WARM ASPHALT MIX TECHNOLOGY
AN OVERVIEW OF THE PROCESS IN CANADA

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ABSTRACT

Warm mix technology has become the latest buzz word in the area of asphalt technology. Worker health and safety, as well as environmental concerns have caused many people to look for different ways of producing asphalt concrete that maintains the physical properties and performance characteristics of traditional hot mix, but are more worker and environmentally friendly.

This paper discusses the various warm mix asphalt processes being evaluated throughout North America. The paper will concentrate on the state of the practice within Canada. A more detailed review of projects carried out by McAsphalt Industries to study the effects of warm mix technology using the Evotherm® technology will also be discussed. The warm mix asphalt projects involved the placement of various types of asphalt mix on prepared granular base as well as overlays on existing asphalt pavements. The use of recycled asphalt pavement (RAP) will also be presented. Environmental testing has been performed on both the hot and warm mixes to monitor the greenhouse gases during production and these results will be discussed in detail.

Based on the results achieved so far the warm mix asphalt technology provides lower emissions (greenhouse gases) than hot mix without compromising the performance properties of the mix; can be produced at hot mix plants with very little changes needed if any. Worker health and safety is being improved through the use of warm mix asphalt technology. Also, it has shown that less oxidation is occurring in the warm mix, which certainly will translate into longer service life. To this date there have been no major issues with any of the warm mix asphalt processes being used around the world.

1.0 BACKGROUND

The use of warm mix technology has many benefits to the environment. Lower mixing and compaction temperatures can provide numerous construction and performance-related benefits including reduced aging of the binder, reduced fumes and odours at the paving machine, as well as increased percentages of Reclaimed Asphalt Pavement (RAP) within the mixes.

The Kyoto Accord protocols, as well as stricter environmental regulations coming into effect, indicate that the pressure is mounting to reduce greenhouse gases throughout the country. The increased environmental pressure to reduce greenhouse gases has started to put pressure on industries to become more proactive in reducing emissions. Warm mix technology is one way of reducing greenhouse gases without adversely affecting the long term quality of the road mixes. Lower mixing temperatures can benefit both the contractor and the environment. As energy costs increase, reduction in mixing temperatures can greatly reduce energy consumption and lower emissions at both the hot mix plant and at the paving operation. With decreased mixing temperatures there is a reduction in the oxidation of the asphalt cement during the manufacturing process, which can translate into longer pavement service life without compromising the quality of the paving mix.

In order to evaluate the warm mix process, field trials are required to compare the physical properties and performance of the warm mix to conventional hot mix.

2.0 INTRODUCTION TO WARM MIX TECHNOLOGY

As originally discussed by Davidson, Tighe and Croteau [1], several new processes have been developed to reduce the mixing and compaction temperatures of hot mix asphalt. These processes are known as warm mix asphalt. The lower temperatures should result in lower plant emissions and lower fuel consumption. Currently there are five of the eight main processes being evaluated in Canada:

- Aspha-min® zeolite developed by Eurovia
- Sasobit® developed by Sasol International
- WAM Foam by Shell
- Low Energy Asphalt by Fairco and Appia
- Double Barrel Green by Astec
- Evotherm® developed by MeadWestvaco
- Revix developed by Ergon and Mathy
- Rediset developed by Akzo-Nobel

The Aspha-min® is produced in granular form [2]. The product contains approximately 20 percent water by weight. When the Aspha-min® is added to the mix the water is released under high temperatures. The high temperatures (100 to 200ºC) cause the asphalt cement to foam slowly while mixing with the HMA aggregate. The foamed asphalt has greater workability and allows for improved compaction and coating of the aggregate particles at a lower temperature. Typically, the mixing and compaction temperatures can be lowered 30ºC.

Sasobit® is a Fischer-Tropsch wax [3]. This wax is produced from coal gasification using the Fischer-Tropsch process. The Sasobit® lowers the viscosity of the asphalt cement at the mixing and compaction temperatures but still maintains the original viscosity at the in-service pavement temperatures. The Sasobit® can be combined with polymers to give the added benefit without creating issues with the warm mix temperatures. Typically 1.5 to 2.0 % is added and the mixing and compaction temperatures can be lowered 15º to 20 ºC.

The WAM Foam process is a two-component binder system where a soft binder is used in conjunction with a foamed hard binder during the mixing stage [4]. The soft binder is mixed with the aggregate at a lower temperature (100 to 120ºC) and then a hard asphalt based foamed asphalt cement is added and foaming occurs. The foaming action gives the mix workability at lower temperatures.

The Low Energy Asphalt (LEA) process is produced by only heating and drying the coarse aggregate fraction of the mix [5]. The second phase of the process is to add the fine aggregate portion of the mix to the hot asphalt coated coarse aggregate. The fine aggregate portion is in a cold and wet state. The LEA process utilizes the interaction of the hot asphalt with the water to create a low temperature mix (90 to 100ºC). Specifically formulated additives are added to the hot asphalt binder to allow for asphalt foaming and coating of the wet particles as well as to prevent stripping.

The Double Barrel Green is a new drum mix plant marketed by Astec. The plant has up to ten foaming nozzles locating on the plant to allow for the foaming of the asphalt cement as it enters the mixing drum. The foaming kit gives a reduction of energy usage of 10 to 15% and a reduction in mixing and laydown temperatures of 30°C from the temperatures associated with hot mix.

The Evotherm® process is based on a chemical process that includes additives to improve coating, workability, adhesion and emulsification [6]. The Evotherm® product is delivered in the form of a high residue emulsion containing between 67 and 69 percent asphalt residue. The Evotherm® process can also be incorporated using a concentrated form directly to the asphalt cement in the pugmill during the wet mix cycle.

The Revix® process is a patented chemical which is added to the asphalt cement. The chemical contains additives which improve coating, workability and adhesion. The Revix relies on lowering the surface tension between the aggregate and the thin film of asphalt cement coating the aggregate.

The Rediset product is also a patented process which is typically added to the asphalt cement. It can also be added to the mix at the asphalt plant. The product reduces the asphalt cement viscosity and reduces the surface tension of the asphalt.

3.0 PROCESS TRIALS

The following sections give an overview of the five processes currently being evaluated in Canada. The other processes have not been evaluated in Canada but a number of trials have been placed in the United States in 2006 and 2007.

3.1 Aspha-Min®

The Aspha-min® process has been placed in the Province of Quebec since August of 2005. Construction DJL Inc. (a large hot mix contractor in Quebec) has been promoting the benefits of warm mix using the Aspha-Min.® process since late 2004 and early 2005.

3.1.1 2005 Season

Three trial sections were placed in 2005 using approximately 500 metric tonnes of mix. All three projects were placed on streets within the City of Montreal during August and September. Two grades of PGAC were used PG 64-28 (one project) and PG 70-28 (two projects). The projects did not use any recycled material in any of the surface mix trials. The hot mix portion was mixed at 160ºC and the Aspha-min® warm mix sections were mixed between 130-135º C. The laydown temperatures were 140 - 150°C for the hot mix and 110 - 125°C for the warm mix.

For all three trials a special batch plant which had been modified ten years ago with a rotary mixer was used. The rotary mixer converted the plant into a continuous type plant. The aggregates are heated and dried in the batch plant dryer and travel up the elevator but bypass the hot screen deck and go directly into the rotary mixer where the bitumen and Aspha-min® are injected.

Figure 1: Warm Mix Placement on Rue Ball in August 2005 and One Year Later

3.1.2 2006 Season

During 2006 three projects were completed by Construction DJL Inc [7]. The first project was a demonstration for the provincial highway department (MTQ) at the end of August using 280 tonnes of surface mix and PG 64-34. The project was located on Autoroute 55 southeast of Drummondville. The hot mix plant used for the project was a drum plant with mixing temperatures of 160°C for the control hot mix section and 130°C for the Aspha-min® warm mix. The laydown temperatures were 150°C for the hot mix and 110 - 120°C for the warm mix.

The last two projects were placed in late November with air temperatures ranging from -1 to +5°C. The first trial on Rue McGill used PG 70-28. The hot mix used a mixing temperature of 160°C and laydown of 150°C, while the warm mix was mixed at 130-135°C and placed at 110 - 120°C. The second trial was placed on Rue des Sommets using PG 58-28. The hot mix temperature for mixing was 145°C. In these two projects, the use of zeolite in the conventional hot mix (same mixing temperature) during late season paving showed the easy compaction behavior compared to the same mix without zeolite.

In conversations with Construction DJL Inc. personnel the warm mix trials in 2005 and 2006 went very well and there were no issues with temperature in achieving the required compaction even during the late season construction. Unfortunately in 2007 no Aspha-min® demonstrations were placed.

Figure 2: Zeolite Injection and Laydown of Aspha-min® Warm Mix on Autoroute 55

3.2 Sasobit®

The use of Sasobit® technology is new to Canada. Bitumar Inc. (an asphalt supplier in Quebec and Ontario) has been pursuing the process in conjunction with a consultant for Sasobit®, Mr. Larry Michaels. Trials were placed using Sasobit® in the City of Ottawa and elsewhere. A trial with the City of Toronto was delayed till 2008 due to poor late season weather conditions.

3.3 WAM Foam

The use of WAM-Foam has been experimented with in western province of Alberta, specifically the City of Calgary. LaFarge Canada in 2005 added a foaming kit to one of their asphalt plants in Calgary and produced some warm mix for a subdivision in northeast Calgary. Since that time there have been no further trials of WAM Foam.

3.4 Astec Double Barrel Green

The double barrel green process started in 2007 in the United States. A contractor in British Columbia purchased a new double barrel green hot mix plant and did a number of small trials in the area around their plant. Earlier this year a small contract has been awarded in the City of Richmond BC using this process. Figure 3 shows the setup for the double barrel green plant.

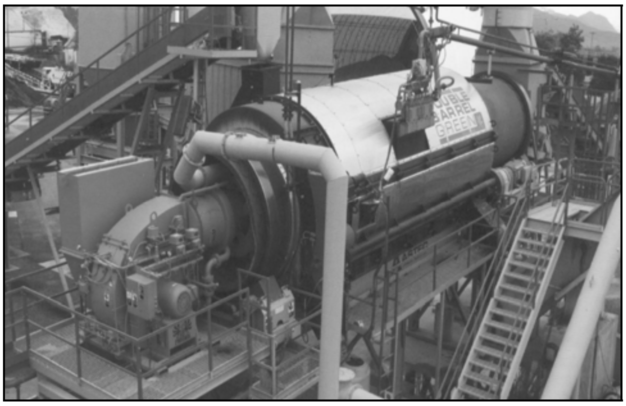

Figure 3a: Double Barrel Green Plant

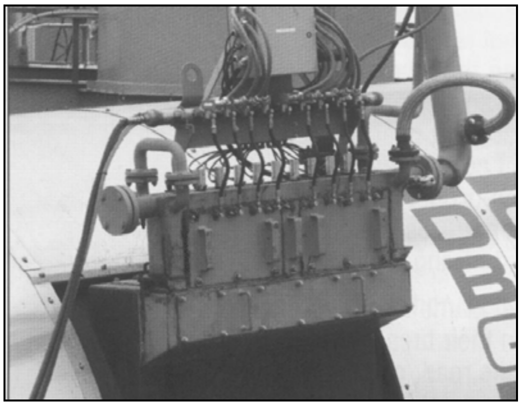

Figure 3b: Foam Injection System

Figure 3: Double barrel Green Asphalt Plant

3.5 Evotherm®

The Evotherm® process has been promoted by McAsphalt Industries since the early spring of 2005. Since that year, eleven (11) trials and demonstrations have been placed across the country using approximately 12500 tonnes of warm mix.

3.5.1 2005 Season

During the construction 2005 season three Evotherm® emulsion warm mix trials were completed using approximately 1700 tonnes of warm mix. For all three trials the warm mix was produced in batch plants. The mixing temperatures for the warm mixes were typically 25 to 30°C lower than the corresponding hot mix and the laydown temperatures for the warm mix varied from 85 to 95°C, which was typically 50°C below the laydown temperature for the hot mix equivalent. The bitumen grade used in all three trials was PG 58-28. For one of the projects environmental emissions testing at the hot mix plant was done for both the hot mix and warm mix. The environmental aspects of the warm mix technology will be discussed in the section 4.0 of the paper. Figure 4 shows the typical operation of the warm mix. Notice in Figure 4b how close the breakdown roller can approach the spreader without any concern to harming the pavement mat.

Figure 4a: Ramara Plant

Figure 4b: Warm Mix Placement

Figure 4: Production and Placement of Evotherm® Warm Mix

3.5.2 2006 Season

The 2006 season was a disappointment in that only one trial was done. The single trial involved the placement of two lifts of base mix covered with a single lift of surface mix. Both the base mix and the surface mix contained 15 % recycled asphalt pavement (RAP). The base bitumen used in the trial was PG 58-28. A total of 1250 tonnes of warm mix was placed. Figure 5 shows some pictures

Figure 5a: Warm Mix Production

Figure 5b: Warm Mix Placement

Figure 5: Production and Placement of RAP Warm Mix

of the project. A review of this warm mix trial was published in the 2007 Proceedings of the Canadian Technical Asphalt Association [8].

This particular trial showed the benefits of warm mix with regards to the large reduction in age hardening that occurs with hot mix compared to warm mix. The recovered penetration of the hot mix was 48 and the recovered penetration for the warm mix averaged 80. The PG 58-28 typically has a penetration of 115 - 120. Even though there is only 15% RAP (penetration = 16) in the mix the hot mix is well on its way to a short service life while the warm mix has a typical penetration value for a virgin hot mix. Table 1 shows the penetration data obtained on the Evotherm trials up to the end of 2007.

As can be seen in the Table 1 the percent loss in the penetration of the warm mix containing RAP (London Trial) is equivalent to the percent loss in penetration of the virgin hot mix from the Ramara trial. Both the London project and the Ramara project used the same virgin PGAC (PG 58-28). The low losses exhibited by the warm mixes should contribute to a longer service life. As to how much this lower age hardening will contribute to longer service life is hard to predict as other factors such as the mix properties and the actual construction can effect the life of a pavement.

Table 1: Recovered Penetration Data

Location	Mix	Original Penetration	Mix Type		% Loss	
			HMA	WMA	HMA	WMA
Aurora	HL8/HL3	118	NA	105		11.02
Calgary	B Mix	163	NA	138		15.34
Ramara	HL4	124	81	107	34.68	13.71
London	HL8R15	116	49	77	57.76	33.62
	HL3R15	121	45	81	62.81	33.06
Hamilton	12.5 FC1	95	60	85	36.84	10.53
Ottawa	12.5 mm	175	125	138	28.57	21.14
Perth Cty	HL3	116	77	86	33.62	25.86
NB DOT	12.5 mm	113	NA	93		17.70
Saanich	Surface	88	52	75	40.91	14.77

Figure 6a: Prior to Rolling

Figure 6b: After Initial Breakdown

Figure 6: Evotherm Laydown Temperatures

Typically the warm mix arrived at the asphalt spreader between 90 - 95°C and after the initial breakdown rolling with the vibratory roller the temperature was in the middle 80's. Figure 6 shows temperature readings illustrating this condition.

3.5.3 2007 Season

The 2007 season gave an opportunity to utilize the DAT (Dispersed Asphalt Technology) system to inject the Evotherm chemical into the mix. At present two of the six demonstrations done so far utilized the DAT concept.

The DAT system is very easy to use and ties into the existing asphalt system. In a batch plant as the bitumen is released into the pugmill at the start of the wet mix cycle the concentrate is also added to the pugmill on a timer to deliver the proper quantity of concentrate to the mix. Typically it runs for 20 to 25 seconds and shuts down. Because there is water in the concentrate it creates a foaming action which allows for coating and mixing the material completely even at lower temperatures. The aggregate temperatures have been lower by 5 to 10°C than with the emulsion system and still have a discharge temperature of around 100°C. Figure 7 shows the DAT process.

Figure 7a: Totes of Concentrate

Figure 7b: Pump/Metering System

Figure 7c: Production of DAT

Figure 7d: Laydown of DAT

Figure 7: Production and Laydown of DAT System

The data collected so far has shown as good as or better results than the emulsion system with regard to compaction and ease of handling.

An interesting project using the DAT system was done in mid-December of 2007. A bridge deck in the New Liskeard area had to be overlaid in order to have both lanes open to traffic for the winter months. As no asphalt plants were open in the north at that time of year it was decided to use warm mix produced in Whitby and hauled 460 kilometres to the jobsite. The four loads of warm mix were produced at the plant in the early morning, tarped to hold in the heat and transported to the jobsite (approximately 8 hours) and then placed on the bridge deck in -10ºC weather. The mix varied in temperature (90 - 130°C) and there was some crusting on the surface of the truck beds. These chunks were broken up and could be placed through the spreader.

Figure 8a: Warm Mix under Tarp

Figure 8b: Placement on Bridge deck

Figure 8c: Breakdown Rolling of Mix

Figure 8d: Intermediate Rolling of Mix

Figure 8: Late Season Placement of Warm Mix

The warm mix was a temporary mix to ensure that the two lanes of traffic could be maintained over the bridge throughout the winter. As of the writing of this paper the mix is performing very well.

4.0 ENVIRONMENTAL DATA

The author is currently aware of environmental data relating to greenhouse gas emissions at the hot mix plant comparing the hot mix to the warm mix and as well the fumes at the asphalt spreader for the Aspha-min® and the Evotherm® processes. In the following two sections the information collected will be discussed in some detail.

4.1 Aspha-min®

Environmental testing has been done on the Aspha-min® product in France. Emission testing has been done at the hot mix plant to measure the greenhouse gases that are being released through the stack both for the conventional hot mix and the warm mix. Comparison testing has also been done at the paving operation to measure the fumes that the workers are exposed to while working around the laydown operation. Table 2 shows how the use of warm mix has lowered the greenhouse gases being produced as well as how much cleaner the air is for the workers at the spreader. Figure 9 shows the environmental setup used at the plant and on the paving equipment and workers. Also by using lower temperatures the quantity of fuel required to produce a tonne of mix has typically been lowered by 20 to 30%.

Table 2: Emission Data – Aspha-min®

Combustion Gas	Emission Reduction
Carbon Monoxide	-19%
Sulphur Dioxide	-18%
Carbon Dioxide	-18%
Oxides of Nitrogen	-23%
Energy Reduction	-23%
Fume Reduction @ Paver	-50%

Figure 9a: Emission Equipment on Workers Figure 9b: Emission Testing at Paver

Figure 9: Emission Testing with Aspha-min®

4.2 Evotherm®

Similar studies have been done by McAsphalt Industries and the Heritage Research Group on the emissions generated by the warm mix in comparison to hot mix [9, 10]. In all cases the data has shown significant reductions in greenhouse gases and the fumes at the asphalt spreader [11]. The limited data on the warm mix regarding energy savings has shown values from as low as 10 percent to as high as 55 percent reduction compared to the same mix produced as hot mix. We have seen this reduction using both the emulsion form of Evotherm® as well as the DAT system of Evotherm®. Table 3 shows a set of emission data obtained from an Evotherm® emulsion trial done at the hot mix plant near Brechin in Ramara Township during the warm mix trial in 2005.

Table 3: Emission Data - Evotherm®

Combustion Gas	Emission Reduction
Carbon Dioxide	-45%
Carbon Monoxide	-63%
Sulphur Dioxide	-81%
Oxides of Nitrogen	-58%
Energy Reduction	-55%
Fume Reduction	-41%

Figure 10a: Emission Equipment

Figure 10b: Stack Location of Probe

Figure 10: Emission Testing of Evotherm® at Ramara

5.0 PERFORMANCE TESTING

As part of the Ramara trial, samples of loose mix as well as slabs and cores were taken from both the hot mix and warm mix sections. These samples were delivered to the Centre for Pavement and Transportation Technology (CPATT) at the University of Waterloo for performance testing, including the resilient modulus and dynamic modulus tests [12,13].

The resilient modulus had some differences in the laboratory prepared and field core samples, overall the variation between the WMA and HMA were statistically the same and the two materials may be considered structurally equivalent. Table 4 summarizes the resilient modulus data. The values in Table 4 represent an average of both the samples prepared from plate samples and cores. Table 5 summarizes the Analysis of Variance (ANOVA) which was run to examine if there were statistical differences between the resilient modulus at the four temperatures.

The testing of the warm and hot mix material for dynamic modulus showed the same results as the resilient modulus. Table 6 summarizes the dynamic modulus results for the Warm Mix Asphalt while Table 7 summarizes the dynamic modulus results for the Hot Mix Asphalt. This would further reinforce the fact that the materials are structurally the same based on the performance testing that was carried out in this study.

Further testing of resilient and dynamic modulus is being carried out by CPATT under Dr. Susan Tighe’s direction on material taken from an Evotherm demonstration project, which occurred in June of 2007 in the City of Hamilton. Half of the project was paved with a Superpave 12.5 mm mix using PG 64-28 and in the second half the PGAC was replaced with Evotherm Emulsion PG 64-28. Data to-date indicates no difference between the hot and warm mixes with respect to void properties as well as some permeability testing performed along the longitudinal joints.

Table 4. Resilient Modulus Comparison of Hot Mix versus Warm Mix - Ramara

Test Temperature °C	Warm Mix (MPa)	Hot Mix (MPa)
0	8273	8227
5	3982	3829
10	4265	4124
22	2357	2102

Table 5. ANOVA Summary of Differences Between Hot Mix and Warm Mix - Ramara

Temperature °C	F Calculated	F Critical	Number of Samples
0	0.001	6.6	5
5	0.22	5.32	9
10	5.98	6.61	6
22	0.82	4.54	16

Table 6. Measured Dynamic Modulus – Warm Mix - Ramara

Frequency	Test Temperature °C			
	-3	**-2**	**21**	**38**
0.1	9188	5441	604	364
0.5	11736	7791	983	419
1.0	12864	8918	1277	506
5.0	15573	11743	2282	868
10	16677	12931	2888	1145
25	18185	14511	3897	1694

Table 7. Measured Dynamic Modulus – Hot Mix - Ramara

Frequency	Test Temperature °C				
	-5	**-1.9**	**21**	**37.8**	**45**
0.1	11539	6771	1125	328	360
0.5	14179	9222	2016	460	418
1.0	15315	10378	2600	571	490
5.0	17901	13193	4506	1004	763
10	18966	14425	5519	1325	978
25	20485	15559	6973	1955	1430

6.0 SUMMARY

Based on the trials of all warm mix placed so far in Canada there have been no issues with mixing, laydown or compaction. The physical properties of the warm mixes have been equivalent to the hot mix in all respects. After three years of service all trial sections are performing as well as the hot mix sections. Some of the major benefits of warm mix are as follows:

- Reduced emissions (lower Greenhouse gas production)
- Reduced production and laydown temperatures
- Lowering of overall energy costs
- Reduced age hardening of mix (longer service life)
- Compaction aid for stiff mixes
- Improved compaction in the field
- Extended paving season (cold weather)
- Longer haul distances

7.0 THE FUTURE

Certainly to the companies promoting the warm mix processes in Canada the feeling is that the trial and demonstration phases are over and it is time to seriously consider full scale contracts. The trials have clearly demonstrated the environmental benefits in greenhouse gas reductions, reduced energy consumption while still maintaining the physical properties needed to meet the traffic demands placed on the road network.

Warm mix technology is the way of the future and will allow the hot mix industry to be leaders in the fight against global warming.

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