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MaineDOT

Transportation Research Division

Technical Report 09-10

Experimental Demonstration of Warm Mix Asphalt Pavement on Rt. 4

Construction and 1st Interim Report, April 2012

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Transportation Research Division

Experimental Demonstration of Warm Mix Asphalt Pavement on Rt. 4

Introduction

A number of new technologies have been developed to lower the production and placement temperatures of hot-mix asphalt (HMA). Generically, these technologies are referred to as warm-mix asphalt (WMA). In Europe and to a lesser extent in North America, WMA has been used in all types of asphalt concrete, including dense-graded, stone matrix, porous, and mastic asphalt. It has also been used in a range of layer thicknesses, and sections have been constructed on roadways with a wide variety of traffic levels.

In 2009 a highway reconstruction project along Rt. 4 from Madrid to Sandy River Plt. (PIN 10019.00) was paved using the "foaming" or "Double Barrel Green" warm mix asphalt technology. The paving contractor was Bruce Manzer of Phillips, Maine.

WMA Technology

A number of methods are used to classify the WMA technologies. One is classifying the technologies by the degree of temperature reduction. Warm asphalt mixes are separated from half-warm asphalt mixtures by the resulting mix temperature. There is a wide range of production temperatures within warm mix asphalt, from mixes that are 30 to 50 C° (55 to 85 F°) below HMA to temperatures slightly above 100 °C (212 °F).

Another way to classify the technologies is those that use water and those that use some form of organic additive or wax to affect the temperature reduction. Processes that introduce small amounts of water to hot asphalt, either via a foaming nozzle (Double Barrel Green) or a hydrophilic material (Zeolite), or damp aggregate (Low Energy Asphalt), rely on the fact that the steam expands the asphalt binder providing improved mix characteristics. Chemical (Evotherm, Rediset WMX) and organic (Sasobit) additives use different mechanisms to provide improved mix characteristics such as enhanced viscosity, coating, adhesion and workability.

Benefits of Warm Mix Asphalt

Reduced emissions. Data indicate plant emissions are significantly reduced. Typical expected reductions are 30 to 40 percent for CO2 and sulfur dioxide (SO 2), 50 percent for volatile organic compounds (VO C), 10 to 30 percent for carbon monoxide (CO), 60 to 70 percent for nitrous oxides (NO x), and 20 to 25 percent for dust. Actual reductions vary based on a number of factors. Technologies that result in greater temperature reductions are expected to have greater emission reductions.

In addition to lowered plant emissions, the jobsite release of aromatic hydrocarbons is reduced for WMA. Industry tests show that releases of asphalt aerosols/fumes and polycyclic aromatic hydrocarbons (PAHs) is lower for WMA as compared to HMA. Potentially a 30 to 50 percent reduction. It should be noted, however that the worker exposure data for these compounds from conventional HMA are below the current acceptable exposure limits.

Reduced fuel usage. Burner fuel savings with WMA typically range from 11 to 35 percent. Fuel savings could be higher (possibly 50 percent of more) with processes such as low-energy asphalt concrete (LEAC) and low energy asphalt (LEA) in which the aggregates (or a portion of the aggregates) are not heated above the boiling point of water.

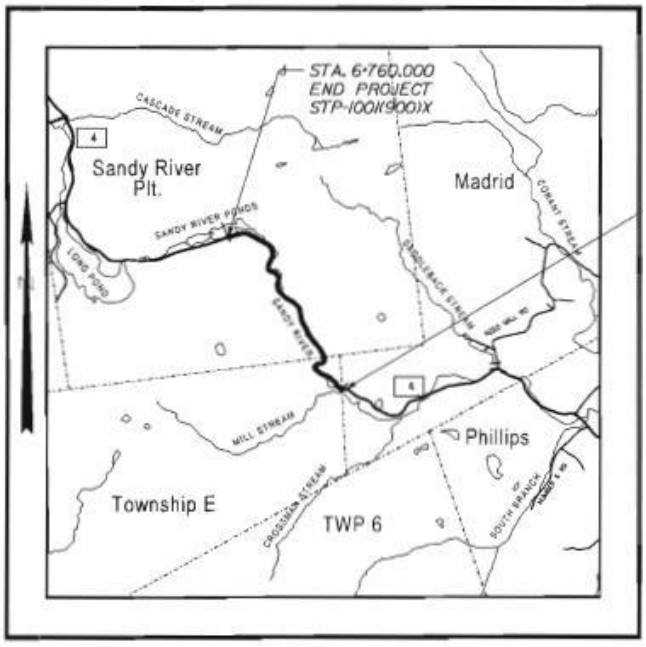
Paving benefits. Paving-related benefits discussed included the ability to pave in cooler temperatures and still obtain density, the ability to haul the mix longer distances and still have workability to place and compact, the ability to compact mixture with less effort, and the ability to incorporate higher percentages of recycled asphalt paving (RAP) at reduced temperatures. In addition since the mix is produced at lower temperatures there is less aging to the asphalt binder which could result in improved long term durability. It has also been documented on some WMA projects that there was less mat segregation.

Cost Considerations

WMA technologies may increase cost, through plant modifications or additive costs. Although there is potential to reduce plant operational costs in fuel reduction, these savings may not offset the increased material costs. The potential to increase RAP usage without sacrificing performance could reduce the cost per ton of WMA.

Project Location

The experimental project is near Madrid on Route 4 in Franklin County. The project begins 0.07 mile southerly of the Twp E town line (Station 1+000), and extends northwesterly across Township E and Sandy River Plantation for approximately 3.8 miles (ending at Station 6+760).



Project Scope

The full construction portion of this project consists of 585 mm (24”) Aggregate Sub-base Course, a 75mm hot mix asphalt base layer, a 50 mm hot mix asphalt intermediate layer and a 40 mm hot mix asphalt surface layer. This project also consists of rehabilitation sections with variable depth gravel and

the hot mix asphalt layers as described in the full construction portion. The shoulder areas for the rehabilitation consist of full depth aggregate sub-base course gravel.

Stationing for the full construction sections are as follows:
Station 1+000 to Station 2+760
Station 4+500 to Station 5+260
Station 5+700 to Station 6+300

All other areas are rehabilitation sections. The differences in these sections are noted and should be considered as overall performance of the pavement is evaluated. The typical sections are shown in Figures 1 and 2.

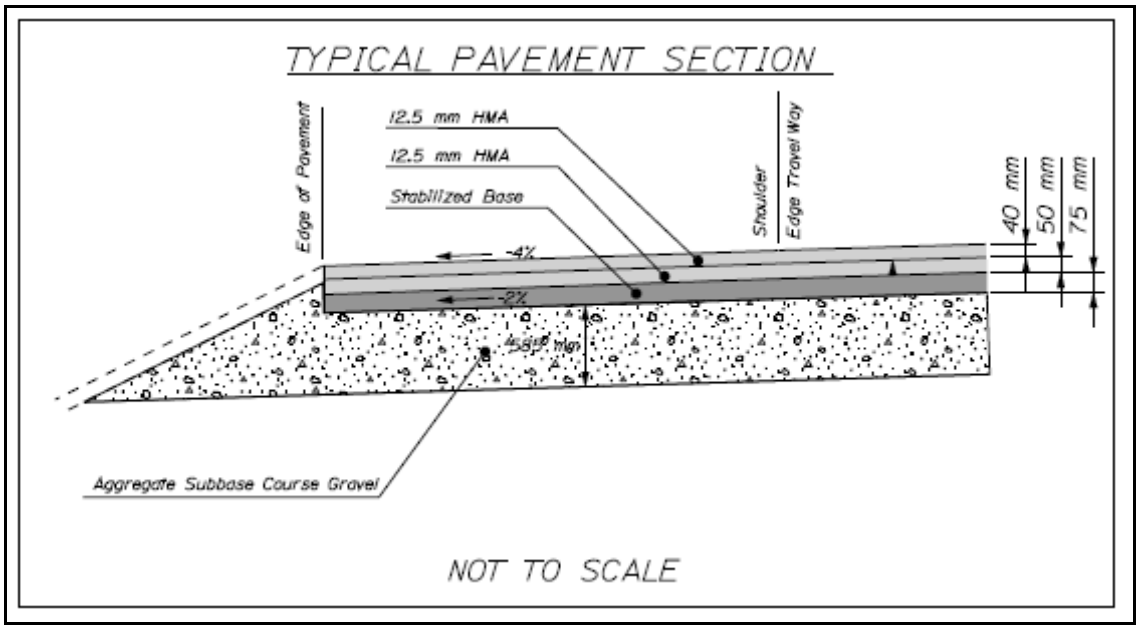


Figure 1 – Typical Section for Full Construction

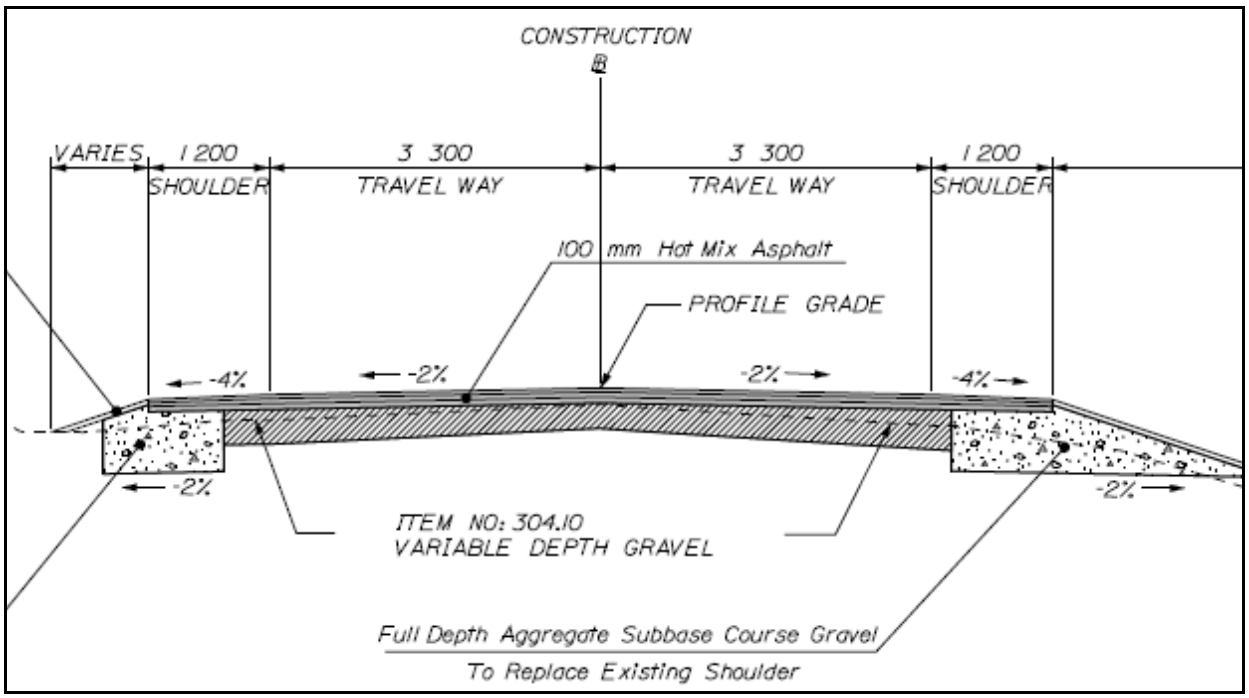


Figure 2 – Typical Section for Rehabilitation

The warm mix asphalt technology was used in numerous combinations described below. The project contract provisions require that, "*This process utilizes an injection system to introduce water to the asphalt stream and "expand" the asphalt prior to mixing with the aggregate in asphalt mixture plant at a rate recommended by the manufacturer. This shall be introduced into the plant mixing chamber by mechanical means that can be controlled and tied directly to the asphalt plants rate of production. Minimum placement temperatures shall be as per manufactures recommendations. A Quality Control Plan shall be submitted for approval by the Department*." (See Appendix for full Specifications).

Test and Control Sections

After review of the paving reports highway sections were selected to represent different pavements that will be compared. Those sections are described in Table 1 and in narrative form below.

Control Section 1 begins at Station 1+000 and ends at Station 1+870. This section consists of a 75mm hot mix asphalt (HMA) base layer, a 50mm HMA binder or intermediate layer and a 40 mm HMA surface layer. This is a full construction section (see Figure 1).

Test Section 1 begins at Station 1+960 and ends at Station 2+220, right lane or northbound lane only. This section consists of a 75 mm HMA base layer, a 50 mm warm mix asphalt (WMA) binder layer and a 40 mm HMA surface layer. This is a full construction section.

Test Section 2 begins at Station 1+980 and ends at Station 2+200, left lane or southbound lane only. This section consists of a 75 mm WMA base layer, a 50 mm WMA binder layer and a 40 mm HMA surface layer. This is a full construction section.

Control Section 2 begins at Station 2+250 and ends at Station 2+760. This section is the same as Control Section 1, a 75mm hot mix asphalt (HMA) base layer, a 50mm HMA binder or intermediate layer and a 40 mm HMA surface layer. This is a full construction section.

Control Section 2A begins at Station 2+760 and ends at Station 3+200. This section is the same as Control Section 1, a 75mm hot mix asphalt (HMA) base layer, a 50mm HMA binder or intermediate layer and a 40 mm HMA surface layer. This is a rehabilitation section (see Figure 2).

Test Section 3 begins at Station 3+280 and ends at Station 4+500. This section consists of a 75 mm WMA base layer, a 50 mm WMA binder layer and a 40 mm HMA surface layer. This is the same as Test Section 2. This is a rehabilitation section.

Test Section 4 begins at Station 4+540 and ends at Station 5+260. This section consists of a 75 mm WMA base layer, a 50 mm WMA binder layer and a 40 mm WMA surface layer. This is a full construction section.

Test Section 4A begins at Station 5+260 and ends at Station 5+530. This section consists of a 75 mm WMA base layer, a 50 mm WMA binder layer and a 40 mm WMA surface layer. This is a rehabilitation section.

Test Section 5 begins at Station 5+900 and ends at Station 6+300. This consists of a 75 mm hot stabilized base (HSB) layer, a 50 mm WMA binder layer and a 40 mm HMA surface layer. The HSB is a standard HMA but with 25% recycle asphalt pavement. This is a full construction section.

Test Section 5A begins at Station 6+300 and ends at Station 6+760. This consists of a 75 mm hot stabilized base (HSB) layer, a 50 mm WMA binder layer and a 40 mm HMA surface layer. The HSB is a standard HMA but with 25% recycle asphalt pavement. This is a rehabilitation section.

Table 1 – Control and Test Section Descriptions

	Control Section 1 **Station 1+000 to Station 1+870**	**Test Section 1** **Station 1+960 to Station 2+220 (Right Only)**	**Test Section 2** **Station 1+980 to Station 2+200 (Left Only)**	**Control Section 2 & 2A** **Station 2+250 to Station 3+200**
40 mm lift - surface	**12.5mm HMA**	**12.5 mm HMA**	**12.5 mm HMA**	**12.5mm HMA**
50mm lift – Binder	**12.5 mm HMA**	**12.5 mm** WMA	**12.5 mm** WMA	**12.5 mm HMA**
75 mm lift – Base	**19 mm HMA**	**19 mm HMA**	**19 mm** WMA	**19 mm HMA**

	Test Section 3 **Station 3+280 to Station 4+500**	**Test Section 4 & 4A** **Station 4+540 to 5+530**	**Test Section 5 & 5A** **Station 5+900 to 6+760**
40 mm lift - surface	**12.5 mm HMA**	**12.5 mm** WMA	**12.5 mm HMA**
50mm lift – Binder	**12.5 mm** WMA	**12.5 mm** WMA	**12.5 mm** WMA
75 mm lift – Base	**19 mm** WMA	**19 mm** WMA	**19 mm** *HSB*

Note: Some Sections have both full construction and variable depth gravel

Materials

Quality Assurance test results for the pavement were collected and reviewed and will be kept on file. Based on a review of the results there appear to be no anomalies. Table 2 contains properties of the HMA and WMA layers. The information is not organized by Test and Control Sections since the QA report format is by Lot. However the stationing of samples for these properties is available and will be kept as a reference.

Table 2 – HMA & WMA Test Properties

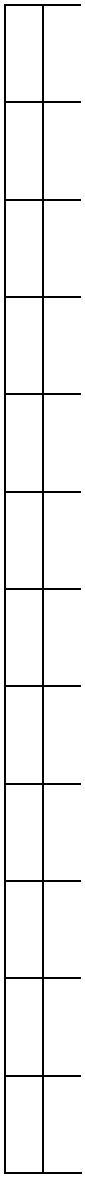
Lot Description Nominal Aggregate Size (Amount Placed)	Average In Place Density (SD)	# of Density Tests	Average Asphalt Content % (SD) Target AC %	AverageVoids % (SD) Target Voids %
HMA – 12.5 mm Surface (4378 MG)	93.45 (1.65)	18	5.23 (0.25) 5.4	4.05 (0.99) 4.0
WMA – 12.5 mm Surface (977 MG)	93.5 (0.89)	8	5.27 (0.12) 5.4	5.3 (0.87) 4.0
HMA – 12.5 mm Binder (3471 MG)	94.83 (1.84)	6	5.62 (0.15) 5.4	3.43 (0.30) 4.0
WMA – 12.5 mm Binder (3442 MG)	93.91 (1.23)	11	5.36 (0.16) 5.4	4.24 (0.71) 4.0
HMA – 19 mm Base (3895 MG)	95.61 (1.29)	7	4.94 (0.43) 5.1	3.24 (0.52) 4.0
WMA – 19 mm Base (4232 MG)	94.48 (1.65)	8	5.05 (0.34) 5.1	3.82 (0.49) 4.0
Hot Stabilized Base – 19 mm (1808 MG)	N/A			

Construction

The construction and paving operations were completed as planned. There were no notable problems encountered in placing the pavement layers that would impact this evaluation.

Smoothness measurements were collected on September 17, 2009 utilizing the departments Automatic Road Analyzer (ARAN). This is an ASTM Class II profile-measuring device that is capable of accurately measuring roadway smoothness. The ARAN measures lateral profile of each wheel path every 50 mm (2 in) then averages those measurements every 20 meters (66 ft). Smoothness is displayed in International Roughness Index (IRI) units that start at zero for a road with no roughness and increases in positive increments in proportion to roughness. Figure 3 contains an IRI scale with verbal descriptions taken from ASTM Standard E 1926-98 “Computing International Roughness Index of Roads from Longitudinal Profile Measurements”.

Figure 3: Road Roughness Scale for HMA Paved Roads



Ride comfortable over 120 km/h. Undulation barely perceptible at 80 km/h in range 1.3 to 1.8. No depressions, potholes, or corrugations are noticeable; depressions < 2 mm/3 m. Typical high quality asphalt 1.4 to 2.3, high quality surface treatment 2.0 to 3.0.

Ride comfortable up to 100 - 120 km/h. At 80 km/h, moderately perceptible movements or large undulations may be felt. Defective surface; occasional depressions, patches or potholes (e.g. 5 - 15 mm/3m or 10 - 20 mm/5m with frequency 2 - 1 per 50 m), or many shallow potholes (e.g. on surface treatment showing extensive raveling). Surface without defects; moderate corrugations or large undulations.

Ride comfortable up to 70 - 90 km/h, strongly perceptible movements and swaying. Usually associated with defects; frequent moderate and uneven depressions or patches (e.g. 15 - 20 mm/3m or 20 - 40 mm/5m with frequency 5 - 3 per 50 m), or occasional potholes (e.g. 3 - 1 per 50 m). Surface without defects: strong undulations or corrugations.

Ride comfortable up to 50 - 60 km/h, frequent sharp movements or swaying. Associated with severe defects: frequent deep and uneven depressions and patches (e.g. 20 - 40 mm/3m or 40 - 80 mm/5m with frequency 5 - 3 per 5 m), or frequent potholes (e.g. 4 - 6 per 50 m).

Necessary to reduce velocity below 50 km/h. Many deep depressions, potholes and severe disintegration (e.g. 40 – 80 mm deep with frequency 8 – 16 per 50 m).

The September 2009 IRI measurements will serve as the initial values and are reported in Table 3 below.

	Left Lane IRI (m/km) Mean, SD, Max, Min	Right Lane IRI (m/km) Mean, SD, Max, Min
Control Section 1	1.05, 0.29, 2.07, 0.67	1.02, 0.27, 1.99, 0.57
Test Section 1	n/a	1.08, 0.33, 1.77, 0.62
Test Section 2	0.94, 0.28, 1.68, 0.66	n/a
Control Section 2	0.95, 0.38, 2.4, 0.51	0.96, 0.37, 2.29, 0.63
Control Section 2A	0.85, 0.18, 1.19, 0.63	0.62, 0.11, 0.84, 0.44
Test Section 3	0.93, 0.23, 1.64, 0.5	0.94, 0.22, 1.61, 0.56
Test Section 4	0.95, 0.29, 1.83, 0.6	0.98, 0.23, 1.68, 0.61
Test Section 4A	0.90, 0.22, 1.37, 0.63	0.75, 0.12, 1.04, 0.61
Test Section 5	0.72, 0.12, 1.04, 0.54	0.77, 0.15, 1.12, 0.48
Test Section 5A	0.81, 0.22, 1.41, 0.61	0.79, 0.17, 1.10, 0.53

Table 3. Project IRI Values, 2009

Material Costs

The asphalt bid quantities and estimated costs are shown in the following table. Actual in-place costs are not included in this report. The following items are included for relative comparison only.

Item	Unit Price	Estimated Quantity	Bid Estimates
HMA 19 mm	$72.08	2,600 tons	$187,408.00
HMA 12.5 mm Surface (WMA)	$79.10	5,650 tons	$446,858.50
HMA Shim	$93.00	180 tons	$16,740.00
HMA 12.5 mm Base (WMA)	$79.09	6,900 tons	$545,721.00
Bituminous Tack Coat	$2.15	11,700 lin.ft.	$25,155.00
Hot Stabilized Asphalt Base	$65.11	2,600 tons	$169,286.00
Hot Stabilized Base with Additive	$64.15	5,200 tons	$333,580.00

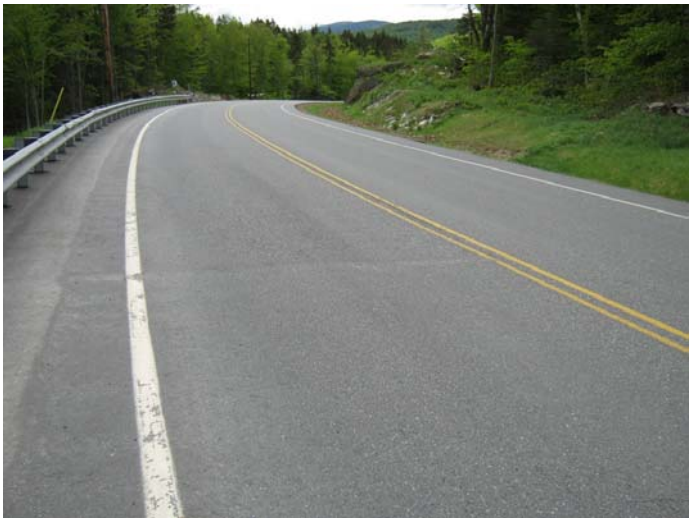
Construction Photos

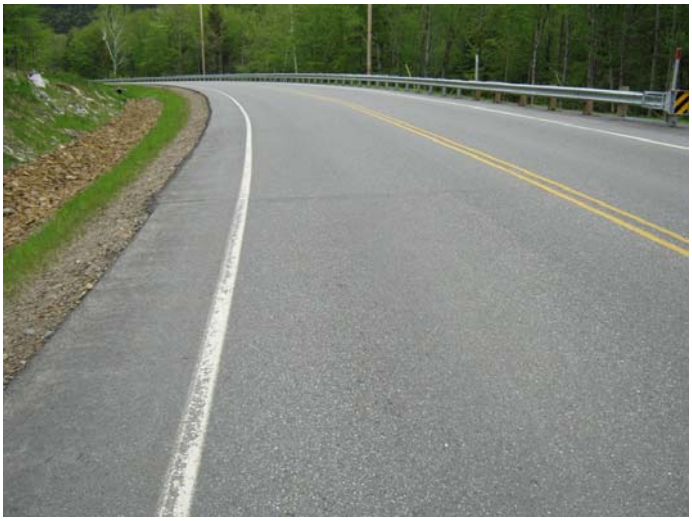
The asphalt mixes for this job were made at the Bruce Manzer plant in Philips. Plant photos are below.

The following series of photos were taken during construction in 2009.

Evaluation Photos

The following photos were taken in June 2011 as part of the Interim Evaluation.





Evaluation

The Madrid project served as a field demonstration for a Warm Mix Asphalt lab and field study with Worcester Polytechnic Institute (WPI). In 2010, WPI conducted FWD and other nondestructive tests on this project. The analysis is being done by WPI and will be presented in an separate WPI report.

This project along with other MaineDOT WMA projects will be monitored over a five year period for pavement performance. Work shall include field visits and observations of distresses, analysis of rut and ride data from the ARAN and if needed subsurface investigations (coring, FWD, etc.) should the pavements have premature failure.

Conclusions

The field inspection did not reveal any unusual degradation. One area showed significant longitudinal cracking. A pavement butt joint appeared to be showing signs of wear. It was apparent that in some areas the aggregate is very visible, leading to the possibility that the asphalt is wearing away. This premature wear phenomenon is not unique to this project; it has been observed on HMA pavements statewide, and is the subject of ongoing observation. So far the performance of this WMA project is on par with conventional HMA pavement.

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Madrid
PIN 10019.00

SPECIAL PROVISION
SECTION 401
HOT MIX ASPHALT PAVEMENTS
(Hot Bituminous Stabilized Base w/ additive)

The Special Provision 401 – Hot Mix Asphalt Pavement, has been modified with the following revisions. All sections not revised by this Special Provision shall be as outlined in the Special Provision 400 Pavements, dated 3-12-2008, section 401 – Hot Mix Asphalt Pavement.

401.01 Description This work shall consist of the removal of all bituminous pavement from the existing roadway, hauling the bituminous pavement to an approved location, and processing together with a Warm Mix Asphalt Additive as per this Specification. The gravel base of the existing roadway shall be regarded and compacted to the tolerances shown on the typicals, or as directed by the Resident. The placement, grading and compaction of additional gravel base shall be paid under the appropriate aggregate base item.

All Hot Bituminous Stabilized Base with Additive shall be placed in one or more courses on an approved base and in accordance with these specifications, and in reasonably close conformity with the lines, grades and thicknesses indicated on the plans, or as established by the Resident. Excess recycled material not used in the Hot Bituminous Stabilized Base process will become the property and responsibility of the contractor.

MATERIALS

401.03 Composition of Mixtures – (paragraph 1) - The Contractor shall compose the Hot Mix Asphalt Pavement with aggregate, Performance Graded Asphalt Binder (PGAB), **Warm Mix Additive** , and mineral filler if required. The mixture shall be designed and tested according to AASHTO T312 and the volumetric criteria in Table 1. The Contractor shall size, uniformly grade, and combine the aggregate fractions in proportions that provide a mixture meeting the grading requirements of the Job Mix Formula (JMF). The Contractor shall submit designs for approval utilizing a minimum of **20%** to a maximum of **40%** of recycled asphalt pavement (RAP) in any Hot Bituminous Stabilized Base course unless otherwise directed by the Department. The Hot Bituminous Stabilized Base shall be designed for an Air Void Target of 6.0 % at 75 Gyrations. **Warm Mix Additives** shall be introduced into the mixture at a in a manner and rate recommended by the additive manufacturer. All recycled asphalt pavement (RAP) utilized in the Hot Bituminous Stabilized Base shall be salvaged from the project, unless otherwise authorized by the Department.

REVISED TABLE 1: VOLUMETRIC DESIGN CRITERIA

Design ESAL's (Millions)	Required Density (Percent of G_{mm})			Voids in the Mineral Aggregate (VMA)(Minimum Percent) Nominal Maximum Aggregate Size (mm)					Voids Filled with Binder (VFB) (Minimum %)	Fines/Eff. Binder Ratio
	$N_{initial}$	N_{design}	N_{max}	25 [1 in]	19 [¾ in]	12.5 [½ in]	9.5 [⅜ in]	4.75 [#4]		
<0.3	≤91.5	96.0	≤98.0	12.0	13.0	14.0	15.0	16.0	70-80	0.6-1.4
0.3 to <3	≤90.5								65-78	
3 to <10	≤89.0								65-75*	
10 to <30										
≥ 30										

*For 9.5 mm [⅜ in] nominal maximum aggregate size mixtures, the maximum VFB is 76.
*For 4.75 mm [#4] nominal maximum aggregate size mixtures, the maximum VFB is 80.

401.031 Warm Mix Additive

Option A - The use of organic additives such as a paraffin wax and or a low molecular weight esterified wax available in 2, 5, 20 or 600 kg [5, 10, 50 or 1250 lb] bags, is required. Wax derived additives shall be introduced at the rate recommended by the manufacture, typically 3 percent by weight (3%) of the mix to gain the desired reduction in viscosity, and should not exceed 4 percent due to the possible impact on the binder's low temperature properties. Wax derived additives shall be introduced into the hot asphalt binder at the asphalt plant and fully blended using a tank agitator / stirrer. Wax additives shall have a melting point of approximately 99° C [210° F]. Minimum placement temperatures shall be as per manufactures recommendations. A Quality Control Plan shall be submitted for approval by the Department.

Option B – The use of a manufactured synthetic zeolite (Sodium Aluminum Silicate), available in a very fine powdered form in 25 or 50 kg [55 or 110 lb] bags, or in bulk for silos. Sodium aluminum silicate additives shall be introduced at a rate recommended by the manufacturer, typically 0.3 percent by mass of the mix. Sodium aluminum silicate additives shall be introduced into the hot mix plant mixing chamber by mechanical means that can be controlled and tied directly to the hot mix asphalt plants rate of production. Minimum placement temperatures shall be as per manufactures recommendations. A Quality Control Plan shall be submitted for approval by the Department.

Option C – The use of a chemical additive technology and a "Dispersed Asphalt Technology" delivery system shall be required. This process utilizes chemical technology delivered into a dispersed asphalt phase (emulsion). The asphalt emulsion with chemical package is used in place of the traditional asphalt binder. The emulsion is mixed with the aggregate in the HMA plant at a rate recommended by the manufacturer. This additive shall be introduced into the hot mix plant mixing chamber by mechanical means that can be controlled and tied directly to the hot mix asphalt plants rate of production. Minimum placement temperatures shall be as per manufactures recommendations. A Quality Control Plan shall be submitted for approval by the Department.

Option D – Other products / processes approved by the Department.

401.05 Performance Graded Asphalt Binder Unless otherwise noted in Special Provision 403 - Hot Bituminous Pavement, PGAB shall be 64-28 or 58-28. The PGAB shall meet the applicable requirements of AASHTO M320 - Standard Specification for PGAB. The Contractor shall provide the Department with an approved copy of the Quality Control Plan for PGAB in accordance with AASHTO R 26-01 Certifying Suppliers of PGAB.

401.052 Repairs Repairs and maintenance for the Hot Bituminous Stabilized Base with Additive, during and after the placing operation, resulting from damage caused by traffic, weather or environmental conditions, or caused by the Contractor's operations or equipment, shall be completed at no additional cost to the Department. Low areas will be repaired using a hot mix asphalt shim course. Areas up to 25mm [1 in] high can be repaired by milling or shimming with hot mix asphalt. Areas higher than 25mm [1 in] will be repaired using a hot mix asphalt shim. All repair work will be done with the Resident's approval at the Contractor's expense.

401.06 Weather Limitations The plant mixed recycled asphalt pavement shall be performed when:

a. Operations will be allowed between May 15th and September 15th inclusive.
b. The atmospheric temperature, as determined by an approved thermometer placed in the shade at the recycling location, is 10°C [50°F] and rising.
c. When there is no standing water on the surface.
d. During generally dry conditions, or when weather conditions are such that proper pulverizing, adding, mixing, and curing can be obtained using proper procedures, and when compaction can be accomplished as determined by the Resident.
e. When the surface is not frozen and when overnight temperatures are expected to be above 0°C [32°F].

401.22 Basis of Payment The Department will pay for the work, in place and accepted, in accordance with the applicable sections of this Section, for each type of HMA specified.

The Department will pay for the work specified in Section 401.11, for the HMA used, except that cleaning objectionable material from the pavement and furnishing and applying bituminous material to joints and contact surfaces is incidental.

The accepted quantity of Hot Bituminous Stabilized Base with Additive will be paid under the contract unit price per Mg [Ton], complete in-place which price will be full compensation for furnishing all equipment and labor for regrading and compacting existing gravel base, processing, mixing, testing, placing, and compacting, excess material relocation, and for all incidentals necessary to complete the work. The placement, grading and compaction of additional gravel base shall be paid under the appropriate aggregate base item. Pavement removal will be paid as Common Excavation.

Payment for this work under the appropriate pay items shall be full compensation for all labor, equipment, materials, and incidentals necessary to meet all related contract requirements, including design of the JMF, implementation of the QCP, obtaining core samples, transporting cores and samples, filling core holes, applying emulsified asphalt to joints, and providing testing facilities and equipment.

The Department will make a pay adjustment for quality as specified below.

401.222 Pay Factor (PF) The Department will use the following criteria for pay adjustment using the pay adjustment factors under Section 106.7 - Quality Level Analysis: Method C Testing criteria

Payments will be made under:

Pay Item	Pay Unit
425.31 – Hot Bituminous Stabilized Base w / Additive	Ton [Mg]

SPECIAL PROVISION
SECTION 401
HOT MIX ASPHALT PAVEMENTS
(Hot Bituminous Stabilized Base)

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401.01 Description This work shall consist of the removal of all bituminous pavement from the existing roadway, hauling the bituminous pavement to an approved location, and processing as per this Specification. The gravel base of the existing roadway shall be regarded and compacted to the tolerances shown on the typicals, or as directed by the Resident. The placement, grading and compaction of additional gravel base shall be paid under the appropriate aggregate base item.

All Hot Bituminous Stabilized Base shall be placed in one or more courses on an approved base and in accordance with these specifications, and in reasonably close conformity with the lines, grades and thicknesses indicated on the plans, or as established by the Resident. Excess recycled material not used in the Hot Bituminous Stabilized Base process will become the property and responsibility of the contractor.

MATERIALS

401.03 Composition of Mixtures – (paragraph 1) - The Contractor shall compose the Hot Mix Asphalt Pavement with aggregate, Performance Graded Asphalt Binder (PGAB), and mineral filler if required. HMA shall be designed and tested according to AASHTO T312 and the volumetric criteria in Table 1. The Contractor shall size, uniformly grade, and combine the aggregate fractions in proportions that provide a mixture meeting the grading requirements of the Job Mix Formula (JMF). The Contractor shall submit designs for approval utilizing a minimum of **20%** to a maximum of **40%** of recycled asphalt pavement (RAP) in any Hot Bituminous Stabilized Base course unless otherwise directed by the Department. The Hot Bituminous Stabilized Base shall be designed for an Air Void Target of 6.0 % at 75 Gyrations. All recycled asphalt pavement (RAP) utilized in the Hot Bituminous Stabilized Base shall be salvaged from the project, unless otherwise authorized by the Department.

REVISED TABLE 1: VOLUMETRIC DESIGN CRITERIA

Design ESAL's (Millions)	Required Density (Percent of G_{mm})			Voids in the Mineral Aggregate (VMA)(Minimum Percent)					Voids Filled with Binder (VFB) (Minimum %)	Fines/Eff. Binder Ratio
				Nominal Maximum Aggregate Size (mm)						
	$N_{initial}$	N_{design}	N_{max}	25 [1 inch]	19 [¾ in]	12.5 [½ in]	9.5 [⅜ in]	4.75 [#4]		
<0.3	≤91.5	96.0	≤98.0	12.0	13.0	14.0	15.0	16.0	70-80	0.6-1.4
0.3 to <3	≤90.5								65-78	
3 to <10	≤89.0								65-75*	
10 to <30										
≥ 30										

*For 9.5 mm [⅜ in] nominal maximum aggregate size mixtures, the maximum VFB is 76.
*For 4.75 mm [#4] nominal maximum aggregate size mixtures, the maximum VFB is 80.

401.05 Performance Graded Asphalt Binder Unless otherwise noted in Special Provision 403 - Hot Bituminous Pavement, PGAB shall be 64-28 or 58-28. The PGAB shall meet the applicable requirements of AASHTO M320 - Standard Specification for PGAB. The Contractor shall provide the Department with an approved copy of the Quality Control Plan for PGAB in accordance with AASHTO R 26-01 Certifying Suppliers of PGAB.

401.052 Repairs Repairs and maintenance for the Hot Bituminous Stabilized Base, during and after the placing operation, resulting from damage caused by traffic, weather or environmental conditions, or caused by the Contractor's operations or equipment, shall be completed at no additional cost to the Department.

Low areas will be repaired using a hot mix asphalt shim course. Areas up to 25mm [1 in] high can be repaired by milling or shimming with hot mix asphalt. Areas higher than 25mm [1 in] will be repaired using a hot mix asphalt shim. All repair work will be done with the Resident's approval at the Contractor's expense.

401.22 Basis of Payment The Department will pay for the work, in place and accepted, in accordance with the applicable sections of this Section, for each type of HMA specified.

The Department will pay for the work specified in Section 401.11, for the HMA used, except that cleaning objectionable material from the pavement and furnishing and applying bituminous material to joints and contact surfaces is incidental.

The accepted quantity of Hot Bituminous Stabilized Base will be paid under the contract unit price per Mg [Ton], complete in-place which price will be full compensation for furnishing all equipment and labor for regrading and compacting existing gravel base, processing, mixing, testing, placing, and compacting, excess material relocation, and for all incidentals necessary to complete the work. The placement, grading and compaction of additional gravel base shall be paid under the appropriate aggregate base item. Pavement removal will be paid as Common Excavation.

Payment for this work under the appropriate pay items shall be full compensation for all labor, equipment, materials, and incidentals necessary to meet all related contract requirements, including design of the JMF, implementation of the QCP, obtaining core samples, transporting cores and samples, filling core holes, applying emulsified asphalt to joints, and providing testing facilities and equipment.

The Department will make a pay adjustment for quality as specified below.

401.222 Pay Factor (PF) The Department will use the following criteria for pay adjustment using the pay adjustment factors under Section 106.7 - Quality Level Analysis: Method C Testing criteria

Payments will be made under:

Pay Item	Pay Unit
425.30 – Hot Bituminous Stabilized Base	Ton [Mg]