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Warm Mix Asphalt reaches Dublin's Fair City

By A Kavanagh[1], G Lohan[2] and D Ryan[3]

1. Technical Manager, Atlantic Bitumen Ltd, **akavanagh@atlanticbitumen.ie**
2. General Manager, Atlantic Bitumen Ltd, **glohan@atlanticbitumen.ie**
3. General Manager, SIAC Bituminous Products Ltd, **denis.aryan@siac.ie**

A Kavanagh

G Lohan

Denis Ryan

Abstract

For sustainability and environmental reasons, interest in the use of warm mix asphalt is increasing throughout Europe. Lower mixing temperatures result in reduced energy use at the mixing plant and reduced carbon emissions. However, in order for customers to accept its suitability as a direct replacement for conventional hot mix asphalt, it must be shown to provide at least the equivalent performance levels. Over the past three years, Atlantic Bitumen has been conducting laboratory studies to compare the performance of warm mix asphalt versus hot mix asphalt. As these studies showed, the warm mix asphalts achieved the required performance levels in the laboratory so that the next step of the evaluation process was to perform on-site trials. For the two site trials described in this paper, the warm mix SMA 10 surface course asphalt was manufactured using a PMB bitumen at a temperature 35 °C lower than that used for the hot mix SMA 10. The PMB bitumen was modified using a chemical additive called CWM® that reduces the surface tension and viscosity of the bitumen, thus facilitating lower mixing and compaction temperatures. The results of the site trials are presented in this paper.

Keywords: Warm mix asphalt, site trial, temperature, carbon emissions, performance

Introduction

Depending on the mix type and bitumen that is used, traditional hot mix asphalt (HMA) is produced at temperatures typically ranging from 140 to 180°C. At these high temperatures, the bitumen becomes less viscous (i.e. more fluid), allowing full aggregate coating to be obtained during the mixing process and good workability during laying and compaction. The main goal of "warm mix asphalt" (WMA) or "low-temperature asphalt" technologies is to reduce these temperatures without sacrificing the performance of the end product. The main benefits of WMA technologies are reduced fuel use and a consequent reduction in carbon emissions at the mixing plant and reduced fumes for the paving crew.

There are many different methods being used throughout the world for the production of WMA. For the site trials described in this paper, the warm-mix asphalt was produced using bitumen that was modified by a chemical additive named CWM®. CWM is manufactured by an Irish company named Chemoran Ltd, and works by reducing the surface tension and viscosity of the bitumen, thus facilitating lower mixing and compaction temperatures.

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Preliminary Site Trial

In the early hours of September 26th 2012, warm mix asphalt was laid for the first time on the streets of Dublin City. As part of a maintenance overlay contract for Dublin City Council (DCC), SIAC Bituminous Products Ltd. were laying binder and surface course asphalt pavement layers on sections of streets in the Rathgar – Rathmines area. Work was being carried out during the night shift to minimise traffic disruption. On the night in question, the asphalt mix being used was **SMA 10 surf PMB 65/105-60 des**. In order to familiarise the plant operator and paving crew with the new warm mix material, one load of warm mix asphalt was manufactured and laid as a preliminary site trial. The warm mix load was made at temperatures of about 30°C lower than the hot mix by dosing the bitumen with 0.4% by mass of CWM. On site, mat temperatures of both the hot and warm mix asphalt were recorded and photos were also taken using a thermal imaging camera.

Figure 1 Hot mix asphalt mat temperature of about 141°C

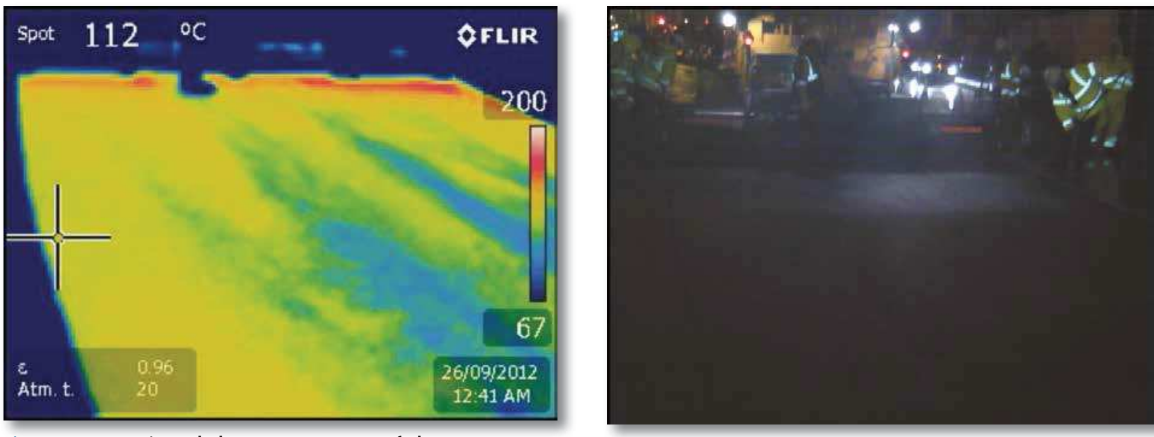

Figure 2 Warm mix asphalt mat temperature of about 112°C

While it took a couple of batches for the plant operator to bring the mixing temperature down to the target of 30°C less than that of the hot mix, once the lower temperature was achieved it was easily maintained. Onsite, the laying crew reported that the material behaved in the same way as conventional hot mix. Images from the thermal imaging camera showed that the mix temperatures were consistent at about 30°C lower than the hot mix, as can be seen from **Figures 1 and 2** above.

Site Trial in North Wall Quay, Dublin City

Having gained experience from mixing and laying one load of warm mix asphalt for the preliminary site trial, SIAC were happy for the second site trial to be larger in scale. In October, SIAC were performing an overlay contract on a section of the North Wall Quay, on the banks of the River Liffey, in Dublin City. This contract was identified by SIAC as an opportunity to conduct a more large scale site trial. Having received approval from DCC to lay part of the surface course using warm mix asphalt, the trial took place on the 15th and 16th of October 2012.

> On site, the laying crew reported that the material behaved in the same way as conventional hot mix

Once again, the asphalt mix being used was **SMA 10 surf PMB 65/105-60 des**. In order to carry out a direct comparison with the performance of hot mix asphalt, part of the surface course was also paved using conventional hot mix SMA 10. The target mixing temperature for the hot mix SMA was 175°C and the target mixing temperature for the warm mix SMA was 140°C. Mix temperatures, smoke emissions, air voids content, surface texture and stiffness modulus of both the warm and hot mix SMA 10 were recorded for comparison purposes.

Mix Temperatures

The recorded delivery temperatures for both the warm and hot mix SMA are shown in **Table 1** opposite. The recorded mix temperatures behind the screed of the paver are also shown. As can be seen, the average warm mix delivery temperature is 33°C lower than the hot mix delivery temperature, while the average temperature of the warm mix asphalt mat behind the screed of the paver is 25°C lower.

VOC emissions

Despite the reduction in mixing and delivery temperatures, the warm mix material looked and behaved in the same way the hot mix material, during and after the laying process. However, thanks to reduced mixing temperatures, there was visibly less smoke coming from the warm mix material, as can be seen from **Figures 5 and 6**, respectively.

	Target Mixing Temp (°C)	Recorded Delivery Temps (°C)	Average Delivery Temp (°C)	Recorded Temps behind paver screed (°C)	Average Temp behind paver screed (°C)
Hot-mix SMA	175	170, 178, 179	175	156, 146, 149, 152, 147, 151	150
Warm-mix SMA	140	142, 136, 148	142	121, 116, 121, 130, 132, 129	125

Table 1 Recorded Mix temperatures

thanks to reduced mixing temperatures, there was visibly less smoke coming from the warm mix material

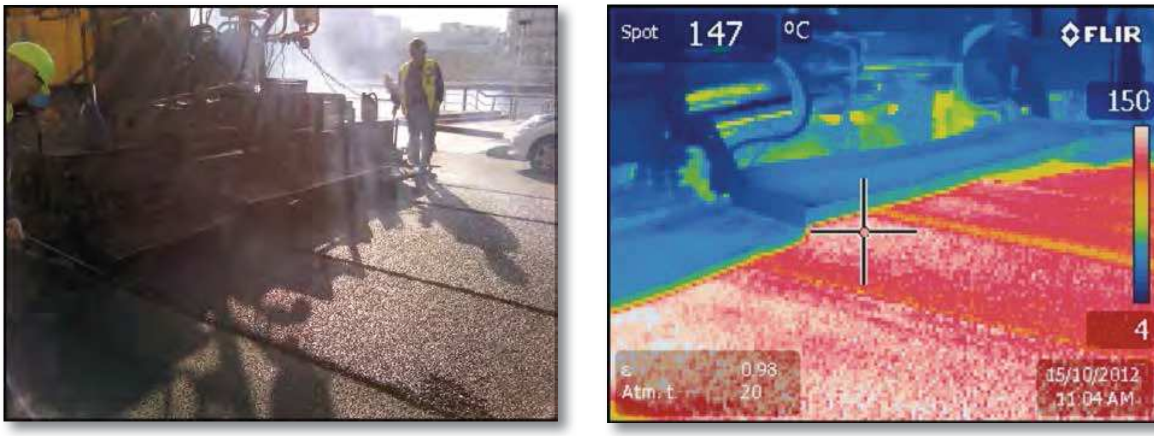

Figure 3 Mat temperatures of hot mix SMA 10

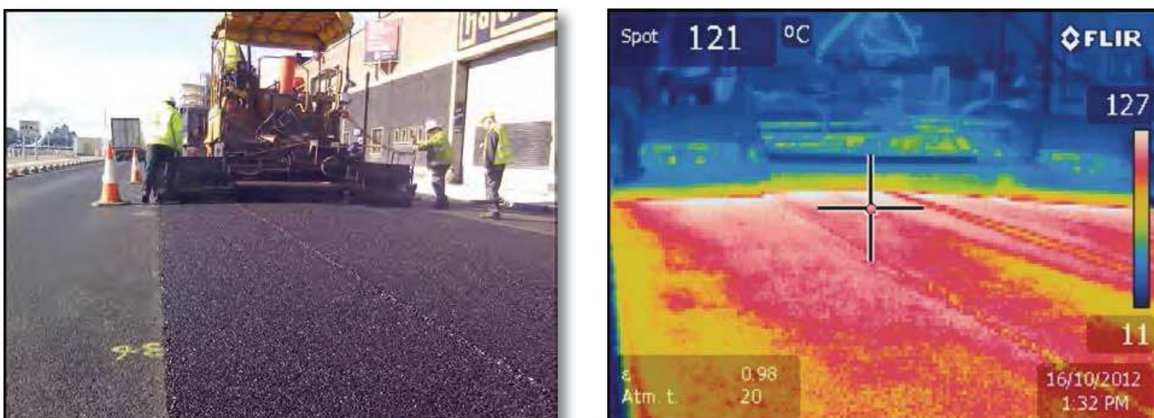

Figure 4 Mat temperatures of warm mix SMA 10

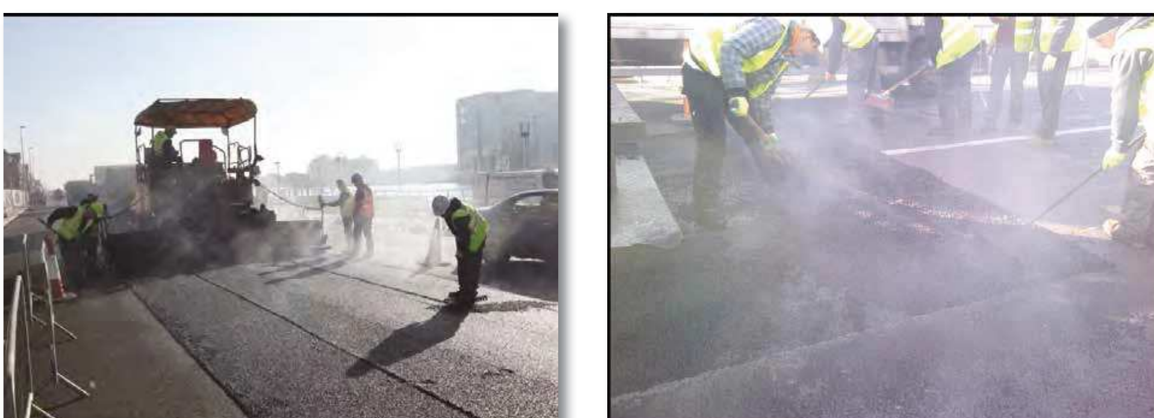

Figure 5 Smoke from hot mix SMA 10

Figure 6 No smoke from warm mix SMA 10

In order to quantifiably demonstrate how much the smoke and fumes were reduced by, volatile organic compound or "VOC" emissions were recorded during laying of both the hot- and warm mix sections by the Air Quality Technology Centre of the National University of Galway. The measurements were made using probes that were attached to the screed of the paver and to two of the paving crew members. VOCs are organic chemicals that have a low boiling point at ambient temperature conditions. This causes large numbers of molecules to evaporate and enter the surrounding air. Some VOCs can be dangerous to human health or cause harm to the environment [2]. During this site trial, all of the recorded VOC emission levels, for both the warm and hot mix SMA 10, were far below the allowable occupational exposure limits. In addition, as can been seen from **Table 2**, the total VOC emissions from the warm mix were 1/5th (21%) of the level of emissions from the hot mix material.

	Hot-mix SMA	Warm-mix SMA
Total VOCs (µm/m³)	77799	16679

Table 2 Recorded VOC emissions

Hot-mix SMA			Warm-mix SMA		
Core No.	Bulk Density (kg/m³)	Air Voids (%)	Core No.	Bulk Density (kg/m³)	Air Voids (%)
1a	2325	7.7	2a	2282	9.4
1b	2279	9.6	2b	2292	9.0
1c	2298	8.8	2c	2301	8.7
Average:	**2301**	**8.7**	**Average:**	**2292**	**9.0**

Table 4 Recorded air voids contents

Air voids content

Despite the reduction in mixing and delivery temperatures, the warm mix SMA material was as workable and easy to compact as the hot mix SMA material. In order to compare the compaction levels achieved, cores were taken from both sections. The air voids contents of these cores were determined and are presented in **Table 4**.

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As can be seen from the above results, the compactibility of both materials was the same, as the repeatability of the test is 17 kg/m³. (The same compaction regime was used for both materials).

Surface Texture

As can be seen from **Figure 7**, the surface texture of the warm mix SMA 10 looked very similar to that of the conventional hot mix SMA 10.

Figure 7 Surface texture of both warm and hot mix SMA 10

For comparison, the surface textures of both materials were measured using the volumetric sand patch test, at three randomly spaced locations. The results are presented in **Table 3** and confirm that the surface texture of both materials is the same at just over 1.5mm.

Hot-mix SMA		Warm-mix SMA	
Test Location	Texture Depth (mm)	Test Location	Texture Depth (mm)
1a	1.51	2a	1.63
1b	1.42	2b	1.72
1c	1.69	2c	1.41
Average	1.54	Average	1.59

Table 3 Surface Texture Results

The main purpose for the development of warm mix asphalts is to reduce fuel use at the mixing plant and to consequently, reduce carbon emissions

Stiffness Modulus

Cores of both materials were also brought to the laboratory for stiffness modulus testing. The results are presented in **Table 5**. The stiffness modulus of the warm mix SMA 10 is marginally higher than that of the hot mix SMA. Other studies have found that, due to reduced oxidative age hardening of the binder, the stiffness modulus of warm mixes is normally lower than their hot mix counterparts [3]. That is not the case here, as the stiffness of SMA type mixes is more due to the aggregate skeleton than the binder used. The same comment would also apply to the rut-resistance of NRA Clause 942 SMA type mixes, as was found in our earlier laboratory study [1].

Hot-mix SMA		Warm-mix SMA	
Core No.	Stiffness Modulus (MPa)	Core No.	Stiffness Modulus (MPa)
1a	781	2a	797
1b	826	2b	1165
1c	722	2c	694
Average:	776	Average:	885

Table 5 Stiffness Modulus Results

Fuel use at the hot mix plant

During mixing of the warm mix SMA at the asphalt plant, fuel use was monitored and was found to be about 20 % lower compared to that for the hot mix SMA.

Conclusion

The main purpose for the development of warm-mix asphalts is to reduce fuel use at the mixing plant and to, consequently, reduce carbon emissions. This trial has shown that carbon emissions can be reduced while, at the same time, maintaining the performance of the end product, namely the SMA 10 surface course for two of Dublin's busiest city streets. Another side effect to reduced fuel use is a reduction in VOC emission, both at the asphalt mixing plant and for the laying crew.

Further work will continue to investigate the performance of warm-mix asphalt. A study to investigate the effect of the above mentioned reduction in oxidative age hardening of the bitumen is currently underway in the Atlantic Bitumen Asphalt Laboratory. The study will examine if reduced age hardening will contribute to a longer fatigue life for a variety of warm-mix asphalts.

Acknowledgements

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