LABORATORY AND FIELD PERFORMANCES OF A WARM MIX ASPHALT ON HIGHWAY A35 IN FRANCE

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ABSTRACT

In Europe, EUROVIA and MeadWestvaco have been working together since 2006 in the development and promotion of warm mix asphalt. Since then, nearly one million tonnes of warm mix asphalt have been manufactured and applied on different types of roads, in different climates, and with various types of aggregates and asphalt binders.

This paper describes one of the most challenging achievements realized thus far: use of warm mix asphalt in the construction of the three base courses of the highway A35, around the city of Strasbourg, France, near the German border. The mix design incorporated 20% RAP materials with a 35/50 pen virgin binder. The average manufacturing temperature of the warm mix asphalt was around 115°C, more than 50°C below the HMA reference. Construction of the warm mix asphalt pavements began in November 2009, when ambient daily high temperatures were around 10°C.

Job materials and mix properties are described. Production details, construction operations, and pavement performance characteristics are also presented. A comparison between the performance of the mix in-situ and in the lab is also discussed in conjunction with comparative performances of the HMA reference.

Keywords: Warm mix, Performances, RAP materials, Highway, Laboratory design

INTRODUCTION

In the context of increasing environmental stresses and energy scarcity, reducing the temperatures of bituminous mixes has become one of the main preoccupations of the various players in the road-industry worldwide. The EVOTHERM DAT® mixes of the TEMPERA® range retain the same characteristics as the classic hot solutions. By eliminating fumes and odours, these new bituminous mixes guarantee a more pleasant environment for residents and work teams while using up to 40% less energy.This collaboration between the two companies has now been in place for over five years. More than one million tons of EVOTHERM mixes have been applied all over Europe, with nearly 300 000 tons for the 2010 year only.Numerous validation tests have been carried out by the EUROVIA Research Centre in Mérignac (33). Several sites over Europe, on different types of bituminous mix, have confirmed the validity of the process. A first article was published in March 2009 in the French magazine "Revue Générale des Routes et Aérodromes"[3]. At the end of 2011, more than 40 hot mix plants in France, UK and Spain will be equipped with DAT kits to manufacture EVOTHERM DAT mixes.This paper describes one of the most challenging achievements realized thus far: use of warm mix asphalt in the construction of the base course of the highway A35, around the city of Strasbourg, France, near the German border. This base course was applied in three different lifts of 10cm (4 inches) each .The mix design incorporated 10% RAP materials with a 35/50 pen virgin binder. The average manufacturing temperature of the warm mix asphalt was around 115-120°C, about 50°C below the HMA reference. Construction of the warm mix asphalt pavements began in November 2009, when ambient daily high temperatures were around 10°C.

PART ONE: DESCRIPTION AND BENEFITS OF THE DAT PROCESS:

1.1 Description

EVOTHERM DAT is a warm mix process based on the addition of a chemical package in an aqueous phase. This additive gives the warm mix the necessary workability to be applied at lower temperatures while maintaining a good adhesion between the binder and the aggregates. An aqueous solution with between 10 to 15% in weight of additive (EVOTHERM H5 ®) just needs to be made. The EVOTHERM H5® additive is water soluble without the need to adjust the pH of the solution. This simple dilution is then injected in-line into the bitumen to the tune of 5 to 10% in weight in relation to the bitumen.

In this way, the coating plant does not require any modification, except for a branch fitted to the bitumen line and the addition of a pump (and a flow meter) to inject the additive.

1.2 Benefits

The first obvious benefit is the reduction in the consumption of energy when manufacturing the bituminous mixes, as the materials necessarily need to be heated less than when manufacturing conventional bituminous mixes. The various sites show a savings of around 40% in energy, with measured gains from 30% to 50% depending on the humidity of the materials and the working conditions.

The second direct consequence of this reduction in temperature is a significant drop in the emission rates of the various gases and particulates in the plant. Measurements highlighted the following levels:

. 48% reduction in greenhouses gases

. 58% reduction in nitrogen oxides,

. 41% reduction in sulphur dioxide, which is responsible for acid rain.

(Jobsite done in September 2006, Ohio, USA – Measurements made by EES group, an independent laboratory)

Finally, the work of the paving crews in-situ has become much less difficult, since the bituminous mixes are generally compacted at between 80°C and 110°C. Also, the drop in nuisance odours makes working in an urban environment much easier and allows asphalt mix plant to integrate more effectively into its immediate environment, especially if there are residential communities nearby.

PART TWO: MANUFACTURING AND APPLICATION OF THE WMA

2.1 Manufacturing of the WMA:

The composition of the mix was based on the blending of different fractions of limestone aggregates as well as 10% RAP.

10/14: 23.5%

6/10: 19%

4/6: 10%

0/4: 32%

filler: 1.1%

RAP: 10%

Virgin Asphalt (35/50pen): 4.1% Total binder content**: 4.6%**

DAT H5: 0.3%

The plant used was a continuous plant, type TSM 28 from ERMONT (Fayat Group)

After settling down, the different manufacturing parameters were:

Mix temperature:	**115 to 125°C**
Flowrate:	**350mt par hour**
Baghouse temp:	**106 – 109°C**
Burner:	**20 %**
Depression inside the drum:	**30Pa**
Fuel consumption:	**1380 to 1500 l per hour**

Nota: *During the manufacturing of the hot mix (165°C) the fuel consumption was* ***2200 liters per hour****. We can therefore estimate the fuel savings to about* ***34.5%*** *on that particular jobsite*

Extractions and binder residues were measured during the manufacturing of the mix and values between 4.55 to 4.60% were found, exactly on the spot of the original mix design.

2.2 Application of the mix:

The project consisted in applying 1400mt of a GB 0/14 cl 3 (Grave Bitume) in three lifts as base courses on the motorway A35. Each lift was about 9 to 10 cm thick The mix was applied with only one finisher on the total width of the road (8.6 meters).

Compaction was achieved with 12 passes (large vibrations) of two CC422 DYNAPAC cylinders (VT2).

Void contents measures on the jobsite just after compaction were situated between 6 to 9 % voids (spec < 10%).

One parameter of interest that we wanted to follow was the evolution of the temperature of the mix on the jobsite and the evolution of the %void content inside the mix according this temperature and the compaction pattern.

We followed a truck from the loading at the plant to its arrival on the jobsite. Then we spotted were the mix was applied and followed the evolution of the temperature of the mix versus time as well as the evolution of its density versus the number of passes.

The truck we followed was loaded with a mix whose manufacturing temperature was 122°C….when applied about 90 minutes later, the temperature inside the finisher was 119°C……115°C behind the table…

The weather was quite severe, with a lot of wind, wet conditions and an ambient temperature of about 14°C….

Measures of the temperature inside the layer applied showed a decrease of the temperature of about 1°C per minute. The layer was applied on 10cm (4 inches) thick. Compaction was still effective with a mix temperature around 85-90°C. Please see the details below.

Time	**T° inside the layer**	**Nb passes (cumulative)** (**CC722 – VT2 type)**	**% voids**
To: 9h20	115	0	21.9
To + 7mn: 9h27	113	4	12.6
To + 16mn: 9h36	109	8	9.1
To + 30mn: 9h50	89	12	6.4 (spec < 10)

End of compaction

PART THREE: Follow-up of the performances on site

To control the manufacturing processes some samples were taken in the plant just after manufacturing. To evaluate the mechanical properties of the mixes some cores were taken for each layer the day after the laying, on the three tracks for the hot mix and the warm mix.

The following tests were performed:

1- Manufacturing control :

- Binder content : NF EN 12697-1
- Binder analysis after extraction : NF EN 12697-3
    - Penetrability 1/10 mm : NF EN 1426
    - Ring and ball temperature : NF EN 1427
    - Rheological test : Isochron 10 Hz
- Determination of aggregate size distribution : NF EN 12697-1 + NF EN 12697-2

To evaluate the impact of the temperature manufacturing on the asphalt, a mix sample was taken just after the manufacturing in the plant and on the site after about 2 hours. The characteristics of these asphalts were compared to those of the asphalt after RTFOT (Rolling thin film oven test : NF EN 12607-1).

2- Mechanical properties on the cores :

- Void content : gamma bench (NF EN 12697-7)
- Dynamic modulus 15 °C, 10 Hz (NF EN 12697-26)
- Indirect tensile strength at 25 °C (NF EN 12697-23)

3.1 Results:

- Analysis of the cores (Table 1):

			Void content (%)	ITS d 25°C	E (15°C, 10 Hz)	
				kPa	MPa	Specifications (EN 13108-1)
Hot Mix	Slow track	layer 1	3,2	1360	15 500	> 9000 MPa (<9% voids)
		layer 2	3,5	1068	13400	
		layer 3	4,7	1178	12100	
	Central track	layer 1	4	1374	14950	
		layer 2	3,5	1093	12600	
		layer 3	6,2	1143	11300	
	Speed track	layer 1	4	1262	15700	
		layer 2	3,1	1140	13300	
		layer 3	5,3	1252	13300	
Warm Mix	Slow track	layer 1	4	1296	14400	
		layer 2	5,2	1283	11900	
		layer 3	5,5	1322	14050	
	Central track	layer 1	4,6	1314	15300	
		layer 2	5,6	1314	10600	
		layer 3	6,8	1134	12500	
	Speed track	layer 1	4,1	1296	15400	
		layer 2	5,5	1344	12400	
		layer 3	6,5	1203	13000	

Table 1: Cores analysis

The grading curves of the aggregates after asphalt extraction are in conformity with the mix design reference.

- Asphalt analysis (table 2):

				Hot mix		Warm mix	
		Asphalt	Asphalt after RTFOT	sample coming from the plant	sample coming from the site	sample coming from the plant	sample coming from the site
T° of the sample				162°C	162°C	121°C	118°C
Time between manufacturing and sampling				t0	+1h	t0	+1h
Binder content	(%)			4,48	4,49	4,35	4,40
	(pph)			4,69	4,71	4,55	4,60
Penetrability at 25°C *NF EN 1426*	(1/10mm)	43	28	32	30	33	33
Ring and ball temperature *NF EN 1427*	(°C)	53,6	59,4	57	58	57	56,8

Table 2: Asphalt analysis

The asphalt was recovered from the mixes following the Infratest method with perchloroethylen.

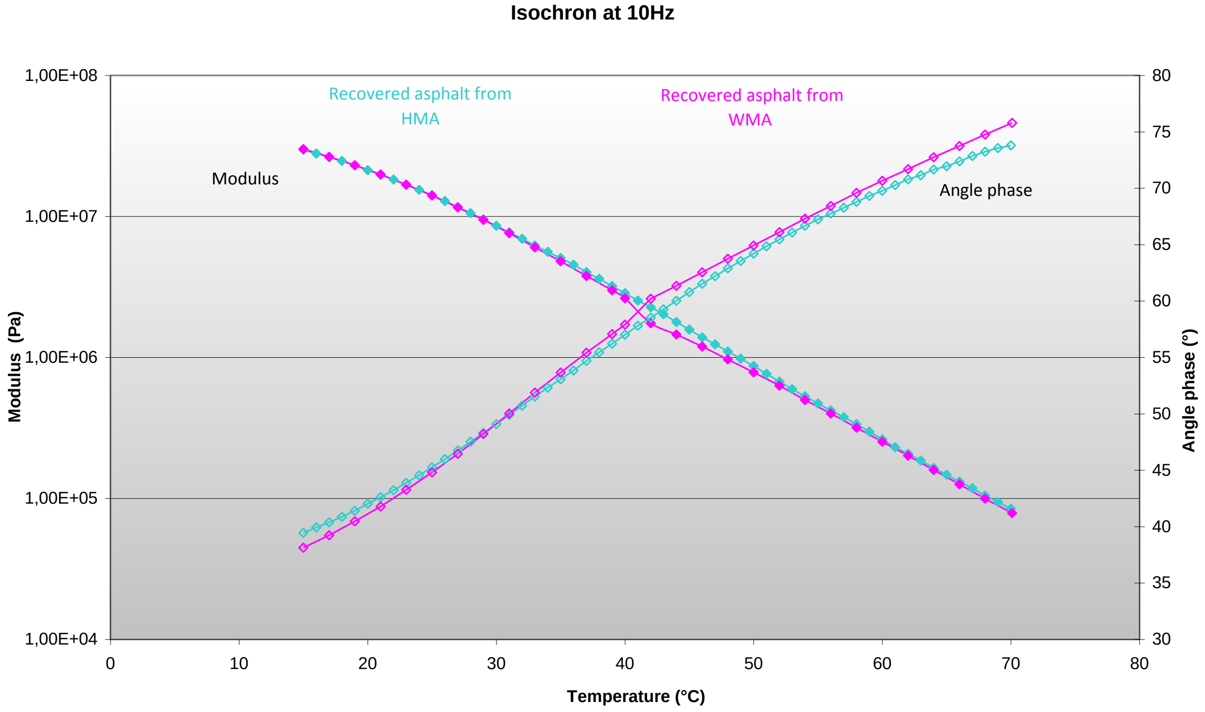

Figure 1: Rheological analysis of asphalts

This graph represents the evolution of the complex modulus after extraction (descending curves) as well as the phase angle of the two binders (ascending curves). No real difference is observed between the two asphalts analyzed.

3.2 Comments

We thought that the difference in temperature would enable us to see a difference of oxidation of the binder. This phenomenon has been observed several times on different jobsites and studies[4,5]. But the data collected for this project show very similar values and a very similar rheological behavior of the two binders extracted from the WMA and the HMA reference. Penetration values tend to show maybe a softer binder (less oxidized) from the WMA core samples. Further investigations are under progress to try to extract the binder from asphalt mixes made in the laboratory and corroborate the data to the one observed on samples from the jobsite.

Nevertheless, data gathered on table 3 show a very similar mechanical behavior of the two mixes, but with 50°C difference application. Modulus and indirect tensile strength of the Evotherm® warm mix asphalt are equivalent to the HMA reference. That is quite an achievement if we take into account the difference of the temperature of the two mixes (around 50°C).
The values found on samples taken from the jobsite also corroborate the ones found during the lab study previously carried out for the validation of the mix design.

3.3 Laboratory study – comparative results

During the site, samples of aggregates and asphalt were taken in order to compare the manufacturing procedure in the lab to the real one at the plant during the jobsite.

In the laboratory, the manufacturing conditions were:

- Heating of the aggregates for at least 16 h at 165 °C for the hot mix and 120°C for the warm mix
- Heating 2 h the RAP at 110 °C
- Mixing 2 minutes the RAP + aggregates
- Adding the bitumen and the additive (for the warm mix)
- Mixing 3 minutes
- For both mixes the curing time before molding samples is 1 h at the manufacturing temperature.

The laboratory results are gathered in the table 5.

	HMA	WMA	Specifications EN 13108-1
Giratory Shear Compactor (GSC)			
NF EN 12697-31			
V100(%)	**6,6**	**6,7**	<10
Slope	3,75	3,53	
Sensitivity to water			
NF EN 12697-12 (B - Duriez)			
CD 18°C (kPa)	8949	9389	
CW 18°C (kPa)	7667	7200	
I/C	**85,7%**	**76,6%**	>70%
Void content (%)	9,7	8,6	
Rutting test			
NF EN 12697-23			
Rutting at 30 000 cycles % (60°C)	2,5	2,76	<5%
Void content (%)	7,7	8,6	7-10
Dynamic modulus			
NF EN 12697-26			
Modulus 15°C/ 10 Hz (MPa)	**12750**	**11 932**	> 9000
Void content (%)	7,1	8,0	7-10
Fatigue test			
NF EN 12697-24			
Appendix A : 2 points bending/ trapezoïdal sample			
e6 (µdef) à 10°C, 25 Hz	**107**	**101**	>90
Void content (%)	7,2	7,4	7-10
Appendix D : 4 points bending/ Prismatic sample			
e6 (µdef) à 10°C, 25 Hz	119	116	
Void content (%)	7,3	7,2	

Table 5: Laboratory Study - Results

Both the reference and the warm mix show very close performances, as far as the workability, the rutting resistance, the modulus and the fatigue are concerned. No differences can be observed. The only little decrease in performances concerns the water sensitivity of the warm with a 10% reduction in performances but still well above the product specification (IC > 70%) and with a reduction of temperature of more than 30% (50°C).

As previously demonstrated, these results were verified on cores sampled from the jobsite, which validates the approach used in the lab but also the excellent performances of the Evotherm DAT® process as an alternative to produce asphalt mixes with in a more eco-friendly way.

CONCLUSION

For five years now, the companies EUROVIA and MEADWESTVACO have been working together to perfect and develop EVOTHERM ® in France and Europe. More than one million tons of Evotherm mixes have already been applied by EUROVIA since then. After a few years of evaluations, confidence in warm asphalt mixes is getting stronger and stronger and big projects as this one on the highway A35 in France are now opened to this technique. In 2011, a 55 000 ton project is forecast in France too.

If some work is still required to fully understand all the phenomena involved in this process, the change is already taking place. Energy-related and environmental pressures on the asphalt industry will only increase over time. There is no doubt that the use of warm technologies will be one of the responses to these pressures. The flexibility and quality performances obtained with technologies like EVOTHERM ® should be able to help "warm up" those least receptive to this change.

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