Cold Weather Paving Using Warm Mix Asphalt Technology

Steven Manolis, P.Eng.
Lafarge Asphalt Engineering
Downsview, Ontario

Tony Decoo, C.E.T.
Decoo Consulting Services LTD
Goderich, Ontario

Paul Lum, P.Eng.
Lafarge North America
Concord, Ontario

Michael Greco
Lafarge North America
Concord, Ontario

Paper prepared for presentation at the
Warm Asphalt as a Sustainable Strategy for Pavements Session
of the 2008 Annual Conference of the
Transportation Association of Canada
Toronto, Ontario

The authors would like to acknowledge the contributions of Jay MacIntosh, Brad Gooderham, Tyler Samson, Garry Bates, Michael Esenwa, Ming Jiang, and Gelu Vasiliu from Lafarge to this paper.

ABSTRACT

A new technology involving asphalt cement modified with HyperTherm was used to demonstrate that warm mix asphalt technology can be used to extend the paving season by facilitating paving in cold weather.

HyperTherm was initially validated as an effective warm mix technology during an overlay project on Katimavik Road in the City of Ottawa. The job involved the City of Ottawa new 4.75 mm FC1 mix intended for traffic level C (3 to 10 million ESAL's) placed at nominal 25mm thickness. PG 58-28 modified with HyperTherm was used as the asphalt cement. The warm-mix was produced at about 120°C at the plant and compacted at between 75°C – 90°C. This corresponds to reductions in mixing and compaction temperatures as compared to conventional hot mix using the same grade of asphalt cement. Visible emissions and odours during the production and placement of the mix were also reduced.

Phase two of the study utilized the improved mix workability properties imparted by warm mix technology to extend the paving season in a cold weather application. Oxford Road 4 in the County of Oxford, Ontario was paved with PG 58-28 modified with HyperTherm during the month of December. By producing the mix at conventional hot mix temperatures, compaction targets were achieved despite the low ambient air temperature and frozen granular grade. The improved workability imparted by the warm mix additive counteracted the cold weather conditions.

INTRODUCTION

Warm mix asphalt (WMA) is gaining acceptance as an emerging technology in North America. The ability to produce WMA at temperatures 20 to 55 ^{o}C lower than normal hot mix asphalt (HMA) [1] offers several environmental and performance benefits. These benefits include reduced fumes and emissions, lower fuel consumption, a reduction in the aging experienced by the asphalt binder during mix production, improved mix workability, the potential for longer haul distances, and the extension of the paving season into cooler weather [2, 3].

Several WMA processes have been described as under evaluation in North America [1, 2]. These include Sasobit®, Aspha-min®, Advera®, Low Energy Asphalt (LEA), Evotherm®, the Double Barrel Green® System, and WAM Foam.

Sasobit® is a synthetic long chain Fischer-Tropsch wax developed by Sasol International [4]. This material is produced using the Fischer-Tropsch process for the gasification of coal. Sasobit® functions as a WMA additive by lowering the viscosity of the asphalt cement at mixing and compacting temperatures by approximately 15^{o}C, while the original viscosity at in-service pavement temperatures is maintained [5]. Improved compaction values at temperatures as low as 88^{o}C have been noted.

Aspha-min® consists of granular zeolite crystals developed by Eurovia [6]. The product contains approximately 21 percent water by mass which is released when Aspha-min® is added to the mix at temperatures ranging from 85 to 182^{o}C. The water released into the mix at high temperatures causes the asphalt cement to foam during the mixing process. The increased workability caused by the foaming process improves the aggregate coating and compaction properties of the mix at lower temperatures. PQ Corporation has developed zeolite based technology for warm mix called Advera®.

Evotherm® is based on a chemical process developed by MeadWestvaco that can be delivered in the form of high residue asphalt emulsion [2, 7]. Water in the form of steam is released when the Evotherm® is mixed with hot aggregate. Evotherm can also be delivered as a water based soap solution known as Evotherm DAT, or as a chemical package that does not contain water known as Evotherm 3G. Additives to improve coating, workability, and adhesion are part of the Evotherm® chemistry.

Low energy asphalt (LEA) is a foaming process that involves heating and combining the coarse aggregates in the mixture with hot asphalt cement [1]. The mixture is then combined with the wet fine aggregate portion of the mix. This produces a foaming action which encapsulates the fine aggregate at temperatures of less than 100^{o}C.

WAM Foam technology, developed by Shell and Kolo Veidekke, utilizes a two-stage production process. In the first stage the aggregate is coated with a soft binder [1]. This is then followed by coating with a hard binder with the assistance of foaming for improved mix workability at lower temperatures.

Astec Industries has developed a Double Barrel Green® System that involves injecting water into the mix along with the liquid asphalt cement. The resulting foaming action allows for the production of warm mix at temperatures that are 28^{o}C lower than normal hot mix temperatures without the use of chemical additives

HyperTherm, a non-aqueous liquid warm mix additive, has been introduced by Lafarge. The additive is either pre-dosed or added in-line into the liquid asphalt cement. While the physical properties of the asphalt cement binder remain substantially unchanged, HyperTherm imparts improved workability in the mix which allows it to be produced and placed at lower than conventional hot mix temperatures. Improved coating and adhesion properties can be imparted by HyperTherm.

The objectives of the work discussed in this paper were two-fold. The initial aim was to validate HyperTherm as an effective warm mix technology in the field. This was followed by the utilization of the improved mix workability imparted by HyperTherm to pave in cold weather.

KATIMAVIK ROAD, CITY OF OTTAWA

An overlay job on Katimavik Road in the City of Ottawa was utilized for the HyperTherm warm mix trial. The project involved the City of Ottawa new 4.75 mm FC1 mix [8, 9] intended for traffic level C (3 to 10 million Equivalent Single Axle Loads or ESAL's) [10] placed at compacted thickness of 25mm.

Approximately 1,600 tonne of warm mix produced with PG 58-28 modified with HyperTherm were placed on test sections. Another 1,200 tonne of hot mix manufactured with conventional PG 58-28 served as the control.

MIX DESIGN AND BINDER PROPERTIES

The mix was designed using a gyratory compactor with 75 gyrations. Superpave properties for the City of Ottawa 4.75 mm FC1 mix are presented in tables 1 and 2.

A mixing temperature of 120°C and a compaction temperature of 90°C were chosen for the warm mix based on the results of the mix design. The PG 58-28 binder for both the hot mix and the warm mix sections was dosed with 0.5% HyperStick anti-stripping additive by weight of binder in order to meet the minimum 83% Tensile Strength Ratio (TSR) specified by the City of Ottawa. The PG 58-28 for the warm mix section was treated with 0.2% HyperTherm by weight of binder

Table 1 – City of Ottawa 4.75 mm FC1 Superpave Mix Design

Material	Source	HMA PG 58-28 4.75 mm FC1 (%)	WMA PG 58-28 HyperTherm 4.75 mm FC1 (%)
¼" Dolomitic Sandstone	Lafarge	8.0	8.0
Burnside Blend Sand	Lafarge	10.0	10.0
Dolomitic Sandstone Screenings	Lafarge	75.0	75.0
Blend Sand	IKO	7.0	7.0
PG 58-28 with 0.2% HyperTherm and 0.5% HyperStick Anti-stripping Additive	Lafarge	--	5.8
PG 58-28 with 0.5% HyperStick Anti-stripping Additive	Lafarge	5.8	--

Table 2 – City of Ottawa 4.75 mm FC1 Mix Properties

Property	HMA PG 58-28 4.75 mm FC1	WMA PG 58-28 HyperTherm 4.75 mm FC1	City of Ottawa SP F-3106 Specification
Mixing Temperature (°C)	145	120	
Compaction Temperature (°C)	136	90	
Bulk Relative Density	2.351	2.355	
Maximum Relative Density	2.448	2.454	
Air Voids (%)	4.0	4.0	
Voids in Mineral Aggregate (%)	16.9	16.8	≥ 15.0
Voids in Fine Aggregate (%)	76.5	75.9	75 - 78
TSR (%)	86.3	86.0	≥ 83
Dust to Binder Ratio	1.7	1.8	0.9 – 2.0
Gmm @ Nini (7 Gyrations) (%)	88.9	88.7	≤ 89.0
Gmm @ Ndes (75 Gyrations) (%)	96.0	96.0	96.0
Gmm @Nmax (115 Gyrations) (%)	97.1	97.1	≤ 98.0
APA, WRT, mm	13.2	14.5	

A PG 58-28 control sample was compared with PG 58-28 modified with 0.2% HyperTherm by weight of binder in order to determine the effects of the warm mix additive on the binder. It was found that the viscosity and other Performance Graded Asphalt Cement (PGAC) properties were only marginally affected by the addition of the HyperTherm (see Table 3 below). From the results below it was inferred that HyperTherm imparts improved workability in the mix via a mechanism other than by reducing the viscosity of the asphalt binder. Both the PG 58-28 control and the PG 58-28 HyperTherm met the required AASHTO M320 [11] specifications for PG 58-28 asphalt binder.

Table 3 – Superpave Binder Data for PG 58-28 and PG 58-28 HyperTherm

Sample	**PG 58-28**	**PG 58-28 HyperTherm**	**AASHTO M320 Specification**
Original Binder			
Rotational Viscosity @ 135°C (Pa.s) @ 163°C	0.293 0.089	0.293 0.087	≤ 3.0
Dynamic Shear Rheometer, G*/sinδ @ 58°C (kPa) @ 64°C	1.474 0.693	1.449 0.692	≥ 1.0
RTFO Residue (AASHTO T240)			
Mass Change (%)	0.198	0.214	≤ 1.0
Dynamic Shear Rheometer, G*/sinδ @ 58°C (kPa) @ 64°C	3.436 1.645	3.576 1.614	≥ 2.2
PAV Residue (AASHTO R18)			
Aging Temperature (°C)	100	100	100
Dynamic Shear Rheometer G* x sinδ @ 19°C (kPa) @ 16°C	 4814 6316	 4793 6308	 ≤ 5000
Bending Beam Rheometer Creep Stiffness @ -18°C (MPa) @ -24°C Slope, m-value @ -18°C @-24°C	 240 485 0.303 0.248	 232 470 0.304 0.245	 ≤ 300 ≥ 0.300
Performance Grade	PG 61.1 – 28.2	PG 61.0 – 28.5	

The asphalt cement from laboratory hot mix and warm mix samples was extracted using n-propyl bromide (nPB) as the solvent and recovered with a rotary evaporator apparatus [12]. The recovered asphalt cement samples were tested as Rolling Thin Film Oven (RTFO) residues and then aged in the Pressure Aging Vessel (PAV) prior to being tested with the Bending Beam Rheometer (BBR).

It was found that the recovered asphalt cement from both the warm mix and the hot mix had different PGAC properties than had been obtained when the original binder had been aged in the RTFO oven. In terms of relative properties, the warm mix had a high temperature performance grade that was about one degree lower than the hot mix, while its low temperature performance grade was about two degrees better than the hot mix (see Table 4).

Table 4 – Superpave Binder Data for Recovered HMA and WMA

Sample	PG 58-28 HMA	PG 58-28 HyperTherm WMA	AASHTO M320 Specification
Original Binder			
Rotational Viscosity @ 135°C (Pa.s) @ 163°C	N/A	N/A	≤ 3.0
Dynamic Shear Rheometer, G*/sinδ @ 58°C (kPa) @ 64°C	N/A	N/A	≥ 1.0
RTFO Residue (AASHTO T240)			
Mass Change (%)	N/A	N/A	≤ 1.0
Dynamic Shear Rheometer, G*/sinδ @ 58°C (kPa) @ 64°C	1.840 0.943	1.653 0.811	≥ 2.2
PAV Residue (AASHTO R18)			
Aging Temperature (°C)	100	100	100
Dynamic Shear Rheometer G* x sinδ @ 19°C (kPa) @ 16°C	 3218 4904	 2749 3890	 ≤ 5000
Bending Beam Rheometer Creep Stiffness @ -18°C (MPa) @ -24°C Slope, m-value @ -18°C @-24°C	 161 341 0.332 0.286	 130 295 0.336 0.301	 ≤ 300 ≥ 0.300
Performance Grade	PG 56.4 – 32.1	PG 55.6– 34.3	

In order to rule out the possibility that residual solvent was affecting the results obtained on the binders recovered from the mixes, a sample of PG 58-28 was dissolved in nPB and tested after being recovered with the rotary evaporator. The PGAC results obtained on the recovered PG 58-28 were very close to that of the control (see Table 5 below). From these results it was inferred that residual solvent was not affecting the results obtained on the binders that were recovered from the mixes.

Table 5 – Control Testing on PG 58-28 Recovered After Being Dissolved in n-Propyl Bromide

Sample	PG 58-28 Control	PG 58-28 Recovered	AASHTO M320 Specification
RTFO Residue (AASHTO T240)			
Dynamic Shear Rheometer, G*/sinδ @ 58°C (kPa)	3.576	3.814	≥ 2.2
PAV Residue (AASHTO R18)			
Aging Temperature (°C)	100	100	100
Dynamic Shear Rheometer G* x sinδ @ 19°C (kPa)	 4793	 4391	 ≤ 5000
Bending Beam Rheometer Creep Stiffness @ -18°C (MPa) Slope, m-value @ -18°C	 232 0.304	 220 0.306	 ≤ 300 ≥ 0.300

MIX PRODUCTION AND PLACEMENT

Both the City of Ottawa 4.75 mm FC1 warm mix and hot mix were produced in October 2007 at the Lafarge Moodie Drive plant. This 6 ton batch plant is equipped with a baghouse dust collector and has a production capability of 375 tonne/hr.

The job site was approximately 15 km from the plant and required a 20 minute travel time. A conventional paver, an 11 ton vibratory breakdown roller, a 20 ton pneumatic tired roller, and a 6 ton static steel finish roller were used to construct the pavement. The mixes were placed in one lift with a compacted thickness of 25 mm.

Figure 1 – Lafarge Moodie Drive Production Facility for WMA and HMA

City of Ottawa 4.75 mm FC1 Hot Mix

The 4.75 mm FC1 hot mix was produced at an average temperature of 155°C using PG 58-28 that had been treated with 0.5% HyperStick anti-stripping agent by weight of binder at the Lafarge Millhaven supply terminal. The PG 58-28 temperature ranged between 150 to 155°C during production. The mix arrived on site at approximately 145 to 150°C. Conventional paving and rolling patterns were used during the construction. The final mat texture appeared uniform.

City of Ottawa 4.75 mm FC1 DuraClime

The 4.75 mm FC1 DuraClime was produced at approximately 122°C using PG 58-28 that had been treated with 0.5% HyperStick anti-stripping additive by weight of binder at the Lafarge Millhaven supply terminal. HyperTherm warm mix additive was injected at 0.2% by weight of the PG 58-28 using a calibrated in-line dosing pump during mix production. The PG 58-28 temperature was maintained at between 150 to 155°C.

The mix arrived on site at between 99^{o}C to 122^{o}C. The temperature after the paver was approximately 113^{o}C. After the vibratory breakdown roller the temperature was about 90^{o}C. Initially the pneumatic tired roller was not used due to concerns about the potential for pick up. Compaction results showed that target compaction was not being achieved without the pneumatic tired roller. This unit was added to the rolling train and compaction was easily achieved without any pick up issues. The rolling pattern involved two to three passes with the breakdown roller, followed by three to four passes with the pneumatic tired roller, and one to two passes with the finish roller. The mat temperature after the pneumatic tire and finish rollers was 75^{o}C.

The paving crew commented that the fumes coming from the warm mix were significantly reduced as compared to the hot mix. The crew members commented that the mix was easy to work with and comparable to laying a standard 4.75 mm mix with the benefit of significantly reduced fumes coming off of the mix. The ease of hand work was comparable to that of the hot mix.

The figures below show the production and placement of the WMA. A reduction in visible emissions was evident as the mix was loaded into the truck box. The final pavement had the same appearance as conventional hot mix. The mat texture was uniform.

Figure 2 – HyperTherm Dosing Pump

Figure 3 – Loading WMA Into Truck Box

Figure 4 – Vibratory Roller on WMA Section

Figure 5 – WMA on Katimavik Road

FIELD TESTING

Compliance testing was performed in the laboratory on field samples taken from the job site (see Table 6 below). The properties obtained were within the limits of the City of Ottawa SP F-3109 specification.

Table 6 – City of Ottawa 4.75 mm FC1 DuraClime Field Samples

Sample	Job Mix Formula	1	2	3	City of Ottawa SP F-3109 Specification
Sieve Size					
12.5 mm	100.0	100.0	100.0	100.0	100
9.5 mm	99.9	100.0	99.7	100.0	95 – 100
4.75 mm	90.0	89.9	90.6	89.5	90 – 100
2.36 mm	60.3	63.5	62.6	62.7	
1.18 mm	49.9	50.5	50.0	52.2	30 – 60
0.600	42.3	44.6	42.3	42.3	
0.300	25.3	25.4	25.9	26.5	
0.150	15.9	14.1	15.3	16.3	
0.075	9.8	7.7	9.3	9.7	6 – 12
Residual AC (%)	5.8	6.13	6.01	5.71	
Bulk Relative Density	2.355	2.314	2.335	2.356	
Maximum Relative Density	2.454	2.436	2.443	2.438	
Air Voids (%)	4.0	5.0	4.4	3.4	

IN SERVICE PERFORMANCE

Katimavik Rd was visited in April 2008 after about five months in service. Both the warm mix asphalt and the hot mix asphalt sections appear to be distress free and performing well after the winter (see Figures xx below)

Figure 6 – WMA After Five Months Service

Figure 7 – WMA Surface Texture

Figure 8 – Katimavik Rd (HMA) Control

Figure 9 – HMA After Five Months Service

<u>OXFORD ROAD 4, COUNTY OF OXFORD</u>

In late 2007 a portion of Oxford Road 4 in the County of Oxford required paving in cold climatic conditions that were not amenable to conventional hot mix paving. Temperatures were dropping below the freezing point and precipitation in the form of rain and snow were being experienced. The objective was to pave over two lanes of granular base on a section of the County Road as well the main truck entrance to the Toyota manufacturing facility cross dock needed to be paved so that they could be opened to traffic. Rerouting traffic until the spring was not acceptable as the truck entrance to Toyota's facility on Oxford Road 4 would be inaccessible. Further widening of the road would be completed during the 2008 paving season in more temperature climatic conditions.

The improved mix workability imparted by HyperTherm was trialed as a solution to the requirement for late season paving. The initial scope involved a trial of 1,500 tonne of mix. This quantity was increased after promising results were obtained in the field. Approximately 3,600 tonne of HL8 binder mix was placed in one lift with a 100 mm compacted depth using PG 58-28 modified with HyperTherm. The project was completed over six paving days during the period of November 30 – December 14, 2007. Temperatures ranged from 2^{o}C down to -13^{o}C during this timeframe. The mix was produced at conventional hot mix temperatures and the improved workability properties resulting from the HyperTherm additive were utilized to obtain compaction in these extreme conditions.

MIX DESIGN

An HL8 Marshal mix design as presented in Tables and 7 and 8 below was used for the County of Oxford trial. Due to extreme weather conditions that the project would be completed in, a control section consisting of conventional HL8 without the improved workability imparted by HyperTherm was not placed.

Table 7 –HL8 DuraPhalt WinterMix Design for Oxford Road 4

Material	Source	HL8 DuraPhalt WinterMix
HL 3 Stone	Lafarge	13.9%
HL 4 Stone	Lafarge	33.3%
¼" Chip	Lafarge	8.3%
Asphalt Sand	Lafarge	28.9%
Asphalt Sand	Lafarge	12.6%
Modified Shingle Mix (MSM)	Lafarge	3%
PG 58-28 HyperTherm	Lafarge	5.2%

Table 8 – HL8 DuraPhalt WinterMix Properties for Oxford Road 4

Property	HL8 DuraPhalt WinterMix	OPSS 1150
Mixing Temperature (^oC)	145^oC	
Compaction Temperature (^oC)	90^oC	
Bulk Relative Density	2.401	
Maximum Relative Density	2.508	
Air Voids (%)	4.2	3 – 5
Voids in Mineral Aggregate (%)	15.0	≥ 14.0
Marshall Stability @ 60^oC (N)	8900	≥ 8000
Marshall Flow @ 60^oC	9.8	≥ 8.0

MIX PRODUCTION AND PLACEMENT

The HL8 DuraPhalt WinterMix was produced was produced at the Lafarge Brantford plant in Brantford, Ontario. The facility is a 5 ton batch plant that is equipped with a baghouse dust collector and has a production capability of 285 tonne/hr.

Production began on November 30, 2007. The HL8 base mix was produced at an average temperature of 155^oC. The PG 58-28 asphalt cement in the mix had been pre-dosed with 0.2% HyperTherm by weight of binder at the Lafarge Millhaven supply terminal. Ambient temperatures were just above freezing and no major difficulties were encountered.

The second day of production was December 4, 2007. The freezing conditions created by an average ambient temperature of -4^oC created operational challenges. The baghouse pulsator froze which limited the dust return back to the mix. Frozen material in the cold-feed bins also affected the flow of material into the mix. These issues affected the gradation and air void properties of the mix. Production was stopped in order to take corrective actions.

Methyl hydrate was added to the air lines for the baghouse pulsator in order to thaw it out and to keep parts from freezing. A compressor supplying air to the pulsator was also replaced with one that created less moisture in order to reduce the chance of freezing. The cold feed bins were enclosed with tarps as a shield from the wind and propane fired heaters were used to keep the material in the bins from freezing. Aggregate supply logistics were coordinated such that material was pulled from a newly exposed face on a stock pile at the quarry in order to minimize frozen masses of aggregate. The aggregates were monitored to prevent any frozen agglomerates from entering the process before they were broken up. Production proceeded without any issues on December 5th once the corrective measures described above were taken.

Paving was completed by Lafarge over a granular base consisting of 450 mm Granular B Type II and 150 mm of Granular A [13] that had been prepared by another party prior to commencement of the project. Precipitation had saturated the granular base during the week prior to paving. Third party testing confirmed that compaction values for the granular base were low. It was anticipated that the poor base compaction would negatively impact pavement performance.

The job site was located approximately 35 km from the plant and required a 30 minute truck haul. The mix arrived on site at approximately 145^oC. A standard paver, a 12 ton vibratory breakdown roller, a 22 ton pneumatic tired roller, and a 2 ton static steel finish roller were used to construct the pavement. The rolling pattern encompassed two to four passes with the vibratory breakdown roller, six to eight passes with the pneumatic tired roller, and one to two passes with the finish roller. Additional rollers were on standby but were not required. The mix temperature ranged between 145 to 120^oC during compaction.

The paving crew commented that the mix was very easy to work with. It had good workability and raked as easy as conventional hot mix did. On site testing with nuclear gauges showed that compaction for HL8 mix was being achieved, but some ‘soft’ spots were observed because of the structural deficiencies in the underlying base.

Despite these issues the project was successfully completed on December 14th. The mix was placed in one lift compacted to 100mm thickness. The total compacted thickness of the pavement was 100 mm. The finished product provided an acceptable riding surface for traffic on Oxford Road 4 through the winter and spring until it could be covered with a surface mix.

Figure 10 – Paving Oxford Road 4 in Dec 2008

Figure 11 – HL8 DuraPhalt WinterMix Mat

Figure 12 – Compacting HL8 DuraPhalt WinterMix

Figure 13 – After Completion of First Lane

FIELD TESTING

Compliance testing against the Ontario Provincial Standard Specification 1150 [14] was performed in the laboratory on field samples taken from the job site (see Table 9 below). Some of the results on the 16.0 mm sieve were outside the limits of the OPSS 1150 specification. This was attributed to the difficulty in maintaining consistent material flows due to the freezing weather conditions. Field testing with a nuclear gauge showed that compaction levels ranged between 92 to 97%.

Table 9 – HL8 DuraPhalt WinterMix Field Samples

Sample	**JMF**	**Nov 30**	**Dec 4**	**Dec 5**	**Dec 6**	**Dec 13**	**Dec 14**	**OPSS 1150**
Sieve Size								
26.5 mm	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100
19.0 mm	100.0	100.0	100.0	100.0	100.0	100.0	100.0	94 – 100
16.0 mm	94.6	95.8	96.7	95.7	94.2	94.8	97.2	77 – 95
13.2 mm	84.0	81.4	82.4	82.3	84.4	81.0	83.0	65 – 90
9.5 mm	63.7	61.6	64.4	61.0	67.0	60.4	61.7	48 – 78
4.75 mm	49.8	47.6	50.0	48.4	50.0	47.3	46.7	30 – 50
2.36 mm	38.8	35.6	36.5	35.6	36.1	33.5	35.6	21 – 50
1.18 mm	31.7	28.1	27.0	28.7	26.8	26.2	28.4	12 – 49
0.600 mm	18.0	17.7	16.6	18.0	16.0	17.2	17.7	6 – 38
0.300 mm	8.8	8.5	6.5	7.9	8.7	9.2	8.2	3 – 22
0.150 mm	6.2	5.7	3.5	4.6	6.2	6.5	5.6	1 – 9
0.075 mm	5.0	4.4	2.4	3.2	4.7	5.1	4.3	0 – 6
Residual AC (%)	5.2	5.21	4.94	5.26	5.36	5.33	5.30	≥ 4.7
Bulk Relative Density	2.401	2.405	2.365	2.404	2.390	2.423	2.416	
Maximum Relative Density	2.508	2.500	2.490	2.497	2.501	2.497	2.490	
Air Voids (%)	4.2	3.8	5.0	3.7	4.4	3.0	3.0	3 – 5

IN SERVICE PERFORMANCE

A site visit was made to Oxford Road 4 in April 2008. The road had been in service for four months over the winter. The pavement had held up given the deficiencies in the granular base on which it was paved. Sections of the road had a rippled appearance. The two lanes that were paved have been providing access to this section of Oxford Road 4 as well as to the truck entrance for Toyota manufacturing facility in Oxford County since December 2007. The road is scheduled to be covered with a surface course during the 2008 season.

Figure 14– Oxford Road 4 in April 2008

Figure 15– Oxford Road 4 in April 2008

Figure 16 – Oxford Rd 4 HL8 Surface Texture After Four Months Service

FINDINGS

The HyperTherm field trials in the City of Ottawa and in the County of Oxford demonstrated that warm mix technology can be used to extend the paving season into cold temperatures when it is necessary to do so. The following findings were made:

1. Modifying PG 58-28 with HyperTherm enabled the production of warm mix at lower than conventional hot mix temperatures by increasing the workability of the mix.

2. While HyperTherm improves mix workability, it does not substantially alter the viscosity or other PGAC properties of asphalt cement at dose rates required for warm mix production and for paving in cold weather.

3. Warm mix can be produced without significant changes at the asphalt production plant. It is possible to meet required volumetric properties by placing and compact warm mix using standard paving machinery and rolling patterns.

4. The improved workability imparted by HyperTherm can be used to pave and meet required volumetric properties in cold temperature conditions with standard paving machinery and rolling patterns by producing the mix at conventional hot mix temperatures.

It is recommended that research investigating warm mix asphalt and low temperature paving applications be conducted. In particular the performance properties of warm mix asphalt field samples such as those relating to permanent deformation, fatigue, and low temperature cracking should be investigated.

BIBLIOGRAPHY

[1] D'Angelo J, Harm E, Bartoszek J, et al. "Warm-Mix Asphalt: European Practice", Report FHWA PL-08-007, U.S. Department of Transportation Federal Highway Administration (FHWA), Washington, DC (February 2008).

[2] Davidson JK, Tigh S, Croteau J-M. "Paving the Way to Environmentally Friendly Pavements Through Innovative Solutions", Proceedings, Canadian Technical Asphalt Association, 51, 97-121 (2006).

[3] Wei Goh S, You Z, Van Dam J. "Laboratory Evaluation and Pavement Design for Warm Mix Asphalt", Proceedings, 2007 Mid-Continent Transportation Research Symposium, Ames, Iowa (August 2007).

[4] Hurley GC, Prowell BD. "Evaluation of Sasobit® for Use in Warm Mix Asphalt", Report 05-06, National Center for Asphalt Technology (NCAT), Auburn, Alabama (June 2005).

[5] Davidson JK, Pedlow R. "Reducing Paving Emissions Using Warm Mix Technology", Proceedings, Canadian Technical Asphalt Association, 52, 39-59 (2007).

[6] Hurley GC, Prowell BD. "Evaluation of Aspha-min® Zeolite for Use in Warm Mix Asphalt", Report 05-04, National Center for Asphalt Technology (NCAT), Auburn, Alabama (June 2005).

[7] Hurley GC, Prowell BD. "Evaluation of Evotherm® for Use in Warm Mix Asphalt", Report 06-02, National Center for Asphalt Technology (NCAT), Auburn, Alabama (June 2006).

[8] "Performance Graded Hot Mix Asphalt – Superpave 4.75 FC1", SP No. F-3109, City of Ottawa Special Provision, Ottawa, Ontario (March 2008).

[9] "Performance Graded Hot Mix Asphalt – Superpave Design Method and Stone Mastic Asphalt", SP No. F-3106, City of Ottawa Special Provision, Ottawa, Ontario (March 2007).

[10] "Material Specification for Superpave Stone Mastic and Stone Mastic Asphalt Mixtures", OPSS 1151, Ontario Provincial Standard Specification (OPSS), Ontario Ministry of Transportation, Downsview, Ontario (November 2005).

[11] American Association of State Highway and Transportation Officials (AASHTO) M320-05. "Standard Specification for Performance Graded Asphalt Binder", Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Part 1B, 26th Edition, Washington, D.C. (2006).

[12] ASTM International (ASTM) D5404, "Standard Practice for Recovery of Asphalt from Solution Using the Rotary Evaporator", Annual Book of ASTM Standards, Road and Paving Materials; Vehicle-Pavement Systems, 04-03, West Conshohocken, Pennsylvania (2003).

[13] "Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material", OPSS 1010, Ontario Provincial Standard Specification (OPSS), Ontario Ministry of Transportation, Downsview, Ontario (April 2004).

[14] "Material Specification for Hot Mix Asphalt", OPSS 1150, Ontario Provincial Standard Specification (OPSS), Ontario Ministry of Transportation, Downsview, Ontario (November 2002).