Vermont Demonstration Project:

Warm-Mix Asphalt Overlay and Rehabilitation of U.S. 4A and VT 30

Final Report
June 2013

HIGHWAYS FOR LIFE
Accelerating Innovation for the American Driving Experience.

U.S. Department of Transportation
Federal Highway Administration

FOREWORD

The purpose of the Highways for LIFE (HfL) pilot program is to accelerate the use of innovations that improve highway safety and quality while reducing congestion caused by construction. **LIFE** is an acronym for **L**onger-lasting highway infrastructure using **I**nnovations to accomplish the **F**ast construction of **E**fficient and safe highways and bridges.

Specifically, HfL focuses on speeding up the widespread adoption of proven innovations in the highway community. "Innovations" is an inclusive term used by HfL to encompass technologies, materials, tools, equipment, procedures, specifications, methodologies, processes, and practices used to finance, design, or construct highways. HfL is based on the recognition that innovations are available that, if widely and rapidly implemented, would result in significant benefits to road users and highway agencies.

Although innovations themselves are important, HfL is as much about changing the highway community's culture from one that considers innovation something that only adds to the workload, delays projects, raises costs, or increases risk to one that sees it as an opportunity to provide better highway transportation service. HfL is also an effort to change the way highway community decision makers and participants perceive their jobs and the service they provide. The HfL pilot program, described in Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) Section 1502, includes funding for demonstration construction projects. By providing incentives for projects, HfL promotes improvements in safety, construction-related congestion, and quality that can be achieved through the use of performance goals and innovations. This report documents one such HfL demonstration project.

Additional information on the HfL program is at www.fhwa.dot.gov/hfl.

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16. Abstract
As part of a national initiative sponsored by the Federal Highway Administration under the Highways for LIFE program, the Vermont Agency of Transportation was awarded a $1 million grant to demonstrate the use of multiple innovative but proven strategies for rehabilitating segments of U.S. 4A and VT 30 near and through Castleton. The three strategies used on the project include warm mix-asphalt (WMA), the Safety Edge[SM], and intelligent compaction. Two other innovative strategies were also used during construction: an infrared bar for monitoring the mat temperature behind the paver and a longitudinal construction joint specification to improve joint performance.

This report details the use of multiple strategies to rehabilitate these routes. Use of the Safety Edge increased safety by making it easier for vehicles that drift off the roadway to return. Use of WMA reduced the time needed for the mat temperature to drop below 140 °Fahrenheit, reducing queue length and the number of vehicles in the queue. More important, use of intelligent compaction increased the uniformity of the mat density and resulted in slightly higher mat densities, increasing the service life of the overlay.

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Unclassified	Unclassified	75	

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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ABBREVIATIONS AND SYMBOLS

AASHTO	American Association of State Highway and Transportation Officials
AADT	annual average daily traffic
DOT	department of transportation
FHWA	Federal Highway Administration
HfL	Highways for LIFE
HMA	hot-mix asphalt
IC	intelligent compaction
IR	infrared
IRI	International Roughness Index
OBSI	onboard sound intensity
OSHA	Occupational Safety and Health Administration
QC	quality control
RAP	recycled asphalt pavement
SI	sound intensity
SRTT	standard reference test tire
VOC	vehicle operating cost
VTrans	Vermont Agency of Transportation
WMA	warm-mix asphalt

INTRODUCTION

HIGHWAYS FOR LIFE DEMONSTRATION PROJECTS

The Highways for LIFE (HfL) pilot program, the Federal Highway Administration's (FHWA) initiative to accelerate innovation in the highway community, provides incentive funding for demonstration construction projects. Through these projects, the HfL program promotes and documents improvements in safety, construction-related congestion, and quality that can be achieved by setting performance goals and adopting innovations.

The HfL program—described in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)—may provide incentives to a maximum of 15 demonstration projects a year. The funding amount may total up to 20 percent of the project cost, but not more than $5 million. Also, the Federal share for a HfL project may be up to 100 percent, thus waiving the typical State-match portion. At the State's request, a combination of funding and waived match may be applied to a project.

To be considered for HfL funding, a project must involve constructing, reconstructing, or rehabilitating a route or connection on an eligible Federal-aid highway. It must use innovative technologies, manufacturing processes, financing, or contracting methods that improve safety, reduce construction congestion, and enhance quality and user satisfaction. To provide a target for each of these areas, HfL has established demonstration project performance goals.

The performance goals emphasize the needs of highway users and reinforce the importance of addressing safety, congestion, user satisfaction, and quality in every project. The goals define the desired result while encouraging innovative solutions, raising the bar in highway transportation service and safety. User-based performance goals also serve as a new business model for how highway agencies can manage the highway project delivery process.

HfL project promotion involves showing the highway community and the public how demonstration projects are designed and built and how they perform. Broadly promoting successes encourages more widespread application of performance goals and innovations in the future.

Project Solicitation, Evaluation, and Selection

FHWA has issued open solicitations for HfL project applications annually since fiscal year 2006. State highway agencies submitted applications through FHWA Divisions. The HfL team reviewed each application for completeness and clarity, and contacted applicants to discuss technical issues and obtain commitments on project issues. Documentation of these questions and comments was sent to applicants, who responded in writing.

The project selection panel consisted of representatives of the FHWA offices of Infrastructure, Safety and Operations; the Resource Center Construction and Project Management team; the Division offices; and the HfL team. After evaluating and rating the applications and supplemental information, panel members convened to reach a consensus on the projects to recommend for approval. The panel gave priority to projects that accomplish the following:

- Address the HfL performance goals for safety, construction congestion, quality, and user satisfaction.
- Use innovative technologies, manufacturing processes, financing, contracting practices, and performance measures that demonstrate substantial improvements in safety, congestion, quality, and cost-effectiveness. An innovation must be one the applicant State has never or rarely used, even if it is standard practice in other States.
- Include innovations that will change administration of the State's highway program to more quickly build long-lasting, high-quality, cost-effective projects that improve safety and reduce congestion.
- Will be ready for construction within 1 year of approval of the project application. For the HfL program, FHWA considers a project ready for construction when the FHWA Division authorizes it.
- Demonstrate the willingness of the applicant department of transportation (DOT) to participate in technology transfer and information dissemination activities associated with the project.

HfL Project Performance Goals

The HfL performance goals focus on the expressed needs and wants of highway users. They are set at a level that represents the best of what the highway community can do, not just the average of what has been done. States are encouraged to use all applicable goals on a project:

- **Safety**
    - Work zone safety during construction—Work zone crash rate equal to or less than the preconstruction rate at the project location.
    - Worker safety during construction—Incident rate for worker injuries of less than 4.0, based on incidents reported via Occupational Safety and Health Administration (OSHA) Form 300.
    - Facility safety after construction—Twenty percent reduction in fatalities and injuries in 3-year average crash rates, using preconstruction rates as the baseline.

- **Construction Congestion**
    - Faster construction—Fifty percent reductions in the time highway users are impacted by an active construction zone, compared to traditional methods.
    - Trip time during construction—Less than 10 percent increase in trip time compared to the average preconstruction speed, using 100 percent sampling.
    - Queue length during construction—A moving queue length of less than 0.5 mile (mi) (0.8 kilometer (km)) in a rural area or less than 1.5 mi (2.4 km) in an urban area (in both cases at a travel speed 20 percent less than the posted speed).

- **Quality**
    - Smoothness—International Roughness Index (IRI) measurement of less than 48 inches per mile (in/mi).

  - Noise—Tire-pavement noise measurement of less than 96.0 A-weighted decibels (dB(A)), using the onboard sound intensity (OBSI) test method.

- **User Satisfaction–**An assessment of how satisfied users are with the new facility compared to its previous condition and with the approach used to minimize disruption during construction. The goal is a measurement of 4-plus on a 7-point Likert scale.

REPORT SCOPE AND ORGANIZATION

This report documents the Vermont Agency of Transportation's (VTrans) demonstration project, which involved rehabilitation of U.S. 4A and VT 30 in Rutland County near the town of Castleton. The report presents project details relevant to the HfL program, including the use of three innovative technologies (warm-mix asphalt, intelligent compaction, and the Safety Edge^{SM}), HfL performance metrics measurement, and economic analysis. Technology transfer activities that took place during the project and lessons learned are also discussed.

PROJECT OVERVIEW AND LESSONS LEARNED

PROJECT OVERVIEW

Three roadway segments were included in this rehabilitation project: two segments on U.S. 4A and one on VT 30. The paving contractor for the project was Peckham Construction Corp. of Lake George, NY. The following is a general description of each segment:

- Project #2908—The segment of U.S. 4A through the town of Castleton is a two-lane roadway (12-foot (ft) lanes) with adjacent parking areas and curb and gutter in limited areas. Figure 1 shows the project limits of this portion and a general view of the roadway in Castleton.
- Project #2705—The segment of U.S. 4A east of Castleton is a two-lane roadway (12-ft lanes) and some areas are confined by guardrails. Figure 2 shows the project limits of this section and a general view of a typical section east of Castleton.
- Project #2909—The segment of VT 30 is also a two-lane roadway (12-ft lanes). Figure 3 shows the project limits and a general view of a typical section north of Castleton.

All of these roadway segments were very rough in localized areas with transverse and longitudinal cracks and other surface disintegration distresses. Figure 4 shows a general view of the pavement before the rehabilitation project. In addition, there were localized areas with edge dropoffs that made the roadway less safe for the traveling public.

Although the roadway was rough, the existing pavement structure was believed to have adequate structural strength for existing and future traffic levels. Thus, a mill and thin overlay with a leveling or scratch layer offered VTrans a cost-effective rehabilitation alternative to restore ride quality. As part of the HfL application, VTrans requested the use of three innovative technologies: WMA, IC, and the Safety Edge.

1. WMA was used for two reasons: reduced odor from paving through Castleton and other communities and lower production temperatures to reduce the amount of time needed for the mat temperature to drop below 140 °Fahrenheit. The project specification required the mat’s surface temperature to be below 140 °F before the lane was opened to traffic, so it was an important value related to traffic congestion through the action construction zone.

2. IC was used to increase the uniformity of the mat density and reduce the number of passes needed to achieve the target mat density.

3. The Safety Edge was used in appropriate areas to eliminate edge dropoffs and increase safety to the traveling public.

Two other technologies were included in the demonstration project: an infrared (IR) bar was used on a limited basis to monitor the mat surface temperatures behind the paver and a longitudinal construction joint specification was included to improve the density and performance of the longitudinal construction joints. The specification was used to determine the benefit from the traditional method used to construction longitudinal construction joints.

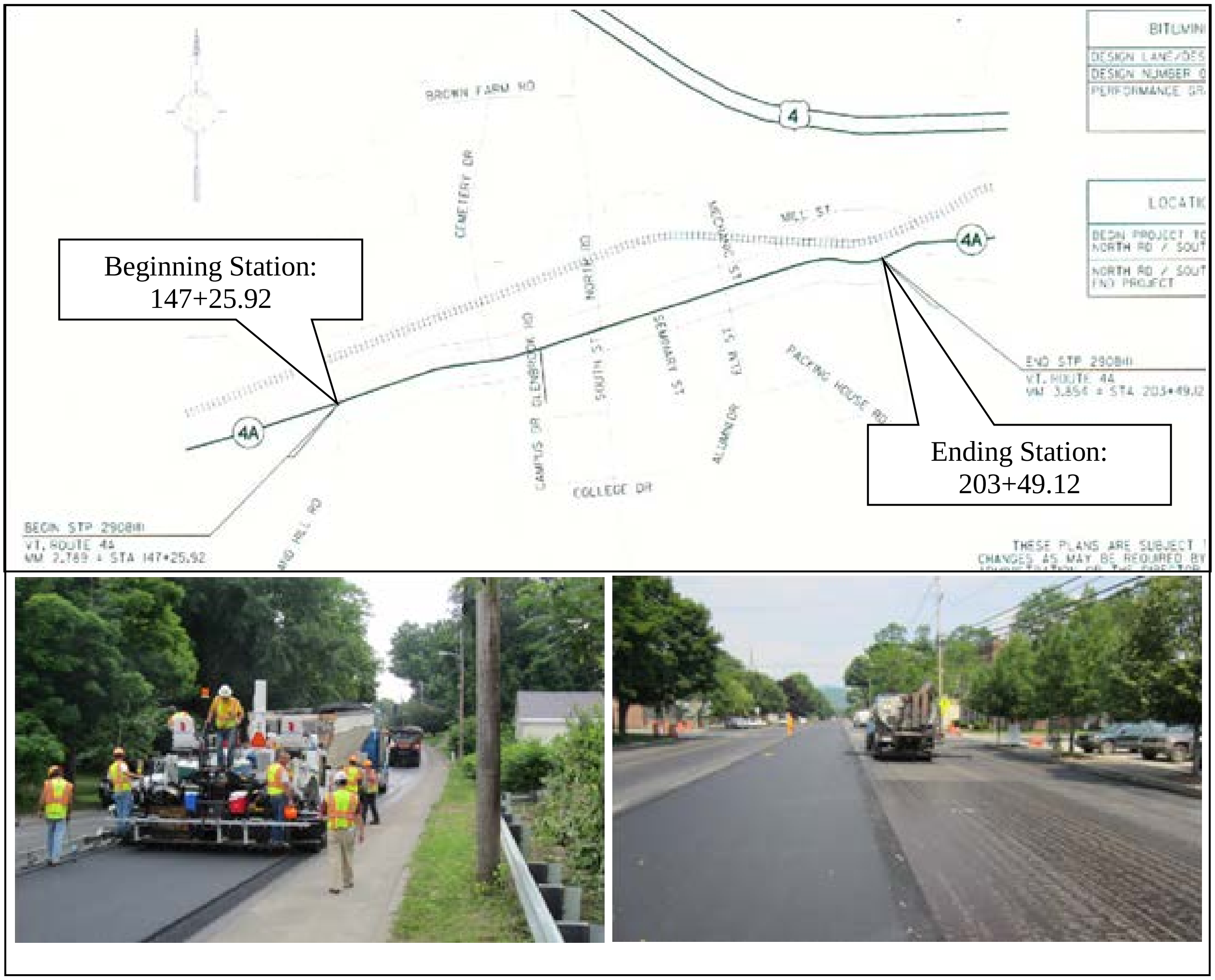


Figure 1. Project #2908—Limits and general view of U.S. 4A segment through Castleton.

Figure 2. Project #2705—Limits and general view of U.S. 4A segment east of Castleton.

HfL Performance Goals

Safety, construction congestion, quality, and user satisfaction data were collected before, during, and after construction to determine if WMA, IC, and the Safety Edge met the HfL performance goals.

- **Safety**
  - Work zone safety during and at the completion of construction—No motorist crashes were reported within the project limits during construction. Traffic control personnel and law enforcement officers played a key role in meeting the goal of keeping the crash rate well below historical levels for these highway segments. It is anticipated that the 3-year average crash rates will meet the HfL criteria of a 20 percent reduction because of the improved riding surface and new safety features, such as the Safety Edge and other shoulder improvements.
  - Worker safety during construction—No worker injuries occurred during construction, which exceeded the goal of less than a 4.0 rating on the OSHA 300 form.

Figure 3. Project #2909—Limits and general view of VT 30 segment north of Castleton.

- **Construction Congestion**
  - Faster construction—WMA allowed the contractor to pave one lane of the two-lane roadway and open it to traffic in a shorter time period because of the lower WMA mat temperatures, reducing the number of traffic control personnel and the number of vehicles in the queue. On average, the lane was opened to traffic 10 to 20 minutes earlier for WMA mixtures compared to the hot-mix asphalt (HMA) mixtures. While not meeting the HfL goal of a 50 percent reduction in the amount of time highway users are impacted, the WMA made a substantial reduction toward this goal.
  - Trip time—The HfL performance goal is no more than a 10 percent increase in trip times through the project limits. The average speed through the construction zone was less than 20 miles per hour (mi/h) because traffic was confined to one lane. The length of the construction zone, however, was kept at a minimum, so the average speed through the project limits was 30 to 35 mi/h, slightly greater than the 10 percent HfL goal.

- Queue length during construction—Even though the trip time was increased from one end of the project to the other, no significant backups occurred, keeping moving queue lengths well below the HfL criteria of 0.5 mi in rural areas, except when the air temperature was above 90 °F. Even in this case, the queue length was less than 0.5 mi. In most cases, fewer than 20 vehicles were in the queue at any time.

Figure 4. General view of pavement condition in two areas of the project before rehabilitation on U.S. 4A near Castleton. Condition of the other segments was similar. (Photos courtesy of Chris Thomas, Peckham Construction.)

Quality

- Smoothness and noise—Quality was measured in terms of smoothness and noise both before and after construction. The field data document a 31 and 40 percent drop in post construction IRI value for U.S. 4A and VT 30, respectively, a considerable increase in smoothness. Preconstruction IRI was 211 in/mi for the existing HMA surface on U.S. 4A, while post construction IRI was 66 in/mi.

Although this is a significant improvement in smoothness over the original pavement, it is higher than the HfL target value of 48 in/mi. Similarly, the preconstruction IRI value for VT 30 was 167 in/mi, while the post construction IRI was 67 in/mi. The smoothness of the new wearing surface is considered reasonable for both roadways based on the user satisfaction survey results from this project (see Appendix A).

- Noise—The average sound intensity level for both roadways decreased from 101.3 dB(A) to 97.6 dB(A). The post construction values are slightly greater than the HfL goal of 96.0 dB(A). The noise level of the new wearing surface is considered reasonable for both roadways.
- User satisfaction—Post construction survey results show the local community was very satisfied with the project, which minimized the number of vehicles in the queue and reduced delay time. Public satisfaction with the finished product is very high and meets the HfL user satisfaction criteria.
- Mat density is not considered a direct goal of the HfL program. However, it can have an indirect but significant impact on HfL goals, especially those related to quality, overall user satisfaction and safety. Mat density was monitored to evaluate the service life of the overlay compared to rehabilitation with overlay projects without these innovative strategies. The most important observation is lower variability across and along the mat or more uniform mat densities. The coefficient of variation of compaction was below 2 percent, which indicates that fewer areas of the mat have densities below the specification value. The presence of fewer areas with low density is expected to result in a longer service life and lower maintenance costs over time.

ECONOMIC ANALYSIS

The benefits and costs of this innovative project were compared with those of a similar resurfacing project not using the innovative strategies. The result of the cost analysis indicates that the VTrans approach is similar in cost over the life of the pavement to conventional rehabilitation projects with similar site features and conditions. Actual savings of $7,800 were realized from using the WMA technology and reducing delays in the active construction zone. Although the savings are only 0.15 percent of the total project, it is expected that greater savings will be realized through fewer crashes with injuries, which are difficult to quantify.

LESSONS LEARNED

With this project, VTrans achieved a better understanding of the WMA, IC, and Safety Edge methods. Until now, the three innovative technologies had not been used for major highway rehabilitation projects largely because of the unknowns and lack of local experience. All of the innovative technologies were successful in demonstrating the constructability of WMA and enlightening designers and contractors on the viability of these innovative methods for rehabilitating flexible pavements and improving highway safety.

The significant lessons learned and reported by VTrans focused on the WMA mixtures and included the following:

1. There were no fumes and significantly reduced smoke at the plant and paving site for the WMA mixtures, compared to traditional HMA mixtures.
2. More compaction or a higher level of compaction was achieved for the WMA mixtures compared to traditional HMA mixtures.
3. VTrans' policy is to allow traffic on the new mat when its surface temperature drops below 140 °F. It took less time for the mat temperature of the WMA mixture to drop below 140 °F than for the HMA mixture because of the lower production temperatures. When the ambient air temperature exceeded 90 °F, however, the time to drop below 140 °F was about 60 minutes for the WMA mixture and over 70 minutes for the HMA mixture, not a huge difference.
4. The emulsified asphalt used as a tack coat did not delay the paving operations and was not significant in reducing the length of the work zones.

The significant lessons learned and reported by the contractor (Peckham Construction) focused on the use of the IC roller and included the following:

1. The IC roller operator really liked the visual display screen for monitoring the rolling pattern and overlap of the different passes. This display helped increase uniformity, especially during nighttime paving operations.
2. The IC stiffness value was monitored during the rolling operation of the WMA and HMA mixtures. The contractor believes the industry still has ways to go before the IC stiffness value can be used for quality control (QC) purposes and has concerns about using it for acceptance.
3. The Carlson Safety Edge device attached to the screed end plate worked very well and was easy to install and use.
4. WMA is a great advantage. With the exception of the production temperature, there was no significant difference between the WMA and HMA mixtures.
5. At the production facility, the WMA laboratory plugs used for QC cooled faster, so the test results were available more quickly than for the HMA laboratory plugs.
6. Deviation and issues with variation in air voids of WMA laboratory compacted plugs are the same as with HMA laboratory compacted plugs.
7. The heated side of the plate for the longitudinal construction joint placement worked very well and densities of the construction joint increased. The longitudinal construction joints appeared tighter than in the traditional method used to place and compact a longitudinal construction joint.
8. The IR bar is a reasonable tool for QC, but its use is more after the fact. The contractor believed the IR bar provided useful information for producing a more consistent product by identifying cold spots and changing the mixture delivery process to eliminate them. Both safety and screed personnel, however, did note the way the IR bar was first installed was a hazard to the screed operators leaving and walking across the back of the screed. The issue was later minimized by using different materials for attaching the IR bar to the back of the screed.

Conclusions

The rehabilitation project on U.S. 4A and VT 30 exemplifies the HfL principles. The WMA, IC, and Safety Edge innovations were major contributing factors in reducing overall project costs. Using WMA also resulted in about 30 percent reduction in time for opening the lane to traffic compared to HMA mixtures, while a high level of safety was maintained for workers and the traveling public. Crashes are expected to be lower over the project's service life because of design features and a more durable pavement surface. The postconstruction smoothness level, while not meeting the HfL goal, is a vast improvement over the smoothness level of the original pavement. Similarly, the noise level after construction is slightly above the HfL target value, but is within the range for similar dense-graded wearing courses. Overall, users of the new roadway are very satisfied with the finished product.

PROJECT DETAILS

BACKGROUND

Ride and distress ratings of the three roadway segments included in this rehabilitation project were considered poor and maintenance costs were increasing. Distresses such as alligator, transverse, and longitudinal cracking were present but variable in extent and severity over the length of the segments. Figure 4 showed the original distressed pavement surface. Within each segment is a two-lane roadway with no major bridges. There are segments with a divider, but those areas are localized. Guardrails are also present in limited locations of each project. Parking areas and curb and gutter are also located in limited areas in the segment through Castleton.

The purpose of this rehabilitation project was to improve ride quality and safety for the more than 10.5 centerline miles of U.S. 4A and VT 30 in and near Castleton (see Figures Figure 1 through Figure 3). As noted previously, the rehabilitation project was a mill and fill or replacement of the existing wearing surface. Construction began in midspring 2012, with cold-planing of the existing wearing surface beginning in May 2012. Paving was completed in September 2012. The bid construction cost was around $5 million for all three projects or roadway segments. The Highways for LIFE grant was $1 million, about 20 percent of the project cost. Figures Figure 5 and Figure 6 show the project construction team members. Peckham Construction Corp. of Lake George, NY, was the contractor for the project. Figure 5a shows the agency personnel directly involved in the project. Figures Figure 5b and Figure 5c show the paving crew and compaction team members, and Figure 6 shows the key inspection personnel and the contractor's quality control (QC) team members.

PROJECT DESCRIPTION

This rehabilitation project consisted of milling/cold planing the existing pavement surface to a depth of about 2 inches (in) and placing a 0.5-in scratch or leveling course followed by a 1.5-in Superpave® Type IVS wearing course. An emulsion CRS1-H tack coat was applied to the milled surface at a rate of 0.08 gallons per square yard (gal/yd^2), while an emulsion RS-1H (referred to as "super glue") was applied to the surface of the leveling course at a rate of 0.025 to 0.04 gal/yd^2 just before placement of the dense-graded wearing surface (see Figure 7). The use of the RS-1H emulsion allowed the contractor to shorten the length of roadway included in the construction zone ahead of the paver. The length of pavement in front of the paver with emulsion was important in paving through the local communities from a traffic control and user delay standpoint.

Three mixtures for the wearing course were produced and placed in different locations during the project: one was HMA and the other two were WMA. The two WMA technologies were the foaming process using a Terex foamer (see Figure 8) and an organic wax additive identified as SONNEWARMix. All mixtures included 20 percent recycled asphalt pavement (RAP). Table 1 summarizes information on the three mixtures.

5a. Agency project team: (bottom row, left to right) Tim Pockette, Sara Luichinger, Jason Murphy, and Joe Burke; (top row, left to right) Logan Markie, Chris Williams, and Bruce Boyle.

5b. Contractor's paving team: (left to right) Chris Thomas, Bernard Granger, Ed Gadrick, Kyland Rafferty, Bill Grant, Lou Gray, John Breault, and Neal Lewis.

5c. Contractor's compaction team: (left to right) Justin Duell, Jim Alexander, and Barry Wilson.

Figure 5. Project agency and contractor construction personnel.

6a. Contractor's quality control team: (left to right) Chris Cronin, Geon Giorgianni, and Chris Thomas.

6b. Inspection team: Richard Tittemore and Bernard Granger.

Figure 6. Project quality control and inspection personnel.

The following summarizes the equipment used to produce, place, and compact the Superpave Type IVS wearing surface:

- The WMA foamed asphalt and organic wax technologies were used in specific locations of the project for comparison with HMA (see Table 1). All three mixtures were produced at Peckham's production facility in Hudson Falls, NY (see Figure 9). A drum mixer with a production capacity of 500 tons per hour was used to produce the mixtures. A #4 or #5 low-grade fuel was used as the burner fuel, but was preheated before combustion.

- The HMA and WMA mixtures were delivered to the project site using two types of delivery trucks (see Figure 10). End dump trucks were used more commonly and "flow boys" or horizontal discharge trucks were used infrequently.

- A ROADTEC RR190 paver was used to place the HMA and WMA mixtures along all three roadway segments (see Figures 10a and Figure 11). The contractor's paving crew had to overcome issues with overhanging trees and power lines when paving along U.S. 4A in Castleton (see Figure 12). The paving crew was able to unload and place the WMA mixture without incident.

Figure 7. Tack coat (RS-1H emulsion) being applied to the surface of the leveling course before overlay placement.

Figure 8. Terex foamer installed at the plant for producing foamed WMA.

Table 1. Summary of mixtures placed in different areas of the project.

Mixture Type		WMA	WMA	HMA
Project #		STP 2705 & 2908	STP 2909	STP2705
WMA Technology		Water, Terex Foamer	Organic Wax SONNEWARMix	NA
Binder Grade		PG 58-28	PG 58-28	PG 58-28
Percent Binder by Weight	Virgin Binder	5.0	5.0	5.1
	Total Binder	6.1	6.2	6.3
Percent RAP		20	20	20
Target Gradation, Percent Passing Sieve Size	12.5 mm	100	100	100
	9.5 mm	100	100	100
	4.75 mm	77	77	74
	2.36 mm	46	46	44
	1.18 mm	29	29	27
	0.600 mm	19	19	19
	0.300 mm	13	13	13
	0.150 mm	8	8	8
	0.075 mm	5.0	5.0	5.0
Voids in Mineral Aggregate		15.6	15.6	15.6
Voids Filled with Asphalt		74.0	74.0	75.0
Maximum Specific Gravity		2.518	2.520	2.518
Mixing Temperature		124-168 °C	124-168 °C	157 ± 11 °C
Compaction Temperature		121 °C ±5 °C	121 °C ±5 °C	142 ± 5 °C

Figure 9. Peckham's drum mix plant in Hudson Falls, NY, used to produce WMA and HMA mixtures.

10a. Typical end dump truck used to deliver the HMA and WMA mixtures to the paver. The end dump trucks were used more frequently by the contractor.

10b. Horizontal discharge trucks or flow boys were also used to deliver the HMA and WMA mixtures to the paver. This type of truck was used less frequently on this project.

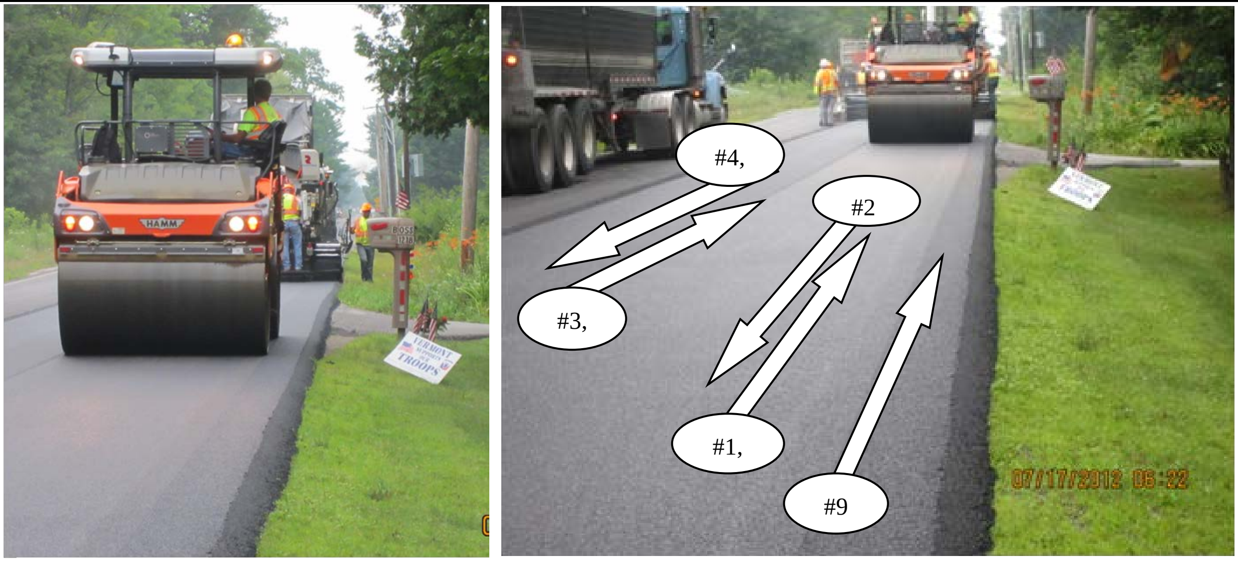
Figure 10. Trucks used to deliver the HMA and WMA mixtures to the paver.

- The HMA and WMA mixtures were compacted using three rollers. The breakdown or primary roller was a HAMM double steel drum equipped with the IC system. The intermediate roller was a Caterpillar pneumatic or rubber-tired roller, and the finish roller was a HAMM double drum oscillatory roller. The following describes the rolling pattern each roller used to compact the HMA and WMA mixtures, which was the same for all three mixtures (WMA foamed, WMA organic wax, and HMA):
  - HAMM IC roller—The rolling pattern consisted of nine passes across the mat, as shown in Figure 13. The display screen on the roller was used by the operator to monitor the temperatures, number of passes and overlap or coverage, and IC stiffness value. The number of passes and coverage were the primary parameters the operator monitored to ensure uniform coverage. All passes of the HAMM IC roller were in the oscillating mode.

- Caterpillar rubber-tired roller—The rolling pattern for the intermediate roller consisted of five passes across the mat, as shown in Figure 14.
- HAMM oscillatory roller—The rolling pattern for the finish roller consisted of a minimum of five passes across the mat, as shown in Figure 15. The number of passes varied, depending on the density readings being measured with a nuclear density gauge to ensure the target mat density was met. Passes 1 and 3 were generally in the oscillating mode, while passes 2, 4, and 5 were in the static position. The mode and number of passes, however, depended on the results of the density readings taken behind the rubber-tired roller.

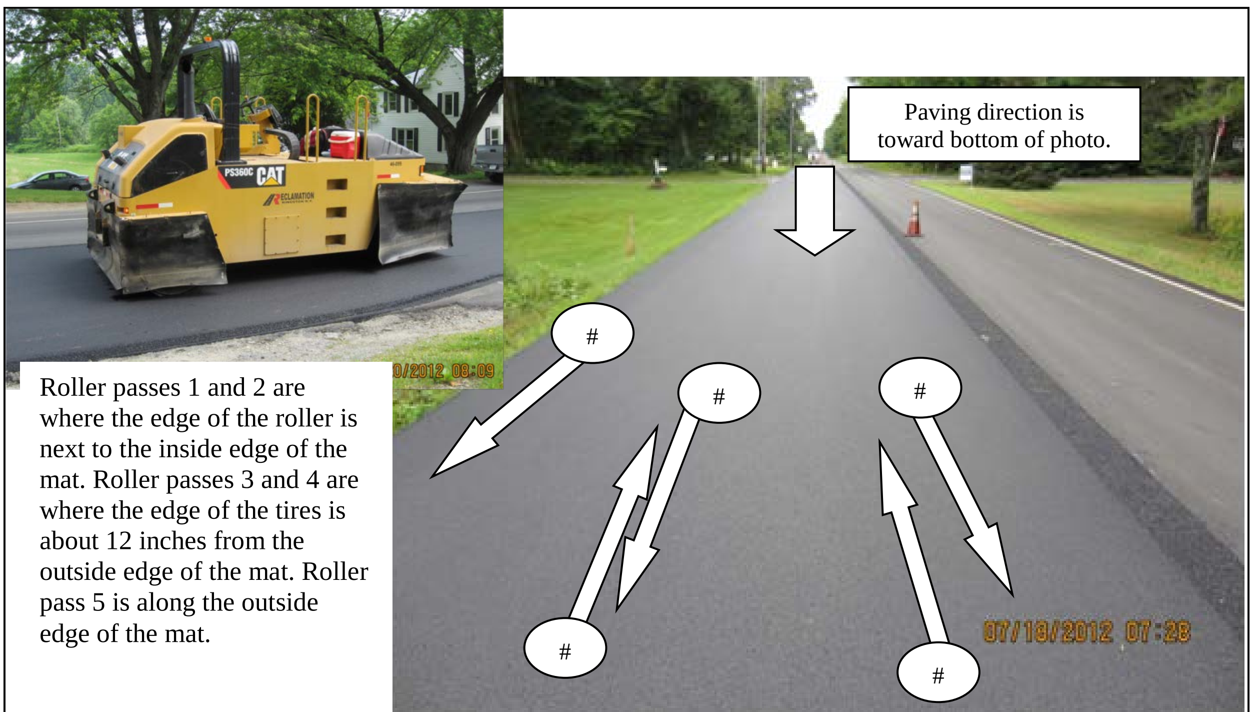
Figure 11. Paver used to place the HMA and WMA mixtures along all three roadway segments.

Figure 12. Overhanging trees and power lines along U.S. 4A in Castleton.



Roller passes 1, 2, 7, and 8 are where the edge of the roller is about 18 inches from the mat's outside edge.
Roller passes 3, 4, 5, and 6 are where the edge of the roller is about 6 inches over the inside edge of the mat.
Roller pass 9 is where the edge of the roller is about 6 inches over the outside edge of the mat.

Figure 13. HAMM IC roller and pattern (primary or breakdown roller) used to compact the WMA and HMA mixtures.



Roller passes 1 and 2 are where the edge of the roller is next to the inside edge of the mat. Roller passes 3 and 4 are where the edge of the tires is about 12 inches from the outside edge of the mat. Roller pass 5 is along the outside edge of the mat.

Figure 14. Caterpillar rubber-tired roller and pattern used for intermediate rolling of the WMA and HMA mixtures.

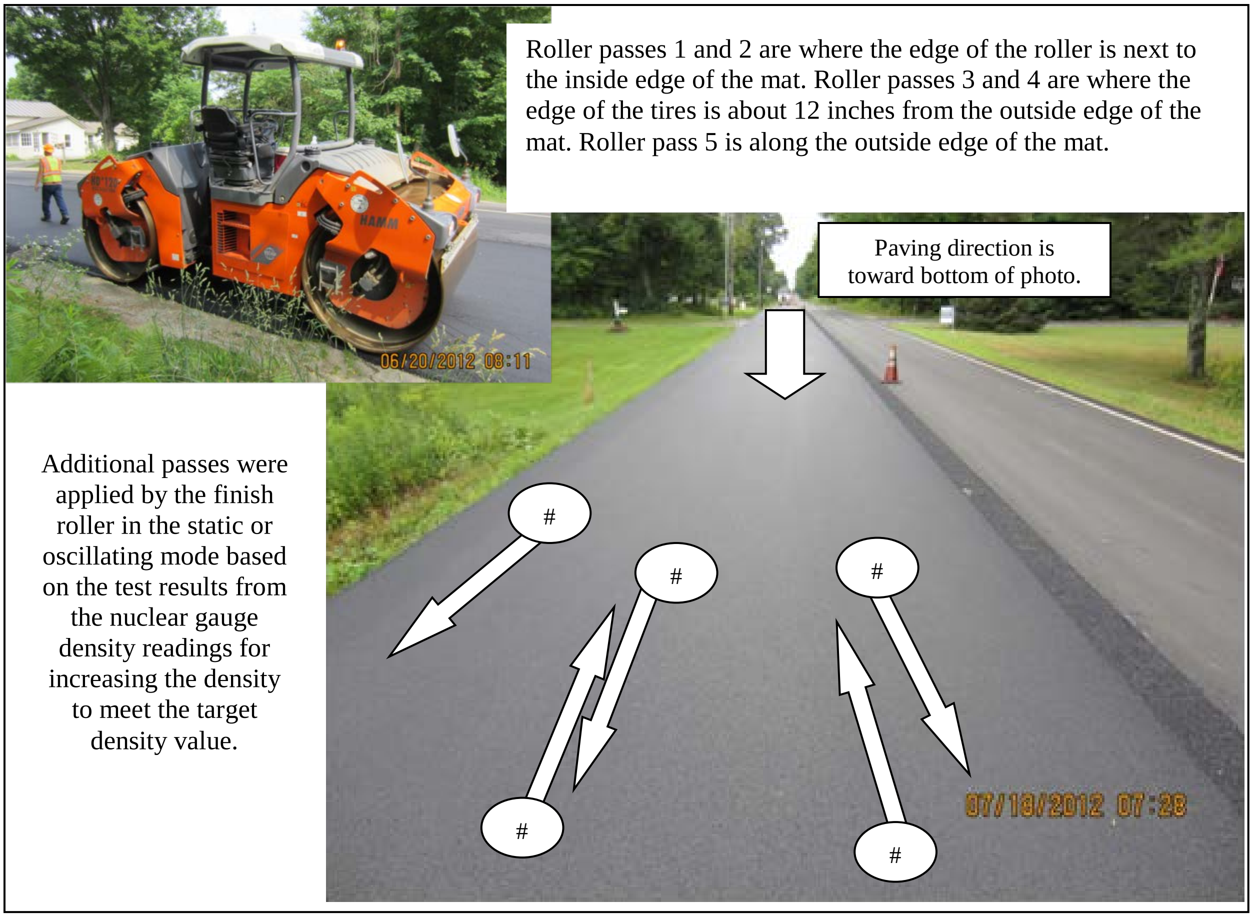


Figure 15. HAMM oscillatory double steel drum roller and pattern used for finish rolling of the WMA and HMA mixtures.

The contractor was aggressive in taking density readings with a nuclear density gauge for QC purposes before completing the compaction operation. Density readings were made frequently between the intermediate and finish rollers and after the finish roller to ensure the target density had been met (see Figure Figure 16a). After the compaction operation was completed, locations were marked on the mat's surface for recovering cores for acceptance purposes. VTrans personnel determined the random number or location of the cores while contractor personnel drilled the cores (see Figure Figure 16b).

The contractor used a nonnuclear density gauge for a limited time to monitor the compaction operation along the segment of VT 30 (see Figure Figure 16c). The contractor's QC team also measured the mat density to determine the longitudinal and transverse density profiles in limited areas at the request of VTrans and FHWA. These results are discussed in the next section. Densities were also measured at periodic locations along and next to the longitudinal construction joint.

16a. Troxler nuclear density gauge used to monitor the mat density during the rolling operation.

16b. Drilling cores in the WMA mat for acceptance.

16c. Transtec's PQI nonnuclear density gauge used for QC purposes on a limited basis during the compaction operation.

Figure 16. Use of nuclear and nonnuclear density gauges for QC and cores for acceptance.

INNOVATIVE STRATEGIES

As noted previously, three innovative strategies were identified in the HfL application for this project: WMA using the foaming and organic wax technologies, IC, and the Safety Edge. Two other strategies were added to the demonstration project: an IR bar and a longitudinal construction joint specification. Table 2 defines the strategies used in each roadway segment.

Table 2. Innovative technologies used in each roadway segment.

Innovation or Technology Used	Project Number		
	STP #2705 (see Figure 2)	STP #2908 (see Figure 1)	STP #2909 (see Figure 3)
Warm-Mix Asphalt	Foaming Process	Foaming Process	Organic Wax, SONNEWARMix
Safety Edge	In Partial Areas	In Partial Areas	In Partial Areas
Intelligent Compaction	√	Not Monitored	√
Infrared Bar	In Partial Areas	In Partial Areas	In Partial Areas
Longitudinal Construction Joint	√	Not Monitored	√

Warm-Mix Asphalt

WMA is a newer technology for Vermont. The Evotherm WMA technology has been used on a few other projects, but this is the first project on which WMA foaming technology was used. The main benefit of WMA is that it allows the mixture to be produced and placed at about 50 °F lower than the compaction temperature for HMA. Less energy is needed to produce the WMA mixture, which results in lower carbon emissions while allowing the roadway to be opened to traffic in less time. Energy savings of 15 percent or more have been well documented.

Another WMA benefit is that it takes less time, energy, and effort to achieve compaction compared to HMA. The reduction in viscosity provides for easier placement through the screed, promoting greater accuracy of placement depths. It also enables compaction with less effort. This allows the construction sequence to progress more quickly and with less energy use in the placement and compaction phase of the project.

Reduced compaction effort also helps reduce any detrimental impact on buried assets, such as culverts, utilities, and sensitive structures next to paving projects. The reduction in compaction energy directly reduces stresses on these structures. Modeling of compaction processes suggests that attenuation routinely occurs in proximity to the surface with proper operations. A reduction of compaction energy provides a higher level of assurance that utilities will not be compromised during the optimization efforts or as a result of changed conditions below the pavement.

Safety Edge

The Safety Edge is another strategy that is relatively new in Vermont (see Figure 17). The key benefit of the Safety Edge is that it allows vehicles driving off the pavement surface at highway speeds to safely return to the travel lane, reducing roadway departure crashes. It also reduces the amount of edge raveling and cracking that occurs along the pavement's edge, reducing future maintenance costs.

Intelligent Compaction

IC has not been used in Vermont, but is a growing technology for compacting HMA and WMA mixtures. IC has multiple benefits. One of the most important is that mat density uniformity can be increased by monitoring the IC display screen to eliminate areas with few to no passes because of inconsistent or no overlap between adjacent passes (see Figure 18). The other important benefit is determining the optimum number of passes over a specific point for maximizing mat density while preventing overcompaction. It is well known and reported that increasing the mat density and/or reducing its variability results in longer pavement or overlay service life and lower maintenance costs.

17a. Carlson Safety Edge device attached to the end plate of the screed.

17b. Safety Edge before the backfill material is placed along the pavement's edge.

Figure 17. Safety edge placed by the Carlson device.

Figure 18. Display screen on the HAMM IC roller for monitoring coverage and other parameters.

Infrared Bar

The IR bar had not been used on any project in Vermont. It was added to this demonstration project to monitor temperatures over the full width of the mat directly behind the paver before rolling (see Figure 19). Significant temperature differentials across the mat and between truck loads result in increased variability and low densities in cold spots. This temperature differential is sometimes referred to as “thermal segregation.” The IR bar does not prevent cold spots, but does identify and locate them so the contractor can change the truck loading and unloading process to eliminate significant temperature differences.

Longitudinal Construction Joint Specification

Like many other agencies, VTrans has observed and reported that the condition of longitudinal construction joints can limit the pavement service life of many flexible pavements. VTrans included this strategy to improve the joint density resulting in improved service life of the asphalt concrete overlay.

Figure 19. IR bar being installed and used to monitor mat temperatures directly behind the paver.

DATA ACQUISITION AND ANALYSIS

Data on safety, traffic flow, quality, and user satisfaction before, during, and after construction were collected to determine if this project met the HfL performance goals. As noted in the previous section, mat and joint densities were also collected because these values have a significant impact on the service life and future maintenance of the asphalt concrete overlay. The objective of acquiring these types of data was to quantify the project performance and provide an objective basis to determine the feasibility of the project innovations and to demonstrate that the innovations can be used to do the following:

- Produce a high-quality project and gain user satisfaction.
- Reduce construction time and minimize traffic interruptions or congestion.
- Achieve a safer work environment for the traveling public and workers.

This section discusses how well the VTrans project met the specific HfL performance goals in these areas.

QUALITY

To evaluate the HfL goal on the quality of the project, three parameters are considered in accordance with FHWA guidelines for HfL projects: smoothness, noise or SI level, and user satisfaction. On this project, an additional parameter was considered in defining the quality goal, which is indirectly related to the needs of the highway user: mat and longitudinal joint densities. Mat and joint densities have a significant effect on the service life of the overlay and project and future maintenance costs. Thus, density was added to this section to raise the bar in highway transportation service. This parameter is also important to the cost and economic analysis of these initiatives and strategies.

Mat and Joint Densities

Mat and joint densities were measured during and after compaction. This section discusses the reasons for and results from these measurements as they relate to the HfL performance goals listed above and in the Introduction.

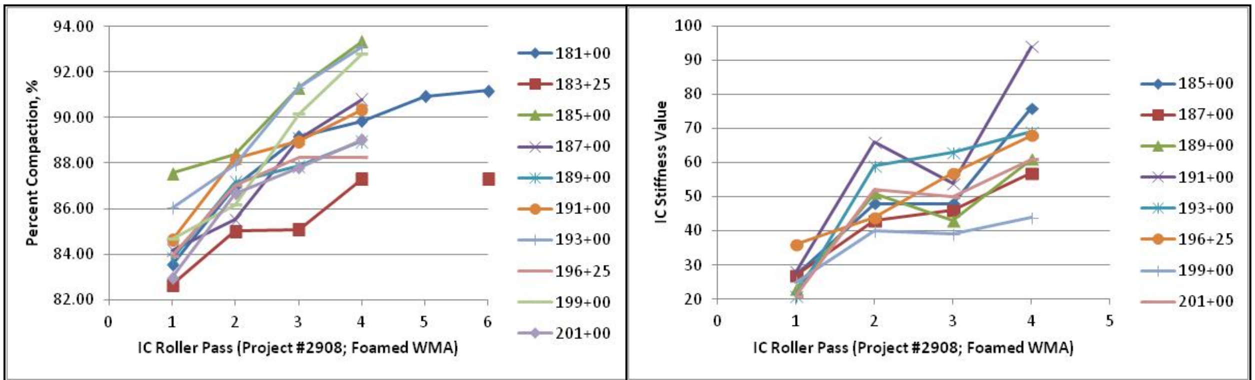
A benefit of IC is that multiple parameters can be monitored during the rolling operation in real time. These parameters include the location of the roller to ensure complete coverage and adequate overlap between adjacent passes, temperature of the mat, and IC stiffness value. In addition, the IC stiffness values can be used during compaction to determine if the mat is being over compacted, resulting in a decrease in the mat density and IC stiffness.

Control strips were established for each mixture and roadway segment to determine the number of passes over a specific point needed to achieve the greatest densification during breakdown rolling. A Troxler nuclear density gauge was used to monitor the mat density at a specific point before compaction and after each pass of the IC roller (see Figure 20). Ten stations were initially located for developing density and stiffness growth curves for each mixture. Figure 21 includes the density and IC stiffness growth curves for each mixture. As shown, the density and IC stiffness value increase with the number of passes. In the interest of time, more than four passes of the roller were used only at selected stations. The mat density and IC stiffness value are still increasing after four passes at most of the stations, but start to level off and decrease at five or six passes of the IC roller. After four passes, there is a much smaller increase in density. Thus, the contractor decided to use a minimum of four passes of the IC roller in setting the rolling pattern. The additional compaction effort for increasing the mat density was applied by the intermediate (Caterpillar rubber-tired) and finish (HAMM double-drum oscillatory) rollers.

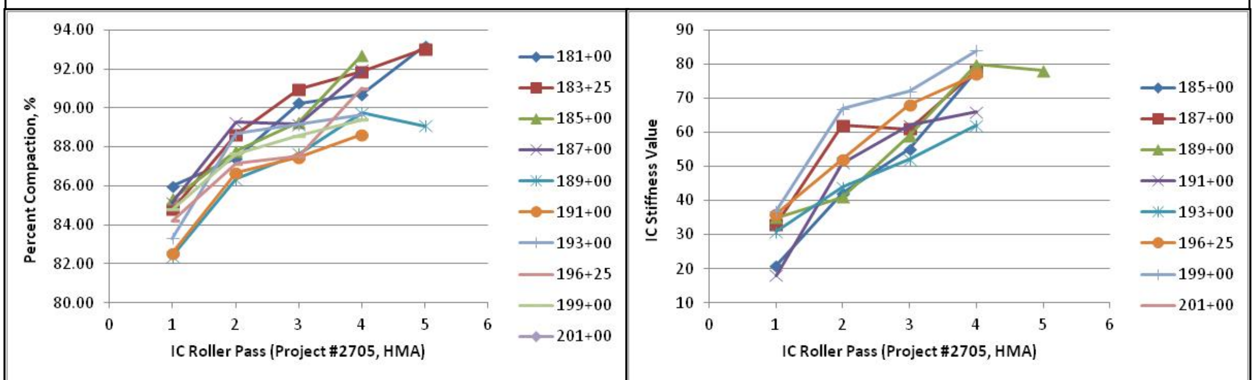
Figure 20. QC personnel taking density readings in the control strip with a nuclear density gauge.

Both VTrans and the contractor wanted to determine the potential for using the IC stiffness value as a QC parameter. The mat density and IC stiffness values were recorded after each pass of the IC roller. Figure 22 is a graphical comparison of the mat density measured by a nuclear density gauge and IC stiffness value. As shown, there is a definite trend between the two values: As density increases, the IC-stiffness increases. However, there is extensive variability in the three data sets. Both VTrans and the contractor were cautious about changing the rolling pattern in real time based on the IC stiffness value alone. Thus, the IC roller operator monitored the IC stiffness, but all decisions on changing the rolling pattern were based on the nuclear density gauge readings made after rolling the mat with the intermediate and finish rollers.

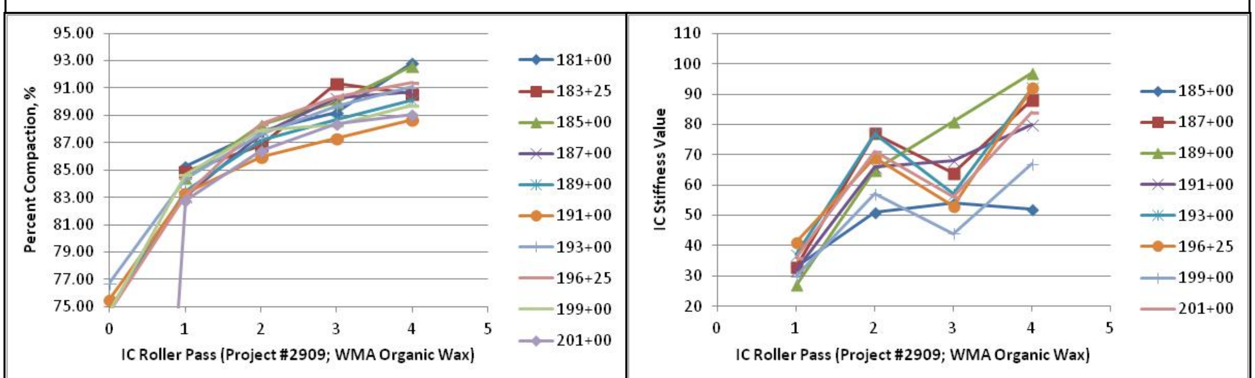
The specification limits for percent compaction of asphalt concrete mixtures varied from 92.5 to 96.5 percent for this project. Chris Thomas of Peckham Construction reported that compaction for the material placed on June 28, 2012, averaged 94.5 percent, resulting in a pay factor of 100.3 percent. Conversely, the material placed on July 2, 2012, resulted in 92.3 percent compaction with a pay factor of 74 percent. Four of the 12 acceptance cores for mixture placed July 2, 2012, fell within or just outside the test section used to establish the rolling pattern using the IC roller. Most of the QC technicians were directly involved in collecting the IC stiffness and density versus number of passes. In addition, the rolling pattern was interrupted during the test section. This resulted in lower mat temperatures than for the other days of paving.



21a. Project #2908, U.S. 4A, foamed WMA mixture, June 21, 2012.

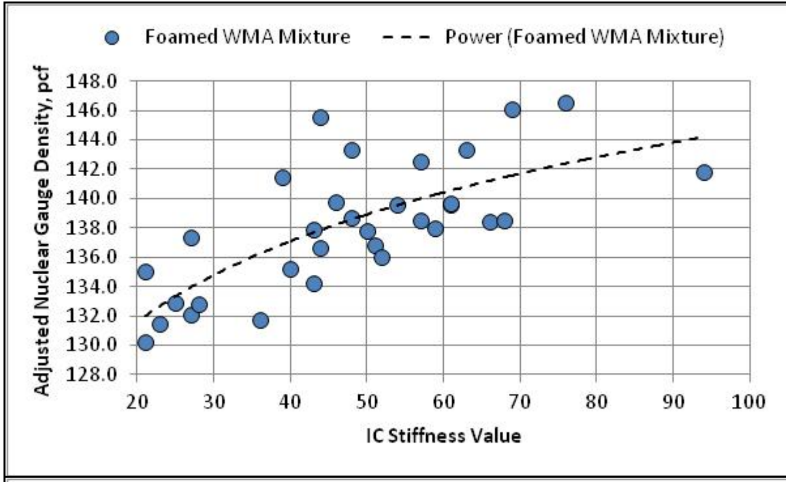


21b. Project #2705, U.S. 4A, HMA mixture, July 11, 2012.

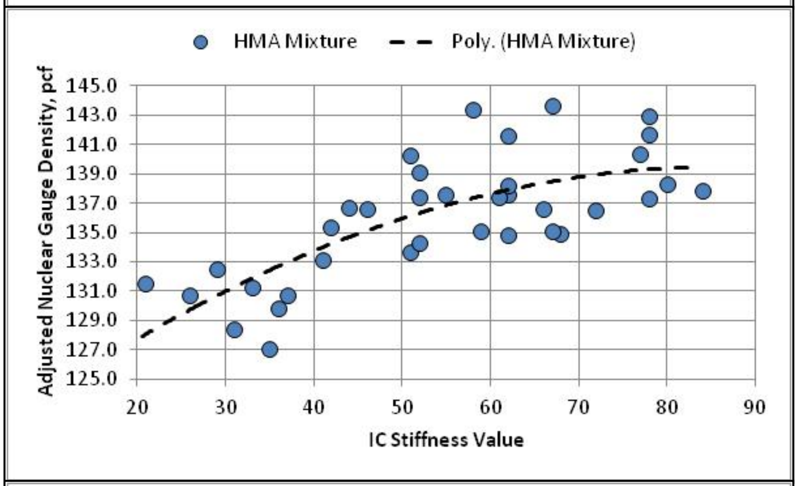


21c. Project #2909, VT 30, WMA organic wax mixture, July 17, 2012.

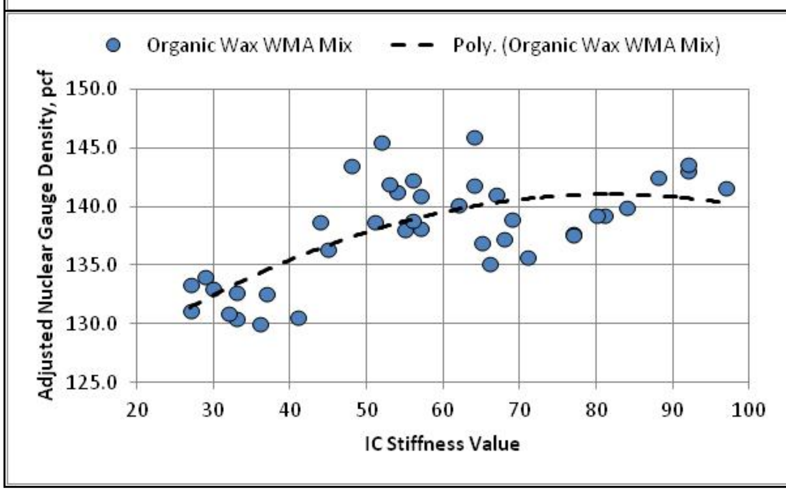
Figure 21. Density and IC stiffness growth curves for the WMA and HMA mixtures.



22a. Project #2908, U.S. 4A, foamed WMA mixture, June 21, 2012.



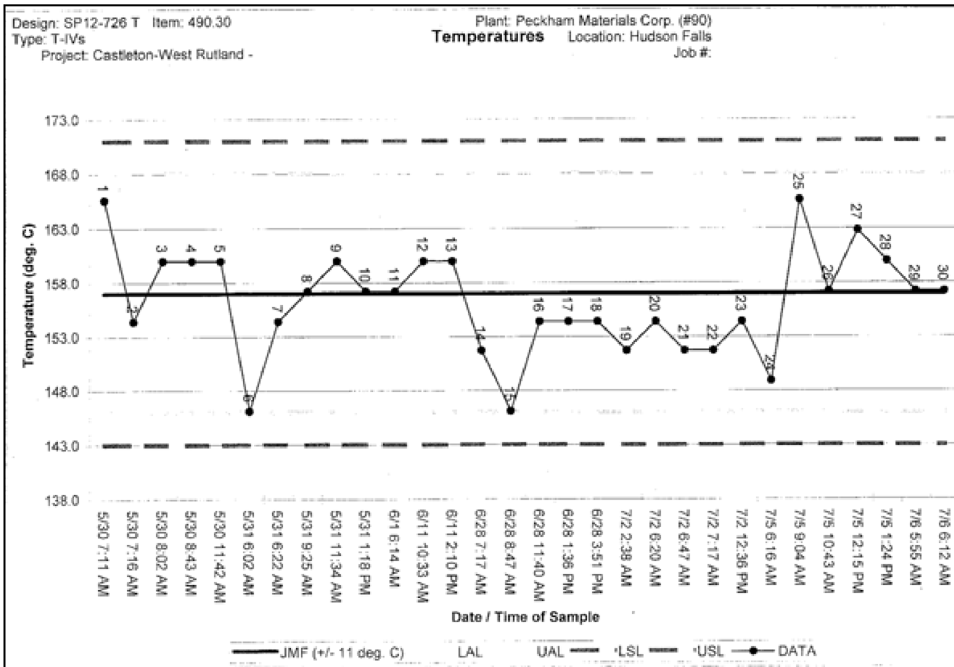
22b. Project #2705, U.S. 4A, HMA mixture, July 11, 2012.



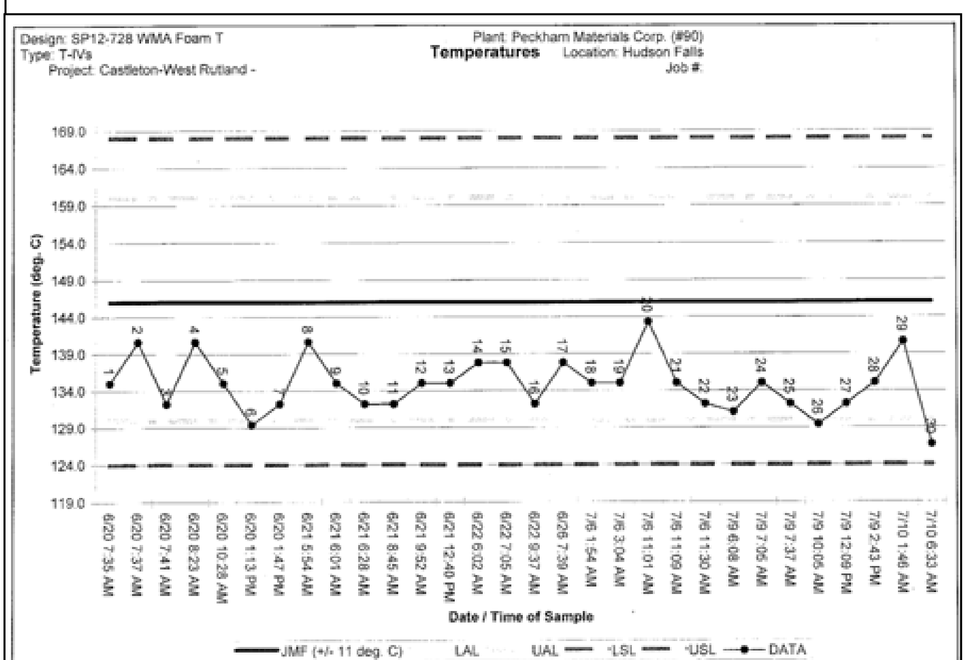
22c. Project #2909, VT 30, WMA organic wax mixture, July 17, 2012.

Figure 22. Relationship between the density measured with a nuclear density gauge and IC stiffness.

Mat temperature is probably the most important parameter for being able to properly compact WMA and HMA mixtures. Figure 23 includes an example of the production facility's control charts for WMA and HMA mixtures. The target production temperature at discharge was about 315 °F for HMA and 270 °F for WMA. The WMA temperature at discharge was later reduced to 260 °F because of a mixture pickup issue with the rubber-tired roller. The discharge temperature for the WMA mixtures generally varied between 255 to 265 °F when the test or control strips were completed.



23a. HMA mixture temperature QC chart.



23b. WMA mixture (foamed) temperature QC chart.

Figure 23. Plant QC charts for mix production temperature.

The mixture temperature behind the paver was monitored with an IR gun and generally varied from 246 to 256 °F, but temperatures as high as 280 °F were measured. Mixture pickup by the rubber-tired roller was more prevalent at the higher temperatures.

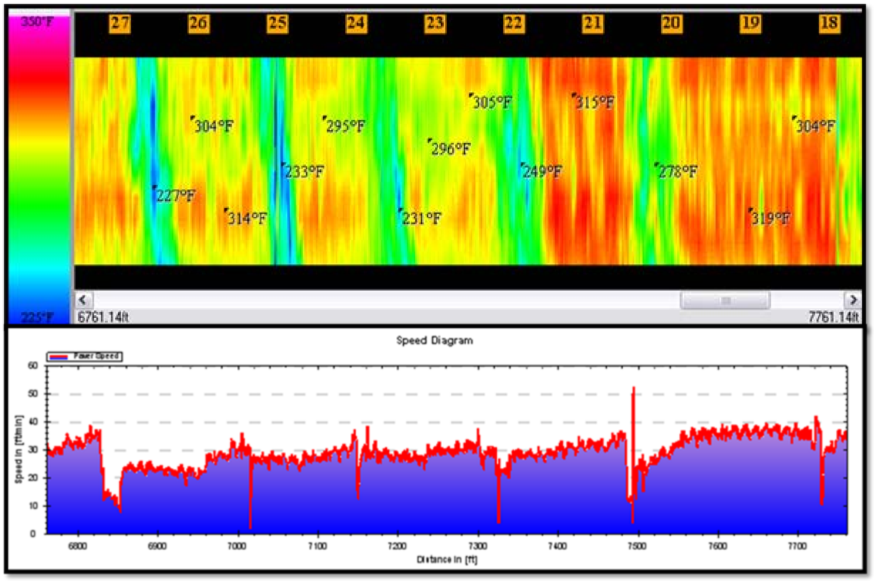
The IR bar was used to monitor mat temperatures across and along the mat. The IR bar showed a high percentage of significant temperature differentials (cold spots) at the beginning of the project or when it was first installed and used on the project. Significant temperature differentials are defined as temperature profiles with more than 50 °F differentials. Table 3 summarizes the temperatures measured by the IR bar at the beginning of the project. Figure 24a shows an example of the IR bar temperature profile during this time. The high percentage of temperature differentials was caused by an insufficient number of trucks delivering mix to the paver, which meant the paver stopped and started many times. The contractor added trucks to resolve this issue. Figure 24b shows a more consistent mat temperature profile when an adequate number of trucks supplied mix to keep the paver moving down the roadway, not stopping and starting between truck loads.

Table 3. Temperature parameters summarized from the IR bar data.

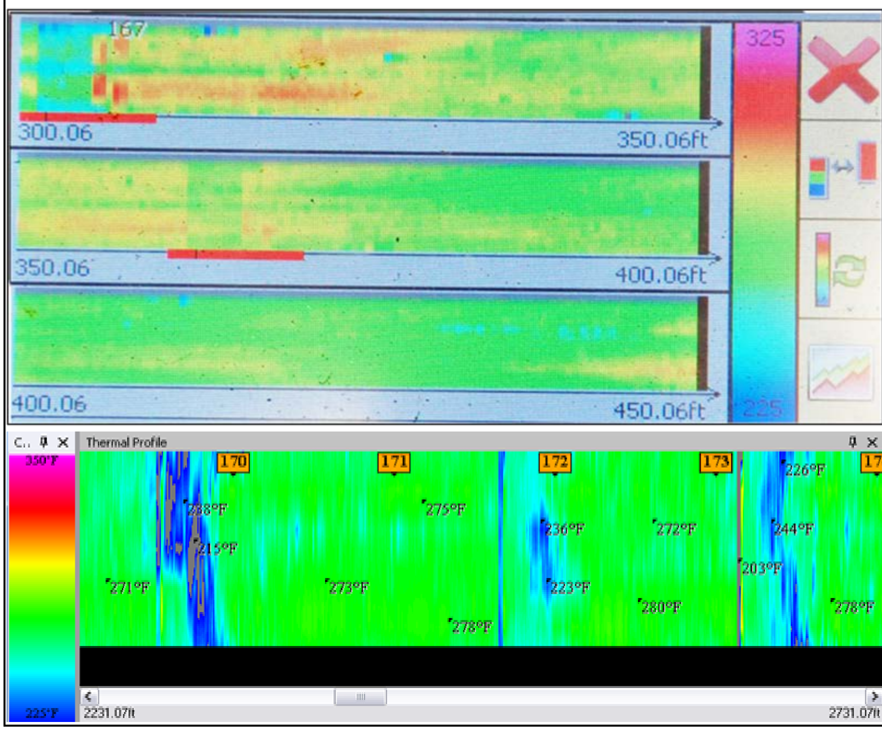
Parameter	**WMA**	**HMA**
Mean placement temperature (°F)	266	291
Standard deviation placement temperature (°F)	12.8	17.6
Typical thermal pattern	Truck-end	Truck-end
Average temperature differential	49	64
Standard deviation temperature differential	14	14
% profiles with temperature differential > 50 °F	47	86

Figure 25 is a histogram of the mat temperatures measured by the IR bar behind the paver. As shown, it is skewed toward lower temperatures because of the cold spots from having an inadequate number of trucks at the beginning of the project. (The IR bar was not used throughout the project; it was used at the beginning, during the open house, and periodically during the test or control strips.)

Mat densities were measured with a nuclear density gauge along and across the mat in each roadway segment after rolling was complete. Figure 26 is a graphical illustration of the longitudinal density profiles, and Figure 27 shows the transverse density profiles. Table 4 summarizes the mat densities. For the most part, the data and profiles exhibit low variability or change in density along and across the mat, with the exception of the readings taken next to the mat's edge, which is expected.



24a. Temperature profile near the beginning of construction, when many cold spots were observed in profiles and an inadequate number of trucks was available.



24b. Temperature profile with an adequate number of trucks and fewer cold spots observed in data.

Figure 24. Temperature profiles and images from the IR bar.

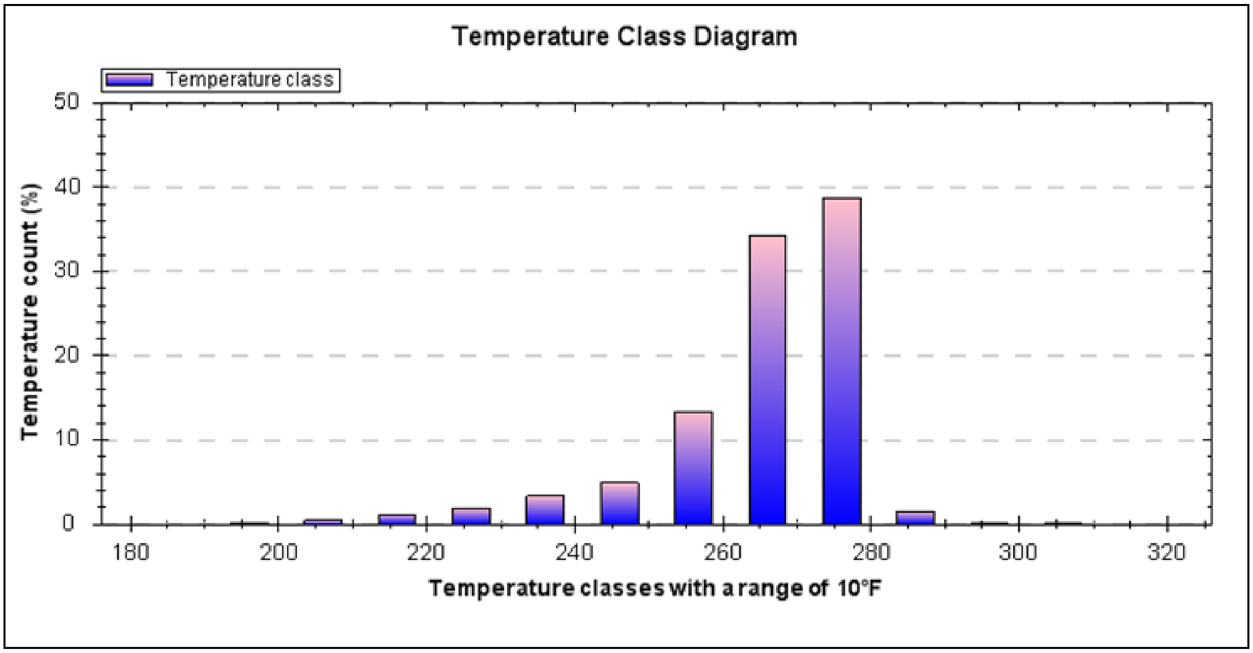


Figure 25. Histogram of mat temperatures (WMA foamed mixture) measured by the IR bar.

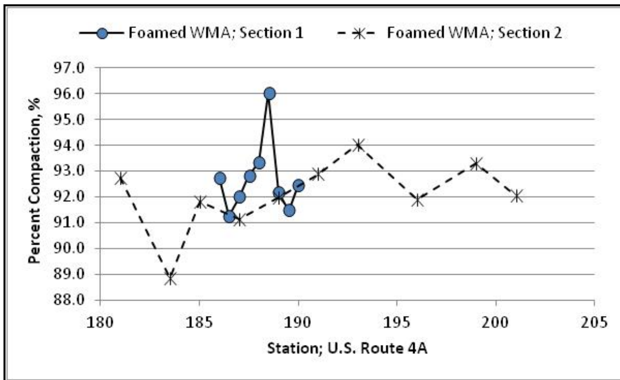
Densities were also measured along and next to the longitudinal construction joint. Figure 28 includes a graphical illustration of the density profiles on the confined and unconfined edges of the longitudinal joint, while Figure 29 includes a comparison of the joint densities measured on the confined and unconfined sides of the joint. Table 5 summarizes the longitudinal joint densities. Some of the joint densities are low (less than 90 percent compaction).

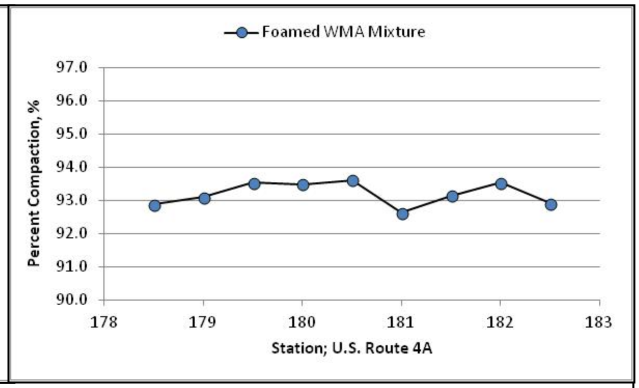
Smoothness

Smoothness testing required by the HfL goal follows the American Society of Testing and Materials (ASTM) E 950 method and was done in conjunction with noise testing using a high-speed inertial profiler built into the noise test vehicle. Figure 30 shows the test vehicle with the profiler positioned in line with the right rear wheel. Smoothness testing was done before and after rehabilitation on U.S. 4A and VT 30.

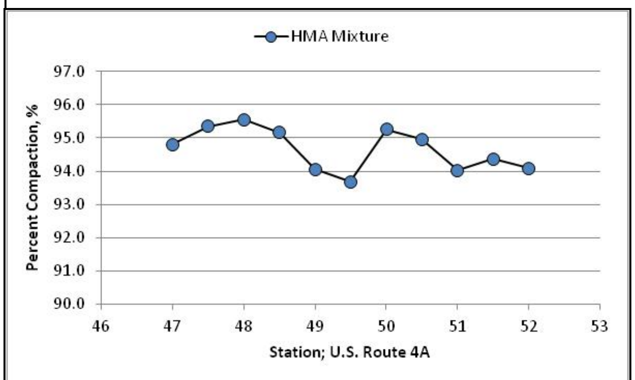
Figure 31 graphically shows the test results taken on a 1-mi section of the original distressed HMA pavement within the project limits on U.S. 4A and VT 30. As shown, the existing asphalt concrete surface was extremely rough in some areas of both routes, approaching and exceeding an IRI value of 200 in/mi. Figure 22 shows the test results on a 1-mi section after overlay placement. As shown, the IRI values are relatively consistent along both routes of the project and represent a significant increase in smoothness.

The smoothness testing shows a 70 and 60 percent drop in the average post construction IRI value for U.S 4A and VT 30, respectively. The average preconstruction IRI for was 211 in/mi for U.S. 4A and 167 in/mi for VT 30, while the average post construction IRI was 66 in/mi for U.S. 4A and 67 in/mi for VT 30. This reduction in IRI is considered a substantial improvement in smoothness over the original pavement surface.

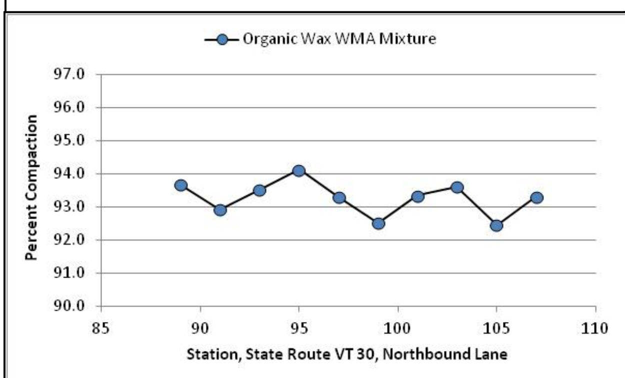


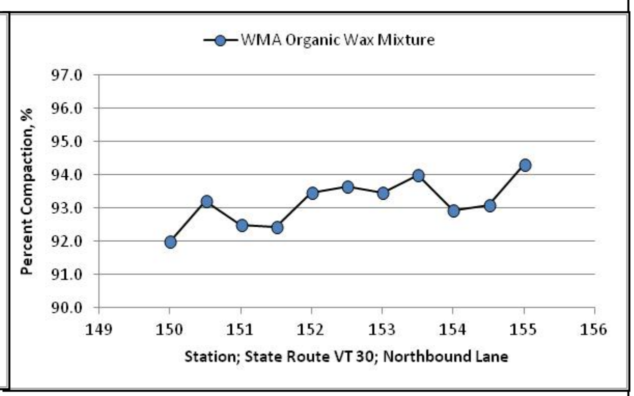


26a. Project #2908, U.S. 4A, foamed WMA mixture, June 21, 2012.



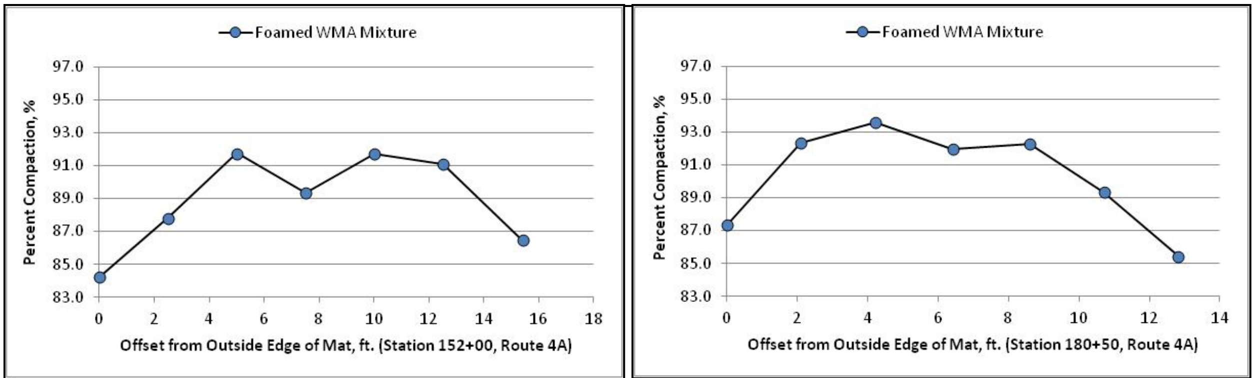
26b. Project #2705, U.S. 4A, HMA mixture, July 11, 2012.



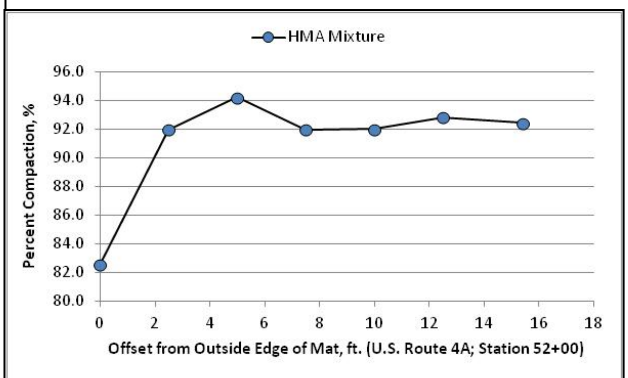


26c. Project #2909, VT 30, WMA organic wax mixture, July 17, 2012.

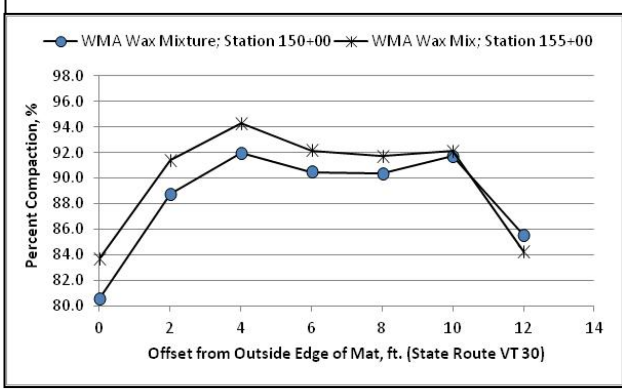
Figure 26. Longitudinal density profiles of the mat.



27a. Project #2908, U.S. 4A, foamed WMA mixture, June 21, 2012.



27b. Project #2705, U.S. 4A, HMA mixture, July 11, 2012.

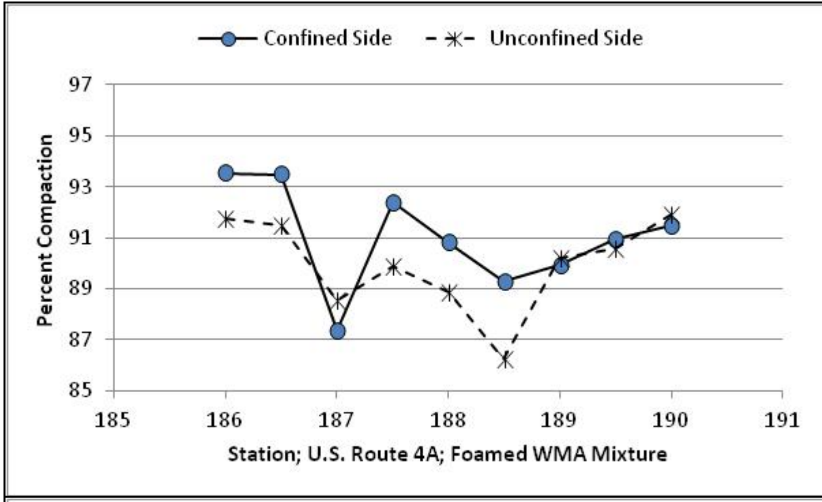


27c. Project #2909, VT 30, WMA organic wax mixture, July 17, 2012.

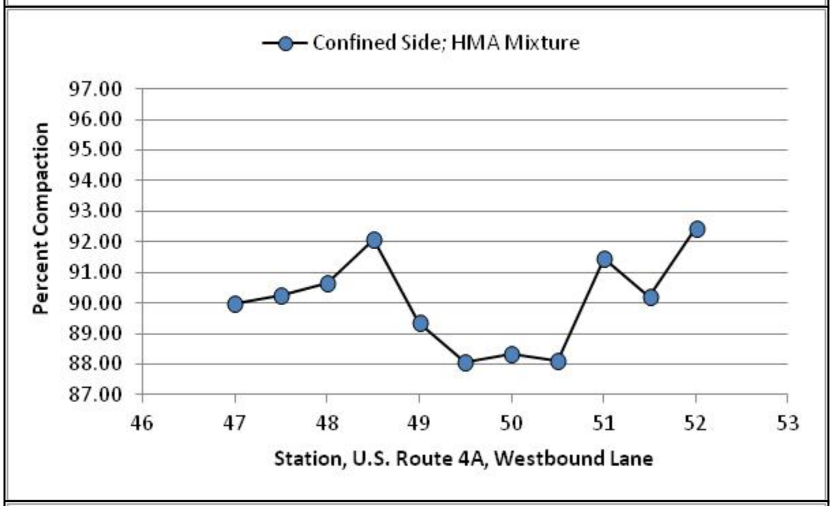
Figure 27. Transverse density profiles of the mat.

Table 4. Mat densities.

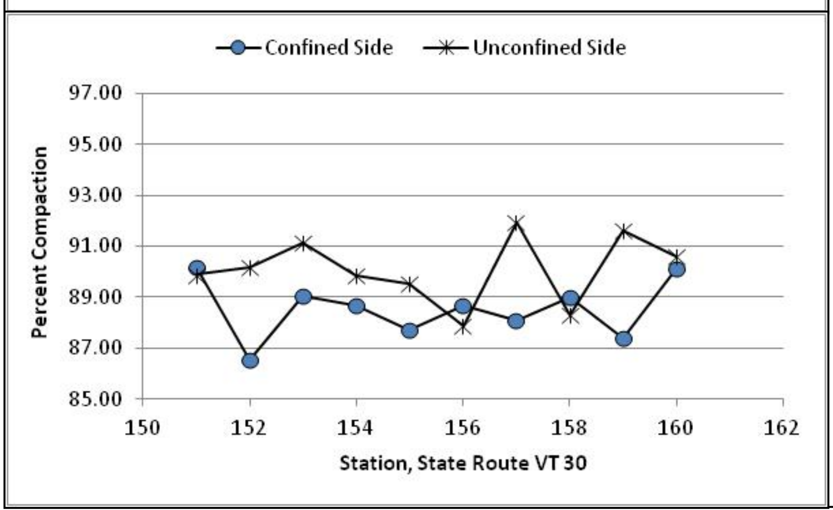
Project	Roadway	Mixture	Average Mat Density, pcf	Average Percent Compaction	Coefficient of Variation, %
2908	4A	WMA Foamed	146.3	93.2	0.38
2908	4A	WMA Foamed	145.6	92.7	1.52
2908	4A	WMA Foamed	144.7	92.1	1.53
2705	4A	HMA	148.7	94.7	0.68
2909	VT 30	WMA Wax	146.4	93.2	0.75
2909	VT 30	WMA Wax	146.5	93.3	0.56



28a. Project #2908, U.S. 4A, foamed WMA mixture, June 21, 2012, density profile along longitudinal joint.

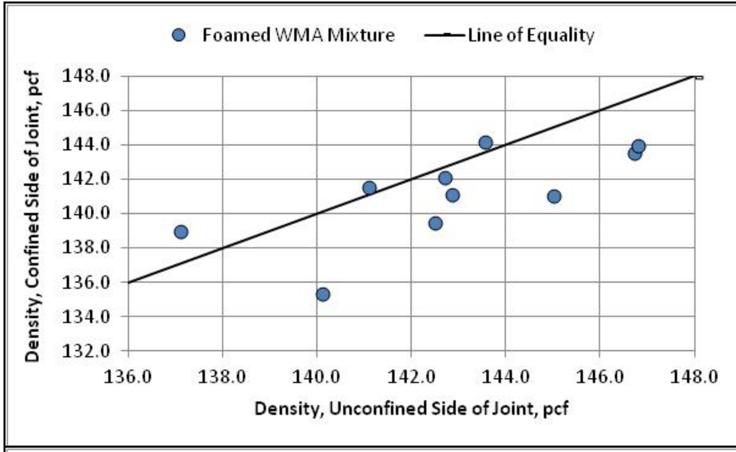


28b. Project #2705, U.S. 4A, HMA mixture, July 11, 2012.

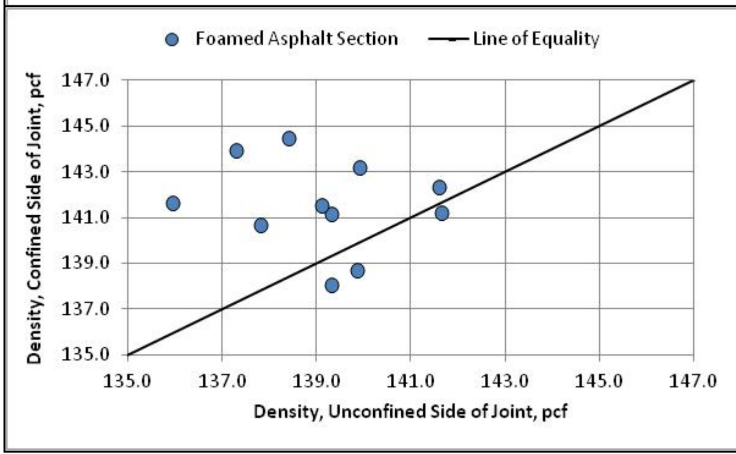


28c. Project #2909, VT 30, WMA organic wax mixture, July 17, 2012.

Figure 28. Density profiles along the longitudinal construction joint.



29a. Project #2908, U.S. 4A, foamed WMA mixture, June 21, 2012.



29b. Project #2909, VT 30, WMA organic wax mixture, July 17, 2012.

Figure 29. Comparison of the joint densities measured on the confined and unconfined sides of the longitudinal joint.

Table 5. Longitudinal joint densities.

Project	Roadway	Mixtures	Joint Density, pcf		Joint Percent Compaction	
			Confined	Unconfined	Confined	Unconfined
2908	4A	WMA Foamed	142.8	141.1	91.0	89.9
2705	4A	HMA	141.4		90.1	
2909	VT 30	WMA Wax	139.1	141.5	88.6	90.1

The contractor did not have any unexpected issues achieving the VTrans smoothness specification, but the new wearing surface does not meet the HfL target value of 48 in/mi. Although the HfL goal was not met, the smoothness of the overlay or new wearing course is considered reasonable, especially considering some of the onsite conditions on this project. At least three factors contributed to the project not meeting the HfL target value:

1. There are many intersecting roadways and driveways, especially through the local communities, in the project limits of each roadway segment. During paving, traffic control personnel permitted some vehicles to travel across the mat after the primary roller, the HAMM IC roller, completed all of its passes in the rolling zone. This resulted in some transverse marks or tracks in areas, which increase roughness.

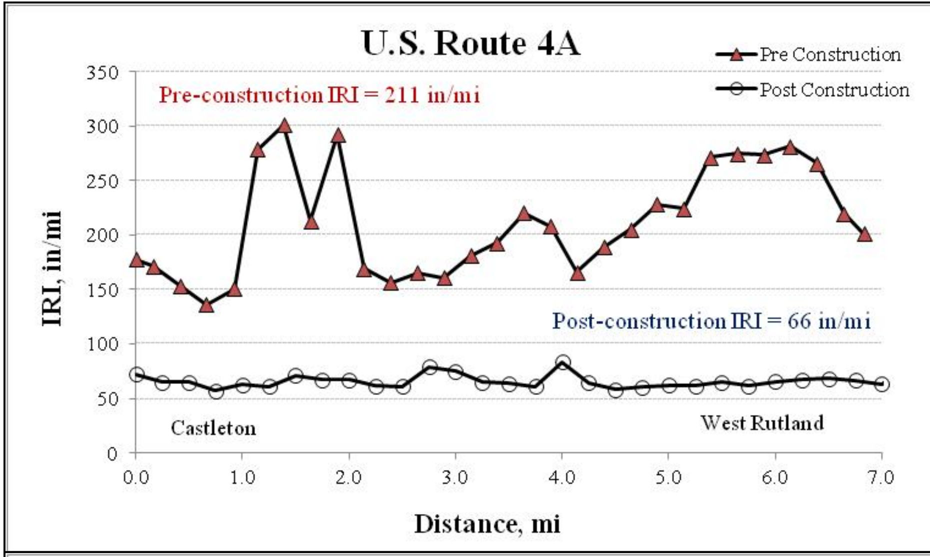
Figure 30. High-speed inertial profiler mounted behind the test vehicle.

2. Paving started along U.S. 4A and there was an insufficient supply of trucks at different times to keep the paver moving. The IR bar clearly identified this situation as significant differences in mat temperature (more than 50 °F) directly behind the paver between some truck loads. Continually stopping and starting the paver increases the roughness or IRI values of the wearing surface. The contractor added more delivery trucks, but the post overlay IRI value was slightly above the HfL target value even with a sufficient number of delivery trucks supplying mixture to the paver.

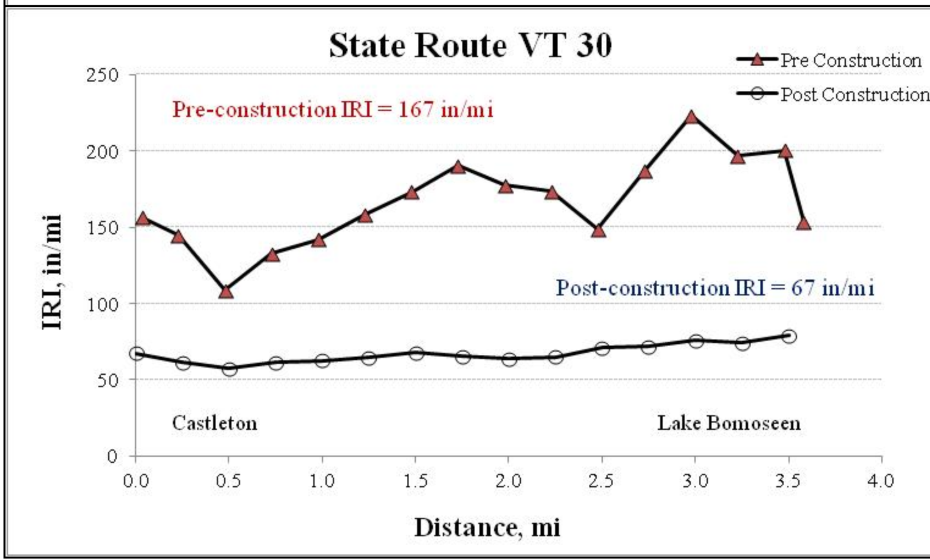
3. The WMA mixture with the foaming technology was used on U.S. 4A, and the WMA organic wax mixture was used on VT 30 (see Table 2). Shortly after paving was initiated beyond the compaction test strip for each WMA technology, it was observed that the rubber-tired roller was picking up the fines or mastic from the surface. Larger pieces of the mastic started falling off the tires in some areas (see Figure 32). The contractor's roller and QC personnel removed many of the larger pieces before the HAMM finish roller. Pickup was more predominate with the organic wax. To remedy this situation, the plant production temperatures were slightly lowered and the pneumatic roller operator delayed his rolling, which reduced the problem of mixture pickup by the rubber tires. The plant temperatures slightly increased over time and mixture pickup returned, which is believed to have caused some of the increase in IRI values toward the north end of VT 30 (see Figure 31b).

Sound Intensity Testing

VTrans has not used the OBSI test method on any past projects. This method, however, was used to collect tire-pavement SI measurements on the existing and overlaid pavement along all three roadway segments. OBSI values were measured at highway speed.



22a. IRI values measured before and after overlay along both segments of U.S. 4A (see Figures 1 and 2).



22b. IRI values measured before and after overlay along the VT 30 segment (see Figure 3).

Figure 31. IRI values measured before and after the rehabilitation project.

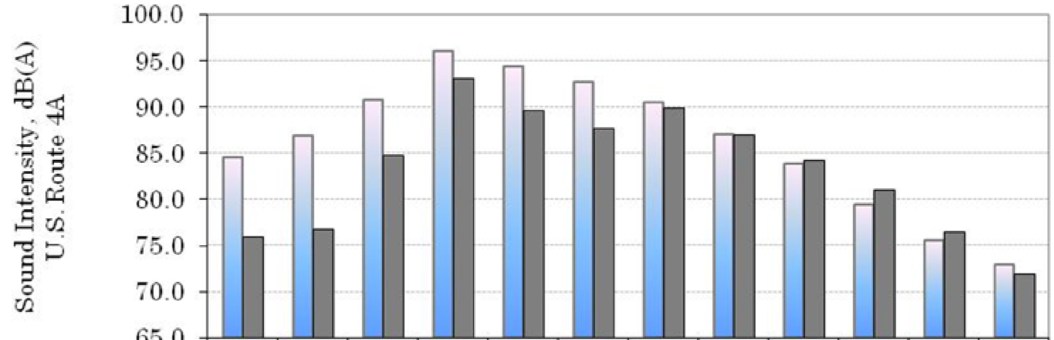
The sound measurements were recorded and analyzed using an onboard computer and data collection system. A minimum of three runs were made in the right wheel path of each roadway segment. The two microphone probes simultaneously captured noise data from the leading and trailing tire-pavement contact areas. Figure 33 shows the dual probe instrumentation and the tread pattern of the SRTT.

The average of the front and rear SI values was computed to produce SI values. Raw noise data were normalized for the ambient air temperature and barometric pressure at the time of testing. The resulting mean SI levels were A-weighted to produce the noise-frequency spectra in one-third octave bands, shown in Figure 34.

Figure 32. Rubber tires picking up the mastic from the WMA surface.

Figure 33. OBSI dual probe system and the SRTT.

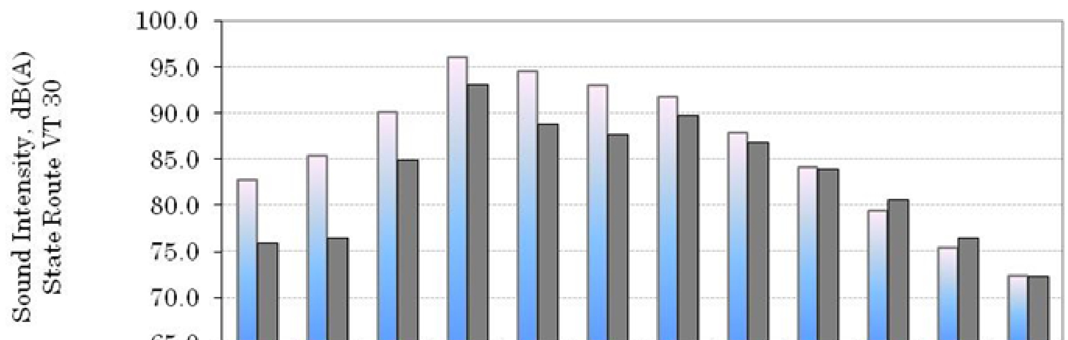
Sound levels were calculated by using logarithmic addition of the one-third octave band frequencies between 315 and 4,000 hertz (Hz). The sound level was 101.0 dB(A) for the original distressed HMA pavement along U.S. 4A and 101.1 for VT 30. The sound level for the same areas after overlay placement was 97.7 dB(A) for U.S. 4A and 97.5 for VT 30. Although the HfL goal of 96.0 dB(A) was not met, the sound level of the new pavement is considered reasonable.



	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Preconstruction	84.6	86.9	90.8	96.1	94.4	92.8	90.5	87.0	83.8	79.4	75.6	72.9
Postconstruction	75.9	76.7	84.8	93.1	89.7	87.7	89.9	87.0	84.2	81.0	76.5	71.9

Frequency, Hz

34a. SI values measured before and after overlay along both segments of U.S. 4A (see Figures Figure 1 and Figure 2).



	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Preconstruction	82.8	85.4	90.1	96.0	94.5	93.0	91.7	87.8	84.1	79.4	75.4	72.4
Postconstruction	75.9	76.5	84.9	93.1	88.8	87.7	89.8	86.9	83.9	80.7	76.5	72.3

Frequency, Hz

34b. SI values measured before and after overlay along VT 30 segment (see Figure 3).

Figure 34. SI values measured before and after the rehabilitation project.

CONSTRUCTION CONGESTION

In general, it took about 10 to 20 minutes less for the WMA mixture to cool to a surface temperature of 140 °F so the lane could be opened to traffic compared to HMA. This represents about 30 percent less time for the mat temperature to fall below 140 °F between the WMA and HMA mixtures. The temperature of 140 °F was included in the project specifications. In the mornings, when the ambient air temperature was lower, the lane could be opened to traffic in about 20 minutes. At midday, however, the time to lane opening was longer in excess of 60 minutes in some cases. However, it did not result in significant savings of user delay times.

The air temperature was over 90 °F when paving through Castleton. The time needed for the mixture temperature to drop below 140 °F was more than an hour. The software program "CalCool" was used onsite to estimate this time; 69 minutes was determined for the WMA mixtures and onsite conditions. After waiting more than 50 minutes with a queue building on U.S. 4A, the contractor and agency personnel decided to artificially cool the mixture with water so the lane could be reopened to traffic and reduce the length of the construction zone (see Figure 35). The temperature of the existing surface was nearly 135 °F on a couple of afternoons.

Figure 35. Recently placed WMA being artificially cooled with water to open the lane to traffic faster**.**

The delay time and average speed through the construction zone was monitored during paving with the WMA mixture. Table 6 includes the average times and speeds along VT 30. The average speed was low through the paving-compaction zone. A low speed was expected from a safety standpoint for paving personnel working along the side of the paver for segments of the roadway without shoulders or with guardrails. The average speed through the entire project limits or roadway segment (see Figures Figure 1 through Figure 3) was slightly double the speed through the paving-compaction zone or 30 to 35 mi/h (traffic restricted to using one lane for both directions and use of a pilot vehicle).

Table 6. Average speed through the paving-compaction zone and number of vehicles in the queue.

Condition	Start Time	End Time	Elapsed Time, minutes	Average Speed, mi/h	Number of Vehicles in Queue
U.S. 4A, July 9, 2012					
During Paving Operations	4:48:00	4:59:00	11.00	14.2	15
	5:08	5:18:45	10.75	14.5	12
	5:20:15	5:31:05	10.83	14.4	9
	5:34:25	5:43:10	8.75	17.8	11
Coring Operations	8:38:25	8:43:00	7.58	20.6	0
VT 30, July 18, 2012					
During Paving Operations	9:43:45	9:48:58	5.21	20.7	7
	9:49	9:59:50	10.33	10.5	11
	10:03:15	10:11:35	8.33	13.0	12
	10:13:00	10:26:10	13.17	8.2	16

SAFETY

Three safety-related factors were monitored during the construction project: crashes in the project area during construction, worker safety during construction, and the slope of the Safety Edge for post construction traffic. Each factor is discussed below.

VTrans provided crash data for the highway before rehabilitation for the 5 years from January 1, 2006, to December 31, 2010. The crash data, as summarized in Table 7, show that one fatal crash occurred within the project limits of VT 30 during the 5-year study period. To keep injury and fatal crashes to a minimum, VTrans upgraded the roadway to enhance safety by placing a Safety Edge in appropriate sections of the project and reduced roughness. At the completion of construction, no incidents involving motorists or construction workers were reported.

As stated previously, the rehabilitation project resulted in a significant reduction in roughness (see Figure 31) for U.S. 4A and VT 30. Reduced roughness will make the roadway safer and result in less vehicle damage.

Worker safety was increased by minimizing the length of and reducing the speed through the active work zone, as noted in the above section, and using WMA. The WMA mixture and mat temperatures were about 40 to 50 °F lower than for HMA mixtures. Paving along U.S. 4A occurred during high summer temperatures for this area—in excess of 95 °F. The surface temperature of the existing pavement surface reached 135 °F on some days. The lower mixture temperatures resulted in less fatigue of the paving crew. No heat-related incidents were reported for construction personnel.

As noted previously, a Safety Edge was added in appropriate segments of the roadway to reduce crashes in the future from vehicles departing the roadway at highway speeds when trying to recover or reenter the travel lane. The average slope of the Safety Edge is shown in Table 8 and was found to vary from about 32 to 37 degrees.

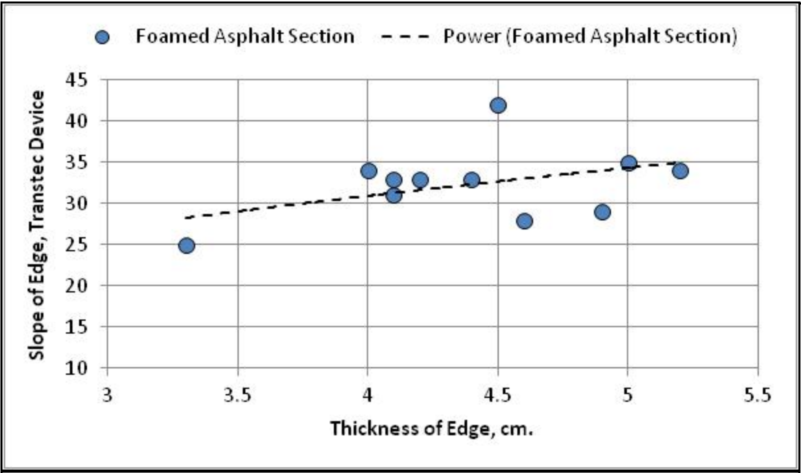
Figure 36 shows a comparison of the Safety Edge's slope and the thickness of the mat's edge. These results and slope variations are typical of other demonstration projects built with the Safety Edge.

Table 7. Summary of crash data along U.S. 4A and VT 30.

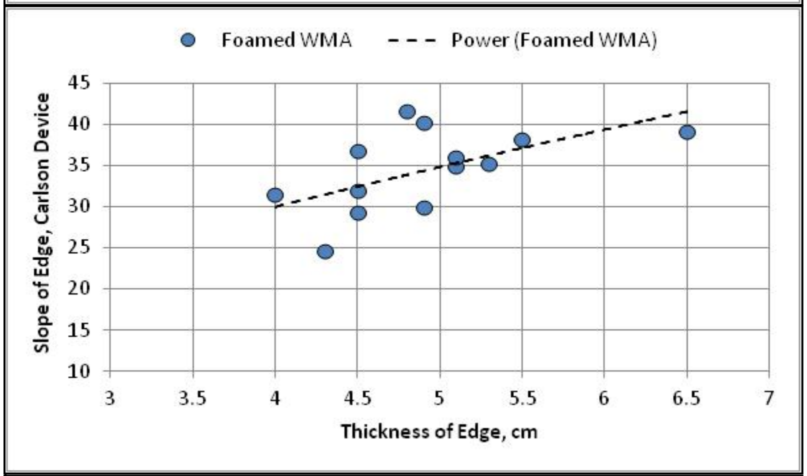
Project Segment		U.S. Route 4A	State Route VT 30
Crash Rate, per million vehicles (MV)		19.1	60.3
Reported Crashes	Total	143	132
	With Injuries	38	48
	With Fatalities	0	1
Number of Injuries from Crashes		58	58
Nature of Crash	Single Vehicle	34	57
	Rear to Rear or Rear End	32	23
	Head On	2	9
	Other	75	43
Weather Related (Snow, Ice, Rain)	Total	21	30
	Rate, per MV	2.81	13.7
Crashes Involving Nonmotorists	Total	5	5
	Rate, per MV	0.67	2.28
Roadway Departures		0	0

Table 8. Safety Edge slope measurements after compaction.

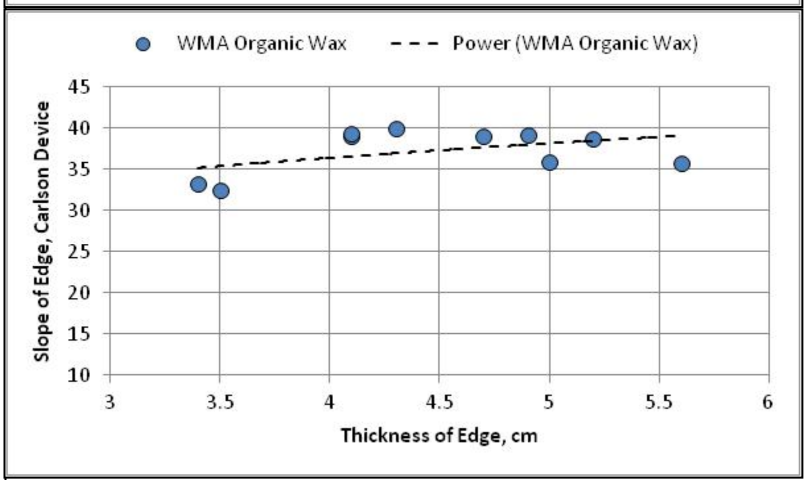
Safety Edge Device	Type of Mixture	Route	Slope of Safety Edge		
			Mean	Standard Deviation	Coefficient of Variation, %
Transtec	Foamed WMA	4A, Section 1	32.5	4.39	13.5
Transtec	Foamed WMA	4A, Section 2	35.7	5.51	15.4
Carlson	Foamed WMA	4A, Section 3	34.6	4.88	14.1
Carlson	WMA Organic Wax	VT 30	37.3	2.74	7.3



36c. Safety Edge placed with the Transtec device along U.S. 4A, foamed WMA, July 10, 2012.



36b. Safety Edge placed with the Carlson device on U.S. 4A, foamed WMA, July 12, 2012.



36c. Safety Edge placed with the Carlson device on VT 30, WMA organic wax, July 17, 2012.

Figure 36. Comparison of the thickness of the mat’s edge and slope of the Safety Edge.

USER SATISFACTION

The HfL requirement for user satisfaction is a performance goal of 4-plus on a Likert scale of 1 to 7 for the following two questions:

- How satisfied are you with the results of the overlaid asphalt concrete pavement compared to the condition of the existing pavement?
- How satisfied are you with the approach VTrans used to overlay the existing pavement to minimize disruption?

VTrans conducted a stakeholder survey in which it distributed survey forms to residents and businesses within a mile of the project during and after construction. Survey forms were also distributed to the public traveling through the paving project. The survey form is in Appendix A. It consisted of four questions and used a 3 or 5-point scale instead of the 7-point scale suggested by HfL. The survey results and comments are also in Appendix A.

- Satisfaction response—Eighty-six percent of the responses were somewhat to very satisfied with the project. A 4-plus (57 percent) favorable response or better on a 7-point scale is equivalent to a 2.9-plus response on a 5-point scale. The mean response value for this question was above 4, which indicates that the level of satisfaction for this project exceeded the HfL goal.
- Delay response—A 3-point scale was used for the delay response through the paving project. More than 35 percent of the responses noted shorter delays, while more than 85 percent noted equal or shorter delays through the paving zone compared to other projects.
- A question was asked about the odor of the WMA mixtures, and 65 percent of the responses identified the mixture as having somewhat low to very low odor in the paving zone. The mean response was also above 3.0 on the 5-point scale, which exceeds the HfL goal. Odor, however, was ranked very low in order of importance to the public, as noted below.
- The final question on the survey form was to rank, in order of importance, certain project parameters. The following lists what the public considered the most to least important of eight parameters.

    1. Safety through the construction site
    2. Quality of ride after construction
    3. Time it takes to pass through the construction zone
    4. Using environmentally friendly techniques
    5. Duration of the project
    6. Project costs
    7. Odor of construction site
    8. Noise

In summary, results from the survey suggest a high percentage of the local residents and traveling public were satisfied with the project.

TECHNOLOGY TRANSFER

FHWA, in conjunction with VTrans, Peckham Road Corp., the Wirtgen Group, and HAMM, sponsored a 1-day open house to showcase the project and three innovations used for pavement rehabilitation. The open house was held July 11, 2012, in Castleton, VT. The event featured workshop presentations by VTrans, FHWA, Wirtgen Group, and Peckham Construction personnel. The workshop agenda is in Appendix B, along with information on the speakers. Nearly 80 transportation professionals from VTrans, FHWA, local agencies, HMA producers, and pavement designers attended the showcase.

WORKSHOP

The workshop, held at Castleton State College (see Figure 37), started with VTrans and FHWA representatives providing an overview of the HfL program and innovations included in the project. Tim Pockette, VTrans project resident engineer, provided an overview of the rehabilitation project. His presentation was followed by detailed descriptions of the innovations included in the project:

- Thomas Harman of FHWA discussed WMA from FHWA's perspective.
- Stephen Sebasta of the Texas Transportation Institute discussed the use of and showed results from the IR bar.
- Richard Evans and Tim Kowalski of the Wirtgen Group discussed IC.
- Mark Woolaver of VTrans discussed longitudinal construction joints and the project specification.
- Andy Mergenmeier of FHWA discussed the Safety Edge.
- Pockette and Bernard Granger and Chris Thomas of Peckham Construction summarized lessons learned from the project from the agency's and contractor's perspectives, *relative to the three innovations included on the project.*

During the presentation on the IR bar, it was reported that the paver was stopped on two occasions for an extended time period—exceeding an hour. The delays were caused by plant problems. The contractor moved the paver off the roadway and created a transverse construction joint when it was realized paving could not continue within a reasonable time period. Creating a transverse construction joint under these conditions is considered good practice. The reason for the long stop time recorded by the IR bar system was that the device was not turned off when the paver was moved off the roadway. There were other delays or longer stop times during a couple of days of paving. The reason for the longer stop times was an insufficient number of delivery trucks on those days, which the contractor resolved by getting more trucks to supply mixture to the paver.

The workshop concluded with a panel question-and-answer session, followed by a visit to the project site (see Figure 38).

Figure 37. Workshop in Herrick Auditorium at Castleton State College.

FIELD VISIT AND DEMONSTRATION

At the project site, participants examined the project innovations used to place and compact the WMA foamed mixture. Specific features of the project demonstrated during the site visit included the following:

Original Innovation as presented in the HFL application:

1. The HAMM IC roller (see Figure 39). This technology was of the most interest to many of the participants, who were able to ride with the roller operator to view the display screen while the roller was in operation.
2. WMA foamed mixture being delivered to and placed by the paver. Most of the questions about the WMA mixtures were addressed during the workshop question-and-answer period.
3. The paver with the Carlson Safety Edge device attached to the end plate of the screed (see Figure 40). Participants viewed geometry of the Safety Edge and adjustments that can be made to the Safety Edge during the paving operation.

Added Innovation not in the HFL application:

4. The IR bar attached to the back of the screed and used to monitor temperatures across the entire mat and along the roadway (see Figure 41). Participants viewed the display screen as the paver moved down the roadway.
5. Longitudinal construction joint. Participants were also interested in the details and equipment used to place and compact the longitudinal construction joint (see Figure 42).

Figure 38. Field visit to showcase the paving and compaction operations along U.S. 4A.

Figure 39. Participants on the IC roller to view real-time data on display screen.

Figure 40. Closeup of Carlson Safety Edge device attached to the end plate of the screed.

Figure 41. Participants viewing the mat surface temperatures displayed on the screen of the IR bar attached to the platform behind the screed.

Figure 42. Participants and construction team members inspecting the longitudinal construction joint.

ECONOMIC ANALYSIS

A key aspect of HfL demonstration projects is quantifying, as much as possible, the value of the innovations deployed. This entails comparing the benefits and costs associated with the innovative project delivery approach adopted on an HfL project with those from a more traditional delivery approach on a project of similar size and scope. The latter type of project is referred to as a baseline case and is an important component of the economic analysis.

For this economic analysis, VTrans supplied the cost figures for the project. The assumptions for the baseline case were also determined from discussions with VTrans, the contractor, and national literature. The baseline condition represents a similar rehabilitation project, but without the Safety Edge, IC roller, IR bar components, joint compaction, and use of WMA mixture on a portion of this demonstration project.

CONSTRUCTION TIME

The actual construction time needed to mill, pave, and strip the roadway for the baseline scenario is considered to be the same for the innovative approach scenario. The only difference between the innovative approach and baseline scenarios is the amount of time required to reopen the new mat to traffic, which affects the delay or traffic congestion. The impact of the additional time is considered minimal to nil on the overall construction time. Thus, the construction time between the innovative approach and baseline scenarios was considered the same.

CONSTRUCTION COSTS

The construction activities for the baseline and innovative approach scenarios for this type of rehabilitation project are the same. Milling, placement of the scratch or level-up layer and overlay, application of the tack coats on the milled and level-up surfaces, stripping, ditch improvements, shoulder work, and other incidental activities are the same for the two scenarios. Furthermore, there is little evidence to suggest that the use of an IC roller and/or the use of WMA, with the possible exception of improved longitudinal construction joint density, will result in increased service life of pavements. The Safety Edge was included in the innovative approach, but had no effect on the construction time or costs. The only difference in construction costs relates to the different mixtures used on the project. The in-place cost for the WMA mixture was about a $1.00 per ton of mix less than for the HMA mixture. Thus, the savings in construction costs from using WMA mixtures, which could be produced more economically, total $7,800 or 0.15 percent of the total project costs.

USER COSTS

Generally, three categories of user costs are considered in an economic or life cycle cost analysis: vehicle operating costs (VOC), delay costs, and crash and safety-related costs.

VOC and delay costs are assumed to be identical for the baseline and innovative scenarios because the route length is the same through the project. As explained earlier, the time to reopen a segment with new WMA was about 30 percent less than when using HMA. However, the impact of the early lane opening on traffic delay or congestion was considered insignificant for the traffic levels on U.S. 4A and VT 30.

The difference in crash and safety-related costs between the two scenarios is obviously related to the expected difference in crashes and injuries from those crashes. Table 7 summarized the crash data provided by VTrans for a 5-year period for these roadways. The number of future crashes and injuries on this facility is yet to be obtained, but with the added Safety Edge and lower levels of distress or roughness because of the more uniform densities, it is expected that crashes and injuries will be lower than the baseline scenario.

INITIAL COST SUMMARY

From an initial construction cost standpoint, the innovative approach scenario was $7,800 less than for the baseline scenario for equal amounts of mixture placed on the project. All other cost differentials were assumed to be zero. It is expected that the WMA overlay will have a longer service life and lower maintenance costs and be smoother for a longer time because of the more uniform densities and higher density level compared to the HMA overlay and the use of the Safety Edge (with less determination along the pavement's edge). In addition, fewer crashes with serious injuries are expected because of the Safety Edge included in the innovative approach scenario.

APPENDIX A: USER SATISFACTION SURVEY

This appendix includes a summary of the results from the user satisfaction survey distributed to local residents during and shortly after the project was completed.

To our highway users,

We are conducting this survey in order to find a suitable and efficient way to surface roads with new cutting edge materials. The Highways for Life program (HFL) sponsored by the Federal Highway Administration (FHWA) will evaluate the success of our new paving methods.

If experimental data and user input prove the project successful, these surfacing techniques will become more prevalent in the future. With your feedback we can make a decision that positively affects road users without compromising the environment.

Please take a few minutes to complete this survey on the recent construction along US 4A and VT 30 in Rutland County Vermont.

Your responses will be valuable when planning future construction projects.

According to the Federal Highway Administration (FHWA), the purpose of Highways for LIFE (HfL) is to advance Longer–lasting highway infrastructure using Innovations to accomplish the Fast construction of Efficient and safe highways and bridges.

The three goals of HfL are to:

- **Improve safety during and after construction**
- **Reduce congestion caused by construction**
- **Improve the quality of the highway infrastructure**

VTrans Working to Get You There
Vermont Agency of Transportation

VERMONT
AGENCY OF TRANSPORTATION

US 4A and VT 30 in Rutland County Vermont, prior to construction.

Please mark the choice that is best represented by the question.

1.) How satisfied are you with the road quality of completed zones along US 4A and VT 30?

☐ Very satisfied ☐ Somewhat satisfied ☐ Neither satisfied or dissatisfied
☐ Somewhat dissatisfied ☐ Very dissatisfied

2.) How did traffic delays compare to past construction?

☐ Delays were longer ☐ Delays were about the same ☐ Delays were shorter

3.) How would you compare the odor of these paving sites compared to others?

☐ Odor was very low ☐ Odor was somewhat lower ☐ No difference odor
☐ Odor was somewhat higher ☐ Odor was very high

4.) Please rank the importance of the following aspects associated with construction sites (1- being most important and 8- being least important)

___ Time it takes to pass through construction ___ Duration of project

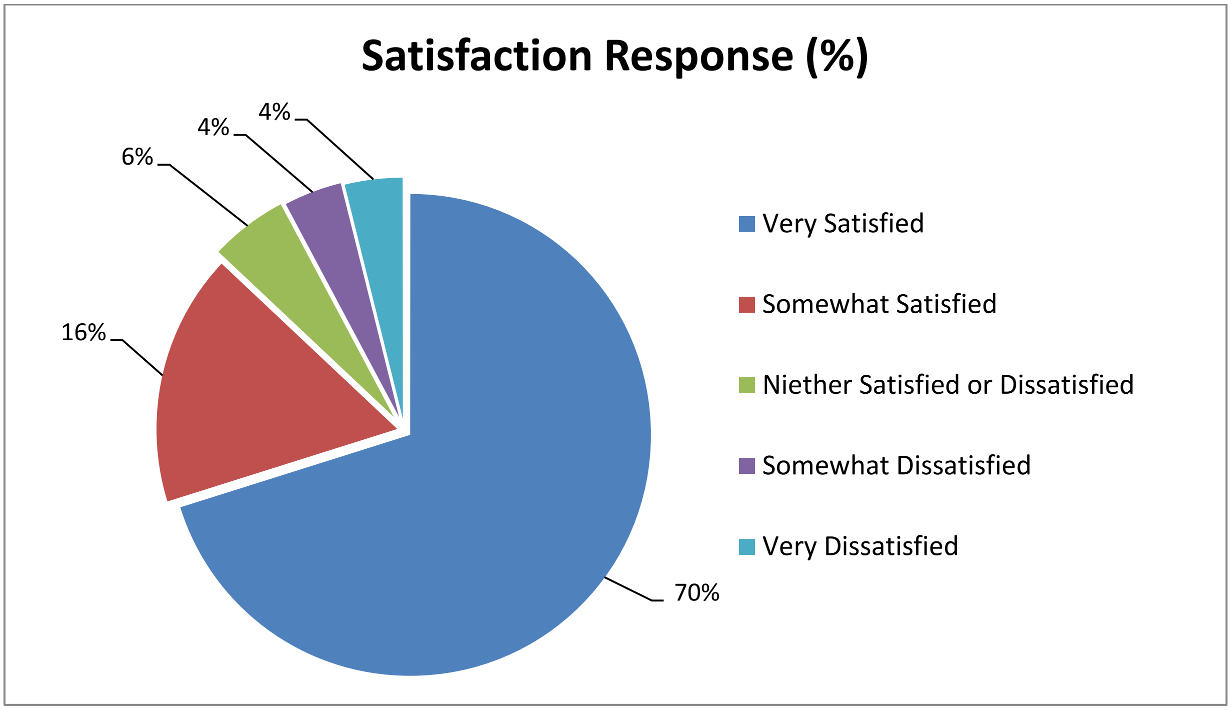
___ Using environmentally friendly techniques ___ Project cost

___ Safety through the construction site ___ Noise

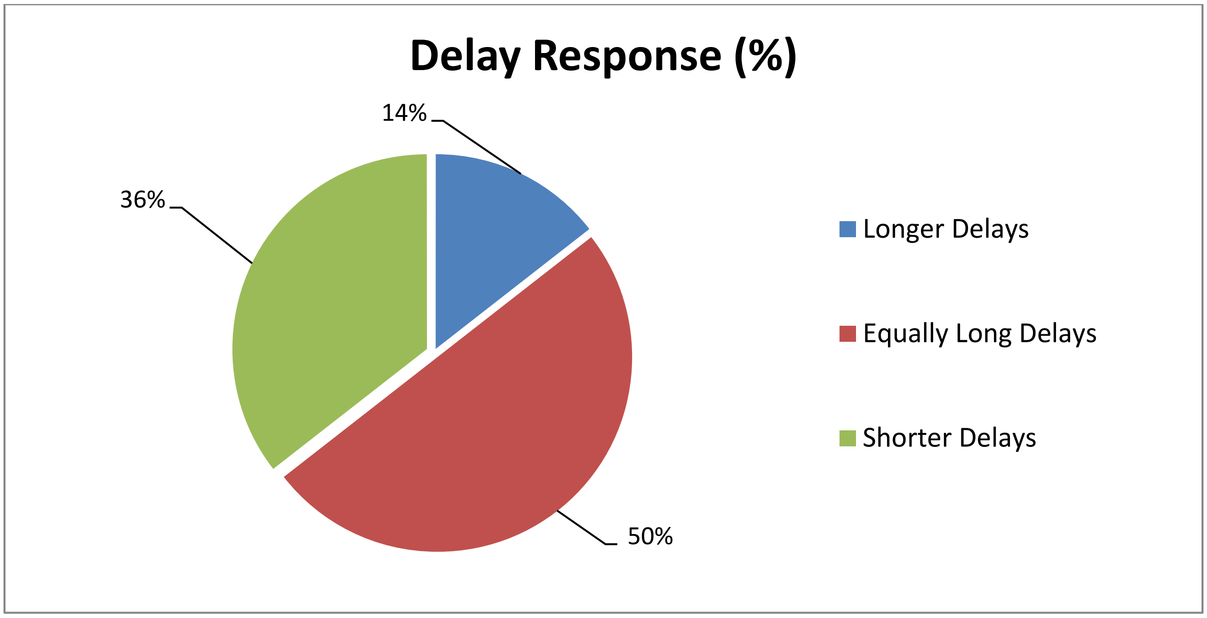
___ Quality of ride after construction ___ Odor of construction site

5.) Please add any additional comments below

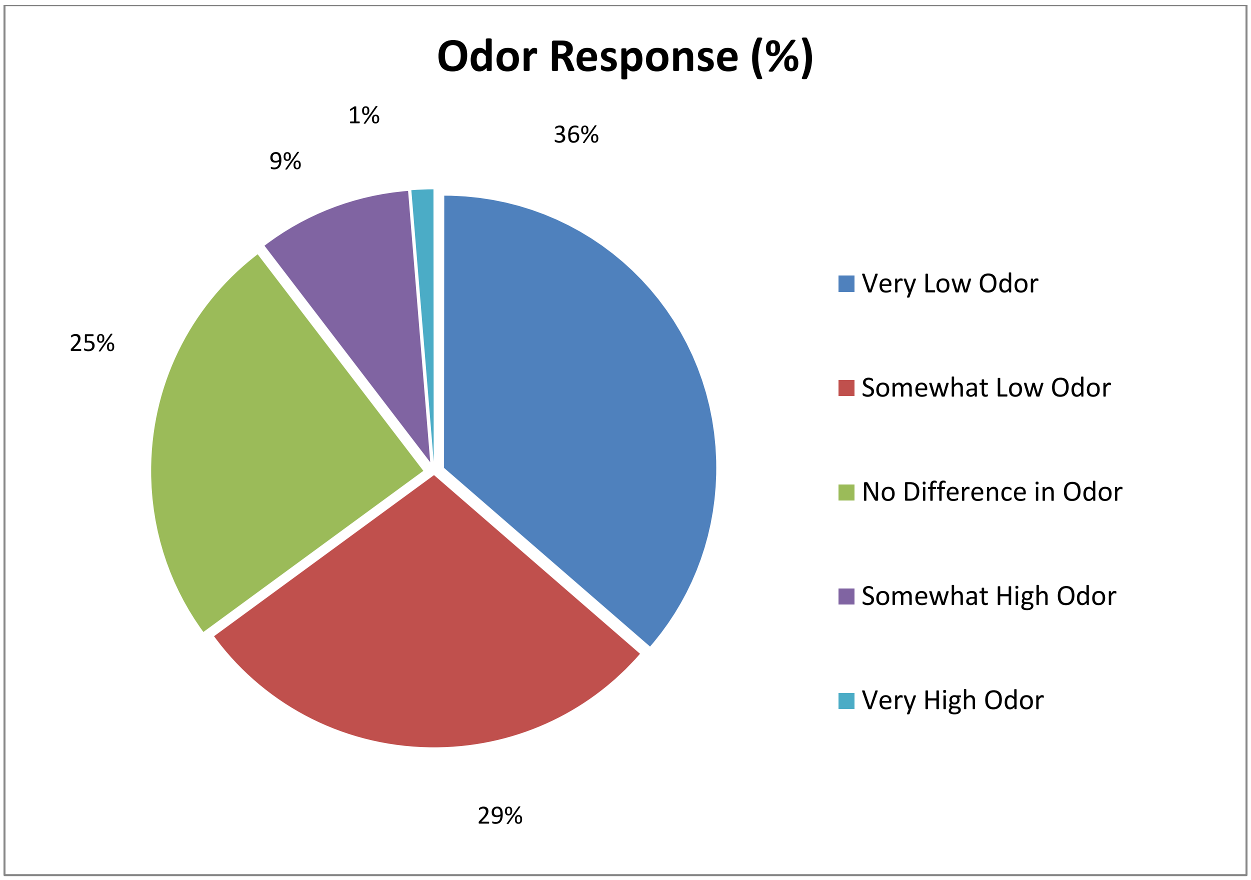
1. Road quality satisfaction response.					
Response	**Very Satisfied**	**Somewhat Satisfied**	**Neither Satisfied or Dissatisfied**	**Somewhat Dissatisfied**	**Very Dissatisfied**
Number of Responses	54	13	4	3	3
Response Percentage	70.1	16.9	5.2	3.9	3.9



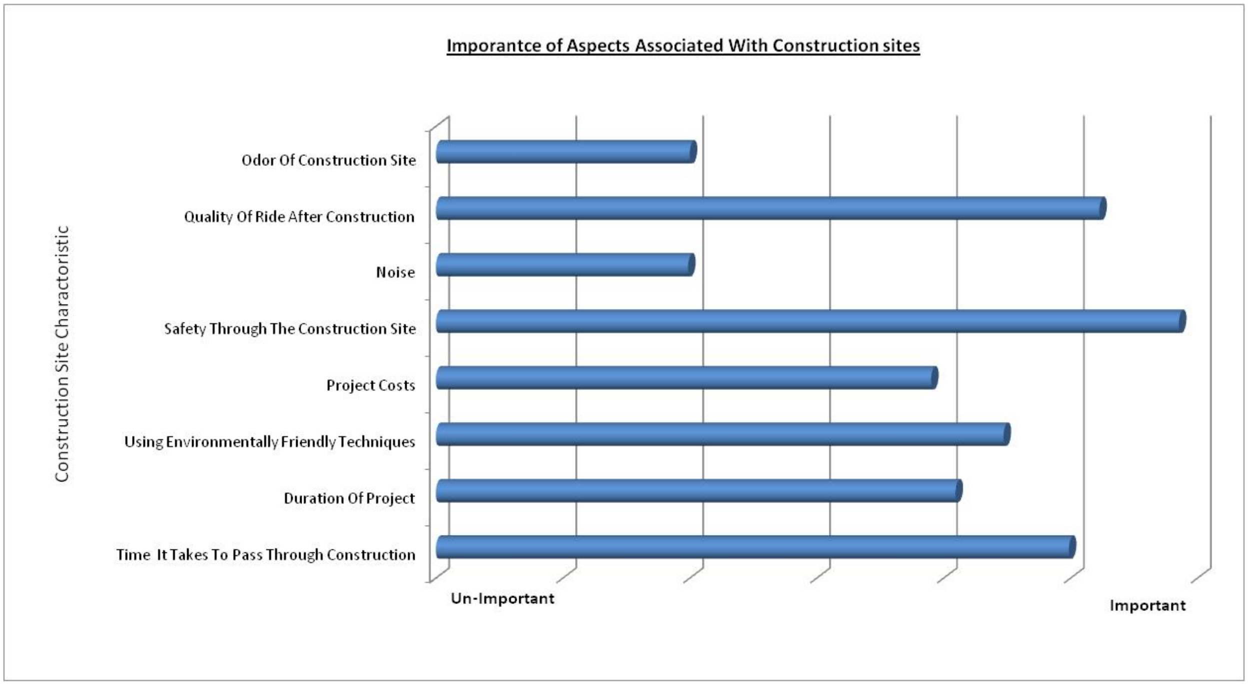
2. Response to traffic delays.			
Response	**Longer Delays**	**Equally Long Delays**	**Shorter Delays**
Number of Responses	11	38	27
Response Percentage	14.5	50.0	35.5



3. Response to site odors.					
Response	Very Low Odor	Somewhat Low Odor	No Difference in Odor	Somewhat High Odor	Very High Odor
Number of Responses	28	22	19	7	1
Response Percentage	36.4	28.6	24.7	9.1	1.3



4. Importance of aspects associated with construction (1–most important, 8–least important).



Castleton Survey Comments

1. None
2. None
3. This construction was not listed on satellite info–VT511? Four men not wearing hardhats on/around paving machine. White car and tar being sprayed was a concern.
4. See question 1+2–why so much longer? Job satisfaction 2 days later rainstorm left hydroplaning possibilities where there were none previously. Why so much overspray on painting of lines? Looks like you used a spray can.
5. I commend the workforce crew on their kindness and politeness in helping us cross the road in front of the Trac Inn in Bomoseen and for their efficiency in doing their job.
6. The pitch of the cut-in patch at the end of my driveway is very steep and will cause bottoming out and unsafe entry to Route 30, especially in inclement weather during the winter months. The scarifying on my driveway was done well in advance of paving, when the paving was done, raising the road by 5-6 inches of paving. It caused our cars to bottom out. Bad enough to knock the muffler off of one of my cars.
7. None
8. Paving should occur at night. Way too many paving projects at the same time on Route 4A, Route 30, and Route 4. Too many delays for people going to work.
9. Too long and too many times had delays. Repairs must be done to insure good roads. Better to spend money here on infrastructure.
10. The finished product is very nice and worth the minor inconveniences.
11. Flaggers and crew respectful of drivers. Everyone seemed very focused on their jobs.
12. None
13. Why pave a secondary road when other major highways need it more.
14. The flaggers are very inconsiderate of motorists. They do not understand the flow of traffic. My question is, do they (flaggers) have a certification? They need to reread, retake that class.
15. None
16. None
17. Both Route 4 and 30 look great.
18. The delay on this project was longer than any I have experienced. However, if the delays have to be longer for environmental reasons, then they should be longer.
19. The traffic controllers were very friendly.
20. None
21. The people controlling traffic were excellent! They were very friendly and professional! Thank you. The work zones look very nice.
22. I travel Routes 30 and 4A daily and the improvement is terrific! However, I also must travel on Route 4 from Castleton to White River Junction on a regular basis. Route 4 from White River to Woodstock should be condemned!!! And what were they doing earlier this week on that section of road? Repainting the centerline and fog line!!!
23. Waited approximately 15 minutes for traffic to move then it took another 5 minutes for a driver of a pickup to talk to a traffic person.
24. The quantity of work and the area covered on any given day was most impressive.
25. None
26. The flagger added more problems. Didn’t seem to know what they were doing. Didn’t hold sign very clear. Tell you to go when cars were coming from other direction.

27. Job well done!!
28. None
29. The quality and how long the road lasts are the important facts at an affordable cost. Appears that a thinner coat of tar is being used and two coats rather than one thick coat. Will this stand up to frost heaves? Repaving every year is not an answer. One issue was that a bridge transition on U.S. 4 was a severe bump in the fast lane, causing my car to bottom out at the posted limit. A bump sign should have highlighted this situation.
30. It is refreshing to see a contractor that can do a project of this scope so efficiently. Appeared to be very well supervised.
31. On June 7 as I drove into Vermont on Route 4, at the ½-mile mark an 18-wheeler hit an orange traffic cone and it slid in front of my pickup and camper. I missed the cone with the left front bumper but the cone broke off the sewer connection on my trailer, at a cost of $140.56 which I had done at Exit 1 RV in Fair Haven, VT.
32. None
33. None
34. None
35. Project done in village just in time for fall college kids. Now they can really squeal the tires and leave tracks. But it is a nice job well done.
36. None
37. None
38. Traffic control was well implemented–delays were not excessive. Workers were cautious on site so drivers were able to concentrate on road and driving.
39. Job seemed good. Tongue-and-cheek, the longest delay was getting this. Road quality seemed OK but was not very level. My truck rocked back and forth noticeably. (I have observed this elsewhere in the state.) My two cents–spend more effort on the road beds.
40. Hope frost in the spring does not break it up. Very nice job.
41. None
42. Although I was quite frustrated with the length of delays during construction (especially on 7/17 and 7/18), the benefit of a smooth road far outweighs the inconvenience of sitting in traffic for a few days. I live right on Route 30 by the Lake House restaurant, and I must say I was extremely impressed and grateful for the flagger who made a point to come across the street to my car and let me know when it was safe for me to exit my driveway. Also, if these are new technologies being used, I'm sure they take time to master, so wait/construction times will probably improve as the crew becomes more familiar with the new cutting-edge materials.
43. None
44. This project probably wouldn't have bothered me except it happened to fall during the same two weeks of swim lessons in Bomoseen. Add that to utility work in Granville and Poultney and it was a major inconvenience. Otherwise it was no big deal for a much better road so far!
45. None
46. Seems like a constant project. Maybe if everyone waits in line every day road will last longer. How much is it costing for this survey???
47. None
48. None
49. One day my wait time wasn't bad; however, the next day I was late for work because a flagger was inefficient in doing her job. I sat there with many others for over a half hour.

50. None
51. Why do paving along both routes at the same time, 4 and 4A. If did one first then could take alternate route till completed?!
52. Good luck. Stay safe.
53. The finished roads are a pleasure to drive on.
54. None
55. None
56. None
57. None
58. None
59. None
60. Overall what one expects in the summertime in N.E.
61. Was curious if the south end of Route 30 will be redone. Needs it bad towards Poultney and Lake St. Catherine.
62. None
63. None
64. None
65. Thank you for the paving work on two very beautiful roads that were in need of work.
66. None
67. None
68. Great Job!
69. Piles of blacktop left on roadside are an eyesore and poor workmanship, environmentally unfriendly. Not consistent on driveway aprons, anywhere from 18 inches to 6 feet. Some places of business seem to have much more than normal–Castleton.
70. A great job in difficult circumstances.
71. Very good job overall–much needed through this area.
72. Go back to Hodter North Traffic Control. They at least know what they're doing.
73. This was a very large project. The only thing that bothered me was there would be a sign saying there was a flagman ahead, so you drove very slow and the flagman wouldn't be close; it would be 4 miles away. That part was confusing.
74. Great signs beforehand and not a lot of delay. Thank you. Great job!
75. The work has been done in a very nice, organized fashion!
76. Great Job!
77. I do wish not all routes from Rutland to Castleton were not done at the same time.
78. Need to make the speed limit sign more visible. Not behind tree or tall grass.
79. None
80. None
81. Money needs to go elsewhere instead of paving a road that could have waited a few more years. Waste of taxpayer and government money. Road condition should be one of the least concerns and lower on the priority list of things that need attention.

APPENDIX B: WORKSHOP AGENDA

U.S. Department of Transportation

Federal Highway Administration

VTrans - Greener, Safer, Better

Concrete Pavement Innovation Showcase

July 11, 2012

Castleton State College - Herrick Auditorium

251 South Street

Castleton, VT 05735

HIGHWAYS FOR LIFE

Accelerating Innovation for the American Driving Experience.

AGENDA

Moderator: Mike Fowler, Pavement Management Engineer – VTrans

7:30am	**Registration/Check-in**
8:00am - 8:10am	**Welcome and Introductions** Richard Tetreault, Director of Program Development – VTrans
8:10am - 8:25am	**Highways for LIFE Overview** Matthew Hake, Division Administrator – FHWA, Vermont
8:25am - 8:45am	**Pavement Innovations: A National Perspective** Thomas Harman, Pavement and Materials TST Manager – FHWA
8:45am - 9:00am	**Project Overview** Tim Pockette, P.E., Resident Engineer – VTrans
9:00am - 9:20am	**Warm Mix Asphalt** Thomas Harman, Pavement and Materials TST Manager – FHWA
9:20am - 9:40am	**Pave IR Bar** Stephen Sebesta, Associate Research Scientist – Texas Transportation Institute
9:40am - 10:20am	**Intelligent Compaction** Richard Evans, Vice President, Sales – Wirtgen Group, Inc. Tim Kowalski, Applications Support Manager – Wirtgen Group, Inc.
10:20am - 10:35am	**Break**
10:35am - 10:50am	**Longitudinal Joint Construction** Mark Woolaver, Construction Paving Engineer – VTrans
10:50am - 11:10am	**Safety Edge** Andrew Mergenmeier, P.E., Senior Pavement and Materials Engineer – FHWA
11:10am - 11:25am	**Lessons Learned (VTrans)** Tim Pockette, P.E., Resident Engineer – VTrans
11:25am - 11:40am	**Lessons Learned (Contractor)** Bernard Granger, Project Superintendent – Peckham Road Corporation Chris Thomas, Project Manager – Peckham Road Corporation
11:40am - 12:00pm	**Open Q&A** All Speakers
12:00pm - 1:00pm	**Lunch - Huden Dining Hall *(provided by Wirtgen America, Inc.)***

1:00pm - 1:15pm	**Site Visit Overview & Safety Briefing** Tim Pockette, P.E., Resident Engineer – VTrans Bernard Granger, Project Superintendent – Peckham Road Corporation
1:15pm	**Depart for Site Visit**
1:30pm - 3:00pm	**Site Visit**
3:00pm - 3:30pm	**Open Q&A** All Speakers
3:30pm	**Evaluations & Adjourn**

Special Thanks to:

U.S. Department of Transportation
Federal Highway Administration

HIGHWAYS FOR LIFE
Accelerating Innovation for the American Driving Experience.

VTrans Working to Get You There

WIRTGEN GROUP

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Showcase Speaker List

VTrans - Greener, Safer, Better

Concrete Pavement Innovation Showcase

July 11, 2012

Speakers

Richard Evans

Vice President, Sales – Wirtgen Group, Inc.
6030 Dana Way
Antioch, TN 37013
phone (615) 501-0600
email revans@wirtgenamerica.com

After graduating in business from Lancaster Polytechnic in Coventry, England, Richard started his career in 1975 in the export sales department of Benford Limited, a manufacturer of Construction Equipment.. After numerous positions within the company, Richard moved to the Middle East where he was responsible for sales in Saudi Arabia and surrounding markets. In 1985, he was given an opportunity to start a business for the U.K. Group in Atlanta, GA to distribute the company's products throughout North America.

In 1993, he started with Hamm Compactors, initially as the South East Regional Manager and was promoted to National Sales Manager in 1999. Hamm was purchased by the Wirtgen Group in 2000 and Richard maintained his position with responsibilities for the U.S. and Canadian market. In 2007, he was appointed Vice President – Sales.

Richard is married with four children and lives outside of Atlanta, GA.

Mike Fowler

Pavement Management Engineer – Vermont Agency of Transportation
1 National Life Drive
Montpelier, VT 05633
phone (802) 828-0160
email mike.fowler@state.vt.us

Mike has worked for the Vermont Agency of Transportation since 1989 in various positions throughout his 22 year career. Over the last 8 years, he has served as the Agency's Pavement Management Engineer.

Bernard Granger

Project Superintendent – Peckham Road Corporation
1557 State Route 9, Suite 3
Lake George, NY 12845
phone (518) 810-9226
email bgran@peckham.com

Bernard has more than 30 years of paving and road construction experience under his belt. He has spent much of this time as a Project Foreman and Superintendent on various asphalt paving, excavation, and bridge construction projects across New York and Vermont.

Speakers

Matthew Hake

Division Administrator – FHWA, Vermont
87 State Street, Suite 216
Montpelier, VT 05602
phone (802) 828-4423
email matthew.hake@dot.gov

Thomas Harman

Manager, Pavement & Materials TST – Federal Highway Administration
10 South Howard Street, Suite 400
Baltimore, MD 21201
phone (410) 962-0134
email tom.harman@dot.gov

Mr. Harman has over 25 years of experience in pavement and materials, research, development, and technology deployment. Prior to joining FHWA in 1990, Tom worked for a national association and an international consultant. He holds a BS in Civil Engineering from the University of Maryland and an MS in Civil Engineering from the University of Illinois. Tom has been married for 16 years and has three beautiful children.

Tim Kowalski

Applications Support Manager – Wirtgen Group, Inc.
6030 Dana Way
Antioch, TN 37013
phone (615) 594-4604
email tkowalski@wirtgenamerica.com

Mr. Kowalski has been in the construction industry for over 23 years with 17 years of experience in Quality Control Management positions for asphalt, aggregate, and concrete. He has worked in the states of Wisconsin, Illinois, Colorado, New Mexico, and Wyoming. Tim is a 1989 graduate from the University of Wisconsin – Madison with a Bachelor of Science Major in Construction Administration and Minor in Business Management. He currently lives in Nashville, TN with his wife, Catherine, and enjoys anything to do with sports and the outdoors.

July 11, 2012

VTrans - Greener, Safer, Better

Concrete Pavement Innovation Showcase

Speakers

Andrew Mergenmeier, P.E.

Senior Pavement and Materials Engineer – Federal Highway Administration
10 South Howard Street, Suite 400
Baltimore, MD 21201
phone (410) 962-0091
email andy.mergenmeier@dot.gov

Mr. Mergenmeier is a Senior Pavement and Materials Engineer with the FHWA's Resource Center. His primary responsibilities include materials acceptance and pavement design and construction. He came to this position in 2007 after 7 years as Virginia DOT's State Materials Engineer. At VDOT, he was responsible for overseeing the Materials Division which included preliminary engineering and construction functions, such as pavement design and materials acceptance programs. Before VDOT, Mr. Mergenmeier worked for the FHWA for 15 years in various locations throughout the country.

Mr. Mergenmeier is a Civil Engineering graduate from the University of Kansas and a Registered Professional Engineer.

Tim Pockette, P.E.

Resident Engineer – Vermont Agency of Transportation, Construction
61 Valley View
Rutland, VT 05701
phone (802) 773-1384
email tim.pockette@state.vt.us

Tim graduated from the University of Vermont with a Bachelor of Science in Civil Engineering and has worked for the State of Vermont for 20 years. He has worked in the Maintenance Division as a District Technician, the Materials and Research Section as Bituminous Hot Mix Lab and Asphalt Lab supervisor, the Central Office of the Construction Section, and in the field of the Construction Section as project supervisor.

Stephen Sebesta

Associate Research Scientist – Texas Transportation Institute
405 Spence Street
College Station, TX 77843
phone (979) 458-0194
email s-sebesta@tamu.edu

Mr. Sebesta is an Associate Research Scientist at the Texas Transportation Institute in College Station, TX. His work focuses in areas of flexible pavements research, including non-destructive testing, identification and development of new techniques for field and laboratory quality control, soil and base stabilization and reclamation, and forensic evaluation. He began working with non-destructive testing for evaluating asphalt paving approximately 12 years ago and actively participated in the development, demonstration, and implementation process for full-coverage thermal profiling in the Texas Department of Transportation. He currently serves as a key researcher on SHRP2 Project R06C, which is currently in the pre-implementation phase of infrared and ground-penetrating radar for uniformity measurements on new asphalt layers.

VTrans - Greener, Safer, Better

Concrete Pavement Innovation Showcase

July 11, 2012

Speakers

Richard Tetreault

Director of Program Development – Vermont Agency of Transportation

1 National Life Drive

Montpelier, VT 05633

phone (802) 828-2663

email richard.tetreault@state.vt.us

Rich has been the Director of Program Development/Chief Engineer for the Vermont Agency of Transportation for the last 7 years. Prior to his current position, he was a District Administrator as well as Chief Bridge Inspector. He is a member of the AASHTO Standing Committee on Highways.

Christopher J. Thomas

Project Manager/Quality Control – Peckham Road Corporation

1557 State Route 9, Suite 3

Lake George, NY 12845

phone (518) 859-0479

email cthom@peckham.com

Chris has been involved with the asphalt paving industry for the last 8 years. He has a background in production facility and field operations Quality Control and recently made the transition into project management while ensuring quality assurance is at the forefront of all Peckham Road Corporation projects.

Mark Woolaver

Construction Paving Engineer – Vermont Agency of Transportation

1 National Life Drive

Montpelier, VT 05633

phone (802) 828-1475

email mark.woolaver@state.vt.us

Mark started with the Vermont Agency of Transportation in 1988 in the Roadway Design Unit and later moved to the Construction Section as a construction inspector. He then spent approximately 15 years in the Agency's Pavement Management Section until transferring back to Construction where he has served in his current role as the Construction Paving Engineer for the past 6 seasons.