Transportation Research Division

Technical Report 16-05

Use of FORTA FI fiber in 1½” HMA Mill & Fill in comparison to Polymer Modified HMA on Route 703 Eastbound and Westbound, South Portland

Construction Report, January 2016
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Use of FORTA FI fiber in 1½” Polymer Modified HMA Mill & Fill on Route 703 Eastbound and Westbound, South Portland

Introduction

This report documents the construction and initial observations of the FORTA FI fiber technology used in hot mix asphalt pavement. The FORTA FI fiber was submitted to the department by FORTA Corporation through its sales representative. According to FORTA Corporation, the use of FORTA FI fiber realizes immediate cost savings by enabling a better performance with less asphalt thickness and extending the treatment life. It also reduces rutting and most importantly cracking.

In August 2015, MaineDOT constructed an experimental construction project using the FORTA FI fiber on Route 703 connector in South Portland. This project was selected because specifications required use of a polymer modified asphalt binder which provides a good control mix for comparison. Also the contractor was willing to do the experiment and cooperate fully in the construction. The project also had adequate tonnage to support a trial.

The project consists of milling the existing pavement at 1½” depth and applying 1½ ” Polymer Modified HMA. Many studies and most recently “HMA Durability Investigation” reported by Derek Nener-Plante have already revealed that the polymer modified HMA has a better performance than the traditional non-modified MaineDOT mixes.

The fiber was added to a regular HMA mix for the test section portion. More than 500 Tons of fibers mix were used for this trial project corresponding to a test section length of 0.682 miles. The remaining length was built with the polymer modified HMA.

Technologies for the trial project

Mill and Fill
The concept behind mill and fill entails removing the existing surface layer with a milling machine and then transporting the material to a storage facility. New hot mix asphalt pavement is then used to replace the milled location, allowing for upwards of seven-to-10 years of service life. To minimize the occurrence of layer delamination, pavement should be removed to the bottom of the existing layer depth. Spot shim may be required at delaminated areas prior to paving surface over the milled area. Milling is widely used for pavement recycling today. For asphalt surfaces the product of milling is reclaimed asphalt pavement (RAP), which can be recycled in the hot mix asphalt (pavement) by combining with new aggregate and asphalt cement (binder) or a recycling agent. This reduces the impact that resurfacing has on the environment.

Polymer modified HMA
Asphalt cement, also referred to as asphalt binder, is used as the glue or binder mixed with aggregate particles to create HMA pavement. It has a viscoelastic behavior, meaning that it displays both viscous (fluid-like) and elastic (solid-like) characteristics. These characteristics are largely temperature dependent and asphalt cement
behaves more like a solid at low temperatures, and more like a liquid at high temperatures. Either behavior extreme can have a negative effect on HMA pavement performance. Thus asphalt pavements will crack if the asphalt cement is too stiff, and rut or deform if it is too fluid. An ideal temperature range exists and is used for each asphalt cement, in which it displays the appropriate combination of viscous and elastic properties for good pavement performance. In order to modify the viscoelastic property of the asphalt cement and enhance its performance, polymers can be added. Therefore the asphalt pavement temperature range will be changed. There are two main classes of polymers used for this purpose: elastomers, which enhance strength at high temperatures, as well as elasticity at low temperatures; and plastomers, which enhance strength but not elasticity.

The primary asphalt grade used in Maine is PG 64-28. Besides the PG 64-28, MaineDOT allows the use of PG 58-28 as an alternative in locations with lower traffic and in northern and western portions of the state. The PG 70-28 grade is a polymer-modified asphalt grade that was specified and used in Maine until 2014. Finally a new polymerized binder referenced PG 64E-28 asphalt was implemented and selected by MaineDOT to closely replicate PG 70-28 binder. The “E” in the PG grade refers to an extremely high traffic level. The PG 64E-24 was the polymerized binder used in this trial project.

FORTA FI Fiber Reinforcement Technology
FORTA FI fiber reinforcement technology is a technology developed by FORTA Corporation. The FORTA FI fiber is high-tensile strength fiber marketed for use in HMA pavement to improve performance in a cost-effective manner. The product is available in three (3) specially-formulated blends:

- HMA Blend for Hot Mix Asphalt
- WMA Blend for Warm Mix Asphalt
- PAT Blend for Hot/Cold Patch Asphalt

The FORTA FI fiber is added to the mix by specialized fiber metering equipment which blows the materials into the drum mix plant. The dosage rate is 1 lb. of fiber per 1 ton of asphalt which is determined to yield the best performance based on manufacturer’s recommendations from triaxial shear strength laboratory tests. The dispensing system feeds the mix with the required dosage of fiber based on tons per hour being produced.

A photo of the equipment used on this pilot project is shown on the Figure 1 below.

Additional information on the FORTA FI fibers reinforcement technology can be found on FORTA Corporation website at www.forta-fi.com

![Figure 1: Fibers Feeder](image)
Benefits of addition of polymer and / or Forta FI fiber

Although the purpose of the trial project wasn’t to evaluate the performance of Mill & Fill treatment, the benefits of mill & fill were identified in order to clearly appreciate the effects of the use of the fiber.

Benefits of Mill & Fill
The first benefit of mill & fill treatment is to reduce the impact that resurfacing has on the environment by using the product of milling, reclaimed asphalt pavement (RAP), which can be recycled in the asphalt hot mix asphalt (pavement) by combining with new aggregate and asphalt cement (binder) or a recycling agent. Milling can also remove distresses from the surface, providing a better driving experience and/or longer roadway life. Some of the issues that milling can remove include: raveling, bleeding, rutting, shoving, ride quality due to uneven road surface such as swells, bumps, sags, or depressions and damage resulting from accidents and/or fires.

It can be also be used to control or change the height of part or the entire road as well as change the slope or camber of the road or for grade adjustments.

Benefits of addition of polymer
It is acknowledged that Polymer Modified Asphalt as compared to conventional-unmodified HMA decreases distress levels and increases the road service life. Several studies included “Quantification of the Effects of Polymer-Modified Asphalt” published by Asphalt Institute in February 2005 have concluded on improving the performance of the binder when it is polymerized. A recent MaineDOT study (footnote to Derek’s report) on HMA durability shows that polymer modified asphalt mixes can significantly improve the service life of HMA pavements. This study concluded also that use of a polymer-modified binder vastly improved performance in the Hamburg Wheel Tracker (HWT) in terms of rutting resistance, but was less pronounced in terms of stripping potential and stripping inflection point. Overall the polymer modified binder performs better than a conventional HMA.

Benefits of addition of FORTA-FI fiber
According to studies conducted by FORTA Corporation, the use of FORTA FI fiber:
- extends the pavement life by reducing rutting and cracking
- reinforces the pavement by providing a tri dimensional reinforcement throughout the treated layers
- enhances the material properties by improving the tensile strength, the resilient modulus, the Marshall Stability and Flow, etc.

The table below shows the potential benefits of use of FORTA-FI fiber in the asphalt mix. With less thickness the polymer modified pavement has a greater or equal performance compared to a conventional asphalt while with the same standard thickness, the polymerized binder performs better.

---

5 Derek Nener-Plante (November 2015), ‘HMA Durability Investigation: Draft Report Version 1.1” MaineDOT
<table>
<thead>
<tr>
<th></th>
<th>FORTA*ied Asphalt</th>
<th>Non-FORTA*ied Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With less thickness</td>
<td>With standard thickness</td>
</tr>
<tr>
<td>Strength</td>
<td>Equal or Greater</td>
<td>Greater</td>
</tr>
<tr>
<td>Service Life</td>
<td>Equal or Greater</td>
<td>Greater</td>
</tr>
<tr>
<td>Fatigue Life</td>
<td>Equal or Greater</td>
<td>Greater</td>
</tr>
<tr>
<td>Rutting Resistance</td>
<td>Equal or Greater</td>
<td>Greater</td>
</tr>
<tr>
<td>Shoving Resistance</td>
<td>Equal or Greater</td>
<td>Greater</td>
</tr>
<tr>
<td>Crack Propagation Resistance</td>
<td>Equal or Greater</td>
<td>Greater</td>
</tr>
<tr>
<td>Erosion (Pot Holes)</td>
<td>Equal or Greater</td>
<td>Greater</td>
</tr>
</tbody>
</table>

Table 1: Comparison between asphalt with FORTA-FI fiber and asphalt without FORTA-FI fiber

Project Location

In 2015 a pavement preservation project along the Route 703 Connector in South Portland utilized 1 ½” Mill and Fill with a 12.5 MM Polymer Modified HMA including a test section of 510.71 Tons of regular HMA with Forta FI fiber. The project started at 0.11 miles East of the Turnpike Toll Booth (Station 33+00) and ended at 0.02 miles West of Main Street (US Route 1): Station 118+55 Left and Station 117+54 Right. The pavement included 1.60 miles Eastbound and 1.62 miles Westbound.

The project location is shown in green and dark blue on the map below.

![Figure 2: 20273.00 Location Map](image)

Project Scope

The original project involved milling the existing pavement at a depth of 1 ½” to 2” followed by 1 ½” Surface 12.5 MM Polymer Modified HMA to the mainline and the 4’ left shoulder. A total of 510 tons of FORTA FI fiber mix was used in the westbound travel lane as a substitute for the polymer modified HMA. This test section started at station 115+50 and ended at station 79+50 for a total length of 0.682 miles. The rest of the project (2.538 miles) was built without the fiber but with the polymer modified HMA.
**Figure 4: Typical section STA.41+00 TO 114+50**

STA. 41+00 TO 114+50

SURFACE SLOPES TRANSITION FROM EXISTING TO NEW OVER 300 FEET

**MILL AND FILL**

Figure 3: Typical section STA.33+00 TO 38+00

STA. 33+00 TO 38+00

MATCH EXISTING

MATCH EXISTING

VARIABLE DEPTH HOT MIX ASPHALT SHIM

1½" HOT MIX ASPHALT SURFACE MILL 2" DEEP

EXISTING PAVEMENT

12.00' TRAVELWAY MATCH EXISTING

12.00' TRAVELWAY MATCH EXISTING

1½" HOT MIX ASPHALT SURFACE MILL 2" DEEP

VARIABLE DEPTH HOT MIX ASPHALT SHIM

8'-40' SHOULDER

4'-00' SHOULDER

12.00' TRAVELWAY MATCH EXISTING

4'-00' SHOULDER

8'-40' SHOULDER

4'-00' SHOULDER

12.00' TRAVELWAY MATCH EXISTING

8'-40' SHOULDER
We will be comparing the section of the road built with a regular HMA and reinforced with FORTA-FI fiber (test section) to the remaining section using the polymer modified asphalt (control section).

The table below shows the ride, rut and pavement condition measurements based on Automatic Road Analyzer (ARAN) network collection data three years, two years and one year prior to the construction. The PCR values obtained in 2014 are inconsistent because they are greater than the previous ones without any treatment of the road.

Overall and prior to the construction, the road section where the fiber was applied seems to be a little more deteriorated than the portion without addition of fiber.

These pre-construction values will be compared to the ones that will be collected post to the construction to evaluate the performance of the entire construction and to compare the performance of the test section and of the control section.
<table>
<thead>
<tr>
<th>Pre-Paving</th>
<th>IRI (in/mile)</th>
<th>Rut Depth Left Wheel Path (inches)</th>
<th>Rut Depth Right Wheel Path (inches)</th>
<th>Pavement Condition Rating (PCR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three Years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Section with Fiber (Test Section)</td>
<td>131.2</td>
<td>0.29</td>
<td>0.38</td>
<td>2.96</td>
</tr>
<tr>
<td>Section without Fiber (Control Section)</td>
<td>104.7</td>
<td>0.21</td>
<td>0.30</td>
<td>3.11</td>
</tr>
<tr>
<td>Two Years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Section with Fiber (Test Section)</td>
<td>126.6</td>
<td>0.29</td>
<td>0.39</td>
<td>2.76</td>
</tr>
<tr>
<td>Section without Fiber (Control Section)</td>
<td>106.4</td>
<td>0.22</td>
<td>0.31</td>
<td>2.98</td>
</tr>
<tr>
<td>Pre-Paving</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One Year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Section with Fiber (Test Section)</td>
<td>134.1</td>
<td>0.31</td>
<td>0.40</td>
<td>3.26</td>
</tr>
<tr>
<td>Section without Fiber (Control Section)</td>
<td>115.4</td>
<td>0.23</td>
<td>0.33</td>
<td>3.43</td>
</tr>
</tbody>
</table>

Table 2: Ride, Rut, and PCR Ratings

Materials & Acceptance Testing

The project was built in accordance to the specifications included in Appendix A.

In addition to the standard testing (volumetric and core densities) used on the project as acceptance testing, Hamburg Wheel Tracking (HWT) test was also used to evaluate the durability and performance of HMA job mix formulas used.

Hamburg Wheel Tracker

Laboratory wheel-tracking devices are used to run simulative tests that measure HMA qualities by rolling a small loaded wheel device repeatedly across a prepared HMA specimen. Performance of the test specimen is then correlated to actual in-service pavement performance. Laboratory wheel-tracking devices can be used to make rutting, fatigue, moisture susceptibility and stripping predictions. The Hamburg Wheel Tracking device was
originally developed and extensively used in Hamburg, Germany since the mid-1970’s, for the evaluation of moisture susceptibility of HMA. The test consists of a loaded steel wheel tracking over the samples in a heated water bath. The deformation is observed vs. the number of loading passes. It tests two sets of specimens simultaneously with two reciprocating solid steel wheels that have a diameter of 203.2 mm and a width of 47 mm. The load applied on each specimen by the steel wheel is $158 \pm 1$ lb. A standard HWT test applies a maximum number of 20,000 passes to the samples. The data produced by the device are customarily reported as rut depth (either average or maximum) versus passes. A linear variable differential transducer measures the rut depth in each sample automatically and continuously with an accuracy of 0.01 mm. Specifications referencing HWT results often require mixes to withstand a minimum number of passes without exceeding a maximum rut depth.

The typical output produced from the HWT test including the test parameters such as the average depth, maximum depth, creep slope, stripping slope, and stripping inflection point (SIP).

Three phases are identified during the HWT test:

1. **Consolidation phase**
The sample goes through an initial consolidation in the first 1,000 to 2,000 passes where the sample ruts at a high rate due to reduction in air voids in the sample.

2. **Creep phase**
This phase begins after the consolidation phase as the rate of rutting decreases because the sample stops consolidating. The slope in this phase is referred to as the creep slope and relates to rutting primarily from plastic deformation.

3. **Stripping phase**
The final phase is the stripping phase, in which the rate of deterioration increases due to the destructive presence of moisture. The slope in this phase is referred to as the stripping slope and is a measure of the accumulation of rutting primarily from moisture damage.

The SIP is the number of passes at the intersection of the creep slope and stripping slope. This is where stripping starts to dominate performance by increasing the rate of deterioration and rutting in the sample. A lower SIP value indicates that the mixture is more prone to moisture damage and failure. Although all samples have a creep and stripping slope quantified not all samples will have a SIP identified.

HWT results in this analysis are reported in the number of passes to reach a 12.5 mm maximum rut depth; referred to as passes to failure. In addition, the maximum depth at prescribed number of passes may be reported as well as a SIP if one is identified by the analysis.
All HWT testing was performed in accordance with the applicable requirements of AASHTO T 324. MaineDOT used HWT machines from two different manufacturers for this study. The first is the Asphalt Pavement Analyzer Jr. (APA Jr.) which is produced by Pavement Technology Inc. and has been owned and operated by MaineDOT since October of 2013. The second device used for the study is the SmarTracker manufactured by InstroTek Inc. and was acquired by MaineDOT in June of 2015. The APA Jr. uses pneumatic cylinders to apply the load upon the samples where the SmarTracker uses a static load to achieve the same result. All HWT tests were run to a either a maximum of 20,000 passes or a maximum deformation of 12.5 mm.

HWT results
As part of this project, 12 tests were conducted with the HWT test; 8 with APA machine and 4 with SmarTracker. 6 tests were performed on samples from the test section and 6 tests on samples from the control section. Figure 10 below presents the histogram of showing the distribution of the passes to failure and SIP for all the HWT tests conducted. One sixth of all samples reached 20,000 passes without failure. It is also noticeable that no sample has a number of passes to failure between 15,000 and 17,500. Except this void the samples are practically uniformly distributed across the bins displayed in the chart from 5,000 passes to 20,000 passes. Regarding the SIP data, 25% of all the samples have a SIP between 12,500 and 15,000 passes while 8% have no SIP identified. All the other values are lower with the most important percentage (33%) having a SIP between 5,000 and 7,500 passes.
The analysis is also performed in term of test temperature and most important in term of the use of type of binder which will highlight eventually the difference regarding the performance of both binders used.

Figures 11 and 12 below show the distribution of number of passes to failure at 45°C and 50°C respectively for all the tests performed. The results at 45°C show that 50% of the samples with polymer, PG64E-28, reached 20,000 passes versus 25% of samples with fiber, PG64-28 yet for the same number of passes. Also all the samples with polymer reached a number of passes to failure greater than 15,000 while 25% of the samples with fiber reached a number of passes between 15,000 and 19,999 and 50% of the last samples reached a number of passes to failure lower than 15,000 but greater than 10,000. At 50°C the samples with a PG64E-28 have been uniformly distributed between the number of passes ranging from 5,000 to 10,000 and from 10,000 to 15,000 while all the samples with a PG64-28 are located in the interval 5,000 - 10,000 passes. The effect of the increased temperature leads to shifting of the distribution to lower passes to failure. This finding was already reported by Derek Nener-Plante (November 2015), “HMA Durability Investigation”.

On the basis of these results, the portion of the road built with a PG64E-28 is predicted to perform better than the one built with a PG64-28 which contains Forta FI fiber. In the light of these findings, it appears that a HMA reinforced with fiber cannot be used in place of a polymerized binder.
Core densities results
In total 10 cores were collected during the trial application. 7 cores were taken in the control section built with PG64E-28 binder and 3 cores were collected in the test section built with PG64-28 containing the fiber. The results of the core densities are shown in table 3.
The mean of the core densities for the mix with PG64E-28 is 93.4 with a standard deviation of 1.005 while the mean of the mix with reinforced with FORTA-FI fiber is 92.7 with a standard deviation of 0.723. At first glance, the mean of the core densities in the control section is a little higher than the mean of the core densities in the test section. In order to have a valuable conclusion on whether or not this difference is statistically significant, a t-Test was performed.

The analysis presented in the table above shows that the difference between the means of core densities in the control section and the test section is not statistically significant (t Stat < t Critical two-tail with t Stat = 1.13 and t Critical = 2.57).

In conclusion, regarding the density, there is no significant difference between the polymer mix and the fiber mix.

### Cost Considerations

It was already acknowledged that the addition of polymers to the binder impacts somewhat the overall project cost. Because the polymer was used only in the mix of the control section, the cost comparison should be done
with regard to a regular HMA cost. An analysis of the pay item Hot Mix Asphalt 12.5 MM price in the bid history based on a similar quantity shows a cost of $90.5 per ton (cf. table 5 below). This value is higher than the cost per ton of the polymer mix asphalt realized for the current project which is $86.750. So the polymer mix asphalt price will be used by default for comparison purpose.

<table>
<thead>
<tr>
<th>WIN</th>
<th>Location</th>
<th>Quantity (ton)</th>
<th>Low</th>
<th>Second</th>
<th>Third</th>
<th>Awd Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>17296</td>
<td>AUGUSTA, HIGHWAY</td>
<td>3,100</td>
<td>$95.00</td>
<td>$100.00</td>
<td>$99.00</td>
<td>Jun-15</td>
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<tr>
<td>20389</td>
<td>BREWER, WILSON ST</td>
<td>3,600</td>
<td>$86.00</td>
<td>$116.00</td>
<td>$121.00</td>
<td>Jun-15</td>
</tr>
<tr>
<td>20430</td>
<td>FORT KENT ROUTE 1</td>
<td>3,950</td>
<td>$102.00</td>
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<td></td>
<td>Jun-15</td>
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<tr>
<td>20387</td>
<td>DEXTER, ROUTE 23</td>
<td>4,780</td>
<td>$90.00</td>
<td>$85.00</td>
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<td>19106</td>
<td>OGUNQUIT, HIGHWAY</td>
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<td>$97.90</td>
<td>$96.50</td>
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<tr>
<td>20378</td>
<td>ELLSWORTH, US ROU</td>
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<td>12780</td>
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<td>$96.00</td>
<td>$98.00</td>
<td>$98.20</td>
<td>May-15</td>
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<tr>
<td>19109</td>
<td>FRYEBURG/ BRIDGTO</td>
<td>9,010</td>
<td>$80.10</td>
<td>$84.00</td>
<td>$88.00</td>
<td>Jul-15</td>
</tr>
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</table>

*Table 5: Cost per ton of HMA 12.5 MM for projects realized in 2015 with similar quantity*

Although the FORTA FI materials used in this trial application were donated, we will simulate that the materials were bought. We will consider also that the fiber equipment was rented in order to evaluate the actual additional costs.

According to Scott Nazar, Technical Manager of Forta Corporation: “the price for fibers is about $6.25 to $6.75 a pound which makes one ton of mix. In addition, the contractor usually puts additional costs like the feeder so the final price ranges between $8 to $10 per pound which makes one ton of mix”.

This final price has been confirmed by adding the fiber cost to the equipment cost estimation based on a sample quotation from Hi-Tech giving some pricing with different lease options for customers along with estimated freight charges for the equipment and the technician installation charges.

With this quotation and considering a weekly lease and a weekly fibers mix production ranging from 3,000 tons to 6,000 tons a cost of $10 per ton of fiber mix seems to be reasonable.

**The use of fibers generates thereby an additional cost of $10.00 per ton which represents 11.5% of the polymer modified asphalt cost.**

**Monitoring Plan**

The section of highway treated with regular hot mix asphalt reinforced with FORTA FI fiber as well as the remaining project built with polymerized binder will be monitored for performance over a five-year period. Field visits and observations will be done. Analysis will include ride data from the ARAN data collection. If needed, subsurface investigations such as coring, and falling weight deflectometer (FWD) will be utilized in the event of
premature failure. Observations from maintenance crews on snow and ice control on this surface will be noted. An interim report will be prepared after two years of service and final report after five years.

**Photos**

Both photos below were taken during the trial application, the first one at the plant and the second on the construction site.

*Photo 14: Addition of fibers to the regular HMA*
Photo 15: Pavement operation
Conclusions

This pilot project is a field demonstration of reinforcing mix asphalt with FORTA FI fiber. The entire project as well as the test strip were built in respect to the specifications included in appendix A and B. Whereas the different densities performed on the cores collected didn’t show any significant difference between both mixes, the HWT tests conducted led to the conclusion that the portion of the project built with the polymer modified mix is predicted to perform better than the portion of the road built with hot mix asphalt reinforced with FORTA FI fiber. This finding needs more analysis on further inspections and ARAN data collection. Nevertheless, the impact of the use of fiber in term of cost is not negligible and the lengthening of the treatment life might not allow concluding unequivocally that the reinforcement with fiber is cost effective. Also it would have been interesting to compare the fiber mix to conventional hot mix asphalt in order to capture easily the impact of the use of fibers both in the view point of the service life and the ratio quality / price.

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Appendix A

SPECIAL PROVISION
SECTION 401 - HOT MIX ASPHALT PAVEMENT

The Standard Specification 401 – Hot Mix Asphalt Pavement, has been modified with the following revisions. All sections not revised by this Supplemental Specification shall be as outlined in Section 401 of the Standard Specifications.

401.18 Quality Control Method A, B & C The Contractor shall operate in accordance with the approved Quality Control Plan (QCP) to assure a product meeting the contract requirements. The QCP shall meet the requirements of Section 106.6 - Acceptance and this Section. The Contractor shall not begin paving operations until the Department approves the QCP in writing.

The Contractor shall cease paving operations whenever one of the following occurs on a lot in progress:

a. Method A: The Pay Factor for VMA, Voids @ N_d, Percent PGAB, composite gradation, VFB, fines to effective binder or density using all Acceptance or all Quality Control tests for the current lot is less than 0.85. No ceasing of paving operations shall be required for fines to effective binder if the mean test value is equal to the LSL or USL and s = 0.

b. Method B: The Pay Factor for VMA, Voids @ N_d, Percent PGAB, composite gradation, VFB, fines to effective binder or density using all Acceptance or all Quality Control tests for the current lot is less than 0.90. No ceasing of paving operations shall be required for fines to effective binder if the mean test value is equal to the LSL or USL and s = 0.

c. Method C: The Pay Factor for Percent PGAB, percent passing the nominal maximum sieve, percent passing 2.36 mm sieve, percent passing 0.300 mm sieve, percent passing 0.075 mm sieve or density using all Acceptance or all available Quality Control tests for the current lot is less than 0.85. No ceasing of paving operations shall be required for percent passing the nominal maximum sieve, percent passing 2.36 mm sieve, percent passing 0.300 mm sieve, or percent passing 0.075 mm sieve if the mean test value is equal to the LSL or USL and s = 0.

d. The Coarse Aggregate Angularity or Fine Aggregate Angularity value falls below the requirements of Table 3: Aggregate Consensus Properties Criteria in Section 703.07 for the design traffic level.

e. Each of the first 2 control tests for a Method A or B lot fall outside the upper or lower limits for VMA, Voids @ Nd, or Percent PGAB; or under Method C, each of the first 2 control tests for the lot fall outside the upper or lower limits for the nominal maximum, 2.36 mm, 0.300 mm or 0.075 mm sieves, or percent PGAB.

f. The Flat and Elongated Particles value exceeds 10% by ASTMD4791.

g. There is any visible damage to the aggregate due to over-densification other than on variable depth shim courses.

h. The Contractor fails to follow the approved QCP.

401.203 Method C Lot Size will be the entire production per JMF for the project, or if so agreed at the Pre-paving Conference, equal lots of up to 4500 tons, with unanticipated over-runs of up to 1500 ton rolled into the last lot. Sublot sizes shall be 750 ton for mixture properties, 500 ton for base or binder densities and 250 ton for surface densities. The minimum number of sublots for mixture properties shall be 4, and the minimum number of sublots for density shall be five.
TABLE 7: METHOD C ACCEPTANCE LIMITS

<table>
<thead>
<tr>
<th>Property</th>
<th>USL and LSL</th>
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<tr>
<td>Passing 4.75 mm and larger sieves</td>
<td>Target +/-7%</td>
</tr>
<tr>
<td>Passing 2.36 mm to 1.18 mm sieves</td>
<td>Target +/-5%</td>
</tr>
<tr>
<td>Passing 0.60 mm</td>
<td>Target +/-4%</td>
</tr>
<tr>
<td>Passing 0.30 mm to 0.075 mm sieve</td>
<td>Target +/-2%</td>
</tr>
<tr>
<td>PGAB Content</td>
<td>Target +/-0.4%</td>
</tr>
<tr>
<td>% TMD (In place density)</td>
<td>95.0% +/- 2.5%</td>
</tr>
</tbody>
</table>

Pay Adjustment Method C

The Department will use density, Performance Graded Asphalt Binder content, and the percent passing the nominal maximum, 2.36 mm, 0.300 mm and 0.075 mm sieves for the type of HMA represented in the JMF. If the PGAB content falls below 0.80, then the PGAB pay factor shall be 0.55.

Density: For mixes having a density requirement, the Department will determine a pay factor using Table 7: Method C Acceptance Limits:

\[ PA = (\text{density PF-1.0})(Q)(P)x0.50 \]

PGAB Content and Gradation The Department will determine a pay factor using Table 7: Method C Acceptance Limits. The Department will calculate the price adjustment for Mixture Properties as follows:

\[ PA = (\% \text{ passing Nom. Max PF-1.0})(Q)(P)x0.05+(\% \text{ passing 2.36 mm PF-1.0})(Q)(P)x0.05+(\% \text{ passing 0.30 mm PF-1.0})(Q)(P)x0.05+(\% \text{ passing 0.075 mm PF-1.0})(Q)(P)x0.10+(\text{PGAB PF-1.0})(Q)(P)x0.25 \]
SPECIAL PROVISION SECTION 401
HOT MIX ASPHALT PAVEMENT
(Material Transfer Vehicle by the Ton)

Description The hot mix asphalt pavement for all leveling, base, binder and wearing courses shall be transferred to the paver by a material transfer vehicle (MTV) on mainline travelways, shoulders, and ramps as denoted in Special Provision 403 - Hot Mix Asphalt Pavement.

The MTV shall operate as an independent unit not attached to the paver. It shall be a commercially manufactured unit specifically designed to transfer the hot mix from haul trucks to the paver without depositing the mix on the roadway. A separate hopper with a capacity of 14 ton shall be inserted into the regular paver hopper. The MTV or the hopper insert shall be designed so that the mix receives additional internal mixing action either in the MTV unit or the paver hopper.

Method of Measurement Hot mix asphalt pavement transferred by the material transfer vehicle and hopper insert will be measured by the ton.

Basis of Payment The accepted quantities of hot mix asphalt pavement transferred by the material transfer vehicle and hopper insert will be paid for at the contract unit price per ton.

Payments will be made under:

Pay Item: Pay Unit:
403.40 Material Transfer Vehicle (MTV) Ton
### SPECIAL PROVISION SECTION 403
#### HOT MIX ASPHALT

<table>
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<tr>
<th>Desc.</th>
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<th>Item Number</th>
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<th>No. Layers</th>
<th>OfComp. Notes</th>
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<td><strong>Variable-Depth Mill &amp; 1 ½” HMA Overlay with Shim</strong></td>
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<td>Mainline Travelway, Third Lane (As Indicated) &amp; 4’ Shoulders</td>
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<tr>
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<td>403.2081</td>
<td>1 ½”</td>
<td>1</td>
<td>5,7,19,20,24,30</td>
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<tr>
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<td>403.211</td>
<td>variable</td>
<td>1/more</td>
<td>1,2,5,7,11,14,20</td>
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<td><strong>1 ½” Mill &amp; 1 ½” HMA Overlay Ramps - Mainline Travelway Only</strong></td>
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<tr>
<td>Wearing</td>
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<td>403.2081</td>
<td>1 ½”</td>
<td>1</td>
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<tr>
<td><strong>Repair Trenches</strong></td>
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<tr>
<td>Base</td>
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<td>403.213</td>
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<tr>
<td>Shim</td>
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<td>403.211</td>
<td>variable</td>
<td>1/more</td>
<td>1,2,5,7,11,14,20</td>
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<tr>
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### COMPLEMENTARY NOTES

1. The required PGAB for this mixture will meet a PG 64-28 grading.
2. The incentive/disincentive provisions for density shall not apply. Rollers shall meet the requirements of this special provision. The use of an oscillating steel roller shall be required to compact all mixtures pavements placed on bridge decks.
3. The design traffic level for mix placed shall be <0.3 million ESALS. The design, verification, Quality Control, and Acceptance tests for this mix will be performed at 50 gyrrations.
4. The design traffic level for mix placed shall be 0.3 to <3 million ESALS. The design, verification, Quality Control, and Acceptance tests for this mix will be performed at 50gyrations.
5. The aggregate qualities shall meet the design traffic level of 3 to <10 million ESALS for mix placed under this contract. The design, verification, Quality Control, and Acceptance tests for this mix will be performed at 75gyrations.
6. Section 106.6 Acceptance, (1) Method A.
7. Section 106.6 Acceptance, (2) Method D.
8. The combined aggregate gradation required for this item shall be classified as a 9.5mm “fine graded” mixture, (using the Primary Control Sieve control point) as defined in 703.09.
9. The combined aggregate gradation required for this item shall be classified as a 9.5mm Thin Lift Mixture (TLM) mixture, using the Aggregate Gradation Control Points as defined in 703.09.
10. Compaction of the new Hot Mix Asphalt Pavement will be obtained using a minimal rollertrain consisting of a 3-5 ton vibratory roller. An approved release agent is required to ensure the mixture does not adhere to hand tools, rollers, pavers, and truck bodies. The use of petroleum based fuel oils, or asphalt stripping solvents will not be permitted.
11. The use of a Material Transfer Vehicle (MTV) shall be required on the mainline travelway and 4’ shoulder surface layer only. See Special Provision 401 – Material Transfer Vehicle for specifics.
20. The Contractor may place the specified HMA pavement course, not to exceed 2 inch compacted depth, over the full single travel lane width, for each production day. If this option is utilized the Contractor will be required to place a matching course of HMA over the adjacent section of travel lane before the end of the following calendar day. The Contractor will also be responsible for installing additional warning signage that clearly defines the centerline elevation differential hazard. Additional centerline delineation such as double RPM application or temporary painted line shall be required for centerline depths exceeding ¼ inch. Pavement layers ¼ inch or less shall require single RPM application placed on the newly placed pavement as a minimum. The Traffic Control Plan shall be amended to include this option and the additional requirements. All signs and traffic control devices will conform to Section 719.01, and Section 652, and will be installed prior to the work, at a maximum spacing of 0.50 mile for the entire length of effected roadway section. On roadways with two-way traffic, the Contractor will be required to place the specified course over the full width of the mainline traveled way being paved prior to opening the sections to weekend or holiday traffic. If this option is utilized, all additional signing, labor, traffic control devices, or incidentals will not be paid for directly, will be considered incidental to the appropriate 652 items.

24. A tack coat of a RS-1, Item #409.15 shall be applied along the longitudinal centerline construction joint, on the horizontal surface immediately adjacent to the construction joint, and in a minimum width of one foot. The rate of application shall be approximately 0.050 to 0.075 G/SY. This application shall be in addition to the normal application of tack coats to the construction joint face and horizontal surfaces prior to placing a new lift.

30. The required PGAB shall be a storage-stable, pre-blended, homogeneous, polymer modified asphalt binder that meets PG 64E-28 grading requirements in AASHTO MP 19.

Tack Coat
A tack coat of emulsified asphalt, RS-1, Item 409.15 shall be applied to any existing pavement at a rate of approximately 0.025 gal/yd², and on milled pavement approximately 0.05 gal/yd² prior to placing a new course. A fog coat of emulsified asphalt shall be applied between shim/base courses and surface course as well as to any bridge membrane prior to the placement of HMA layers at a rate not to exceed 0.025 gal/yd². Tack used will be paid for at the contract unit price for Item 409.15 Bituminous Tack Coat.
Appendix B

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<th>REFERENCE_DNO</th>
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<th>TESTED_DATE</th>
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<th>TEST_T_EMP</th>
<th>CR_AR_VOID</th>
<th>AVG_DEFORMATION</th>
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<th>NO_PASSED_AT_MAX_IMPRESSION</th>
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<th>GET_BINDER</th>
<th>GET_REFINNER</th>
<th>GET_SUPPLIER</th>
<th>CREEP_SLOPE</th>
<th>STRIP_SLOPE</th>
<th>ISSUEANTSTRIP</th>
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