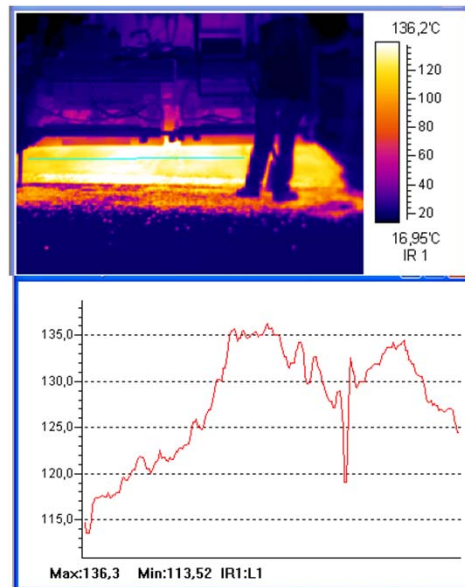
HMA



WMA

B. Thermographic Analysis of the Pavement Trial

- 1) Temperature of the mixtures were monitored during application and compaction, using a thermographic camera and a thermometer;
- 2) The temperature reduction observed between the production and the application was around 30 °C (165 °C minus 135 °C) for the HMA and 20 °C (140 °C minus 120 °C) for the WMA



Temperature variation along a line transverse to the spreading direction, immediately after the beginning of mixture application



4. Comparison Between Laboratory and Trial Mixtures

- 1) Several slabs were cut from the pavement trial in order to extract specimens for determination of their performance in comparison to the laboratory prepared mixtures.
- 2) Volumetric properties of field specimens were determined and a significantly higher voids content was observed on both mixtures (between 7 and 8%), which was later associated to a problem detected in the asphalt plant that was modifying the gradation curve of the final mixture; the comparison between the HMA and WMA mixture is still valid as both were produced with the same aggregate and under the same conditions.



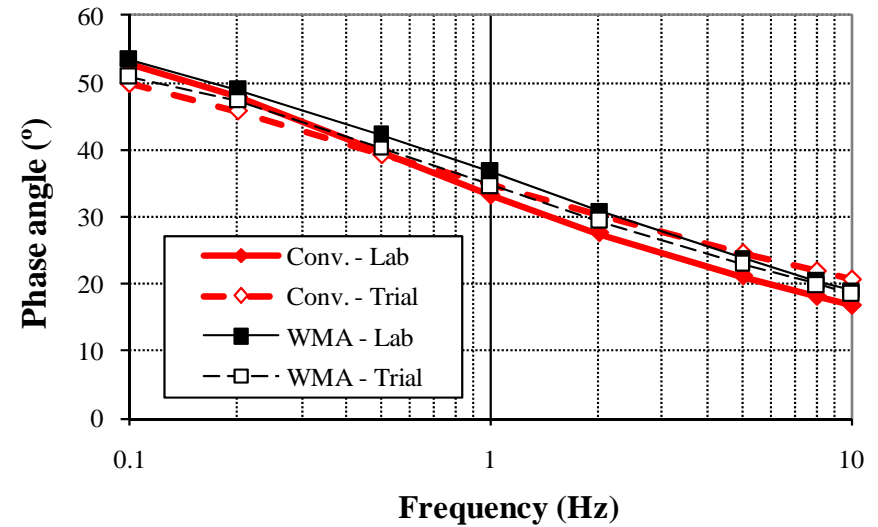
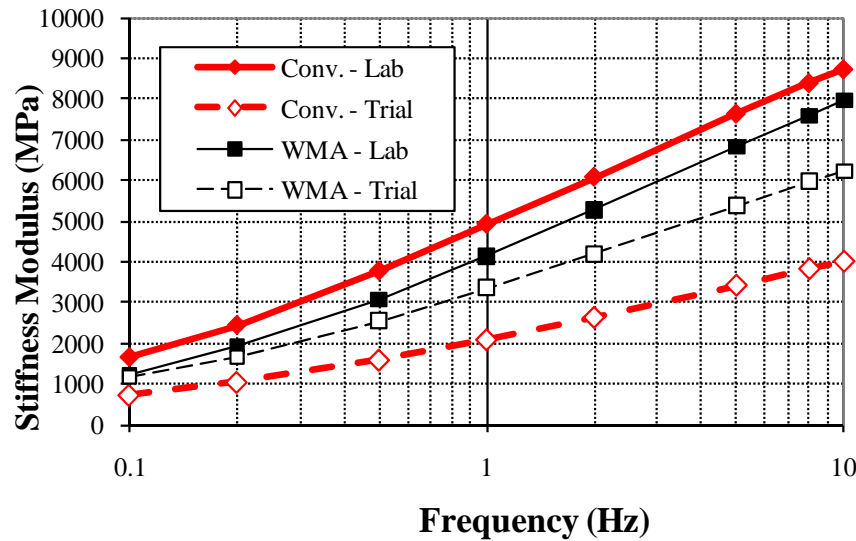
Mixture	WMA	HMA
ITSR (%)	57.6%	71.4%
WTS _{AIR} (mm/10 ³ cycles)	0.20	0.47

Water sensitivity and rut resistance of the mixtures applied on the trial section

- 3) The differences between the results are inconclusive, as the HMA has shown a lower water sensitivity but the WMA has shown a higher rut resistance. This may be an effect of the presence of the additive in the WMA mixture.



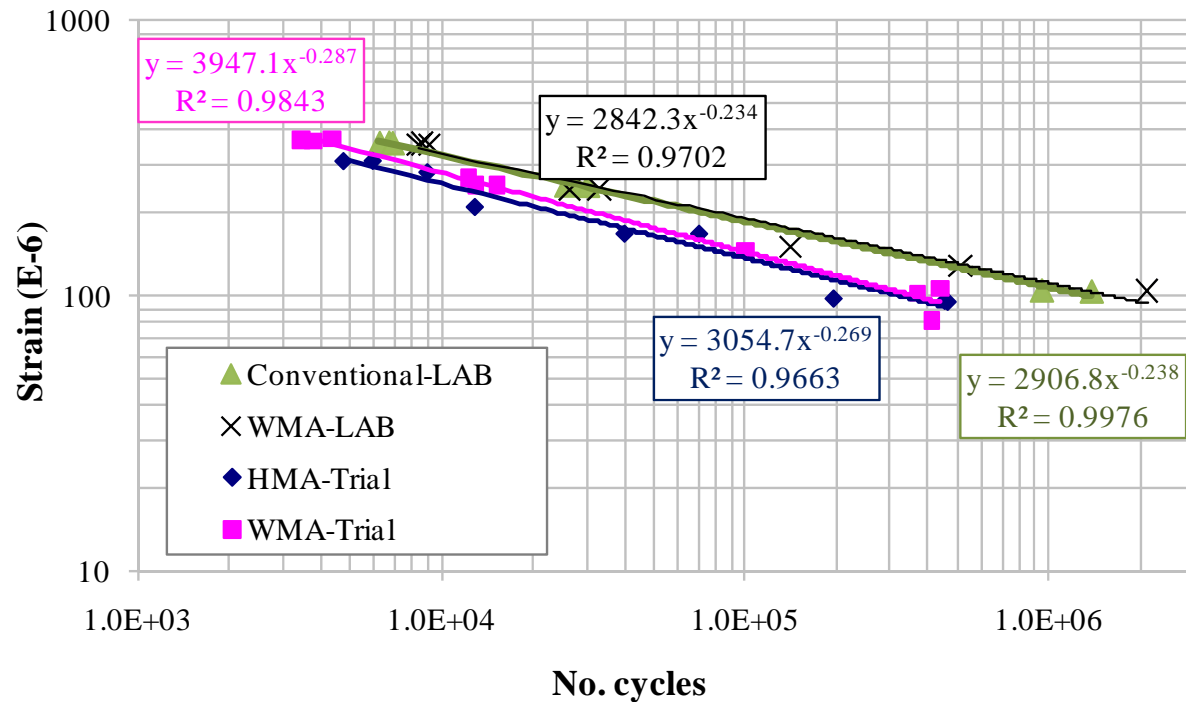
2ND INTERNATIONAL WARM-MIX CONFERENCE



- 4) In comparative terms, the field mixtures have shown a slightly lower stiffness modulus measured at 20 °C, which may have been caused by a higher air voids; WMA mixture outperformed the HMA, due to the contribution of the additive.



2ND INTERNATIONAL WARM-MIX CONFERENCE



- 5) In comparative terms, the field mixtures have shown a slightly higher fatigue resistance measured at 20 °C, which may have been caused by a higher air voids; WMA mixture exhibited a similar fatigue resistance to HMA.



Conclusions

- 1) The WMA additive used in this study does not affect the lower service temperature properties of the binder and, consequently, of the bituminous mixture, while improving the properties of the binder at higher service temperatures, e.g., increasing the softening point.
- 2) The use of the studied additive allowed a reduction of 25 °C on the production temperature of the mixture.
- 3) The fundamental properties of the WMA mixture were similar to those obtained for the HMA mixture, which indicates that the additive is effective on reducing the production temperature without compromising the mixture performance.



Conclusions (II)

- 4) An asphalt plant problem with the sieves in the batching system resulted in an inadequate aggregate gradation on the field mixtures, but the comparison between the WMA and HMA mixture was still valid since both mixtures were prepared in similar conditions. Thus, it was found that the fundamental properties of the WMA trial mixture were also similar to those obtained for the HMA trial mixture.



2ND INTERNATIONAL WARM-MIX CONFERENCE

Thank You for your Attention

Transport Infrastructures Research Laboratory
University of Minho