Case Study of Infrared Deployment

Technologies to Enhance Quality Control on Asphalt Pavements

Pave-IR Scan™

October 2017

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16. Abstract

Infrared (IR) technology was recommended as part of the SHRP2 *Technologies to Enhance Quality Control on Asphalt Pavements (R06C)* product. As part of that recommendation, field projects were completed to demonstrate the use and effectiveness of an IR asphalt pavement scanner for control of asphalt mixture temperature uniformity, and to confirm the short and long-term benefits of the IR technology. A total of ten field demonstration projects and eight workshops were completed. The purpose of this report is to provide a summary of the field demonstration projects and workshops.

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Introduction

In-place density is a critical factor in determining pavement durability in hot mix asphalt (HMA) mixtures. Localized non-uniform zones of mix, often defined as segregation, are low-density areas in the HMA mat. Although very localized, segregation is a major construction-related problem with an adverse impact on pavement service life. For example, Figure 1 includes a photograph of two cores that exhibit longitudinal aggregate segregation at the surface of a mat.

Figure 1. Longitudinal Aggregate Segregation and Top-Down Cracking.

The core to the right in Figure 1 clearly shows a concentration of coarse aggregate at the surface. This concentration of coarse aggregate caused a “weak” spot where a longitudinal crack started at the surface and is propagating downward through the HMA. The core to the left is similar, but the crack has propagated through all of the HMA layers and the coarse aggregate have become dislodged by traffic and exhibits severe raveling along the longitudinal crack. This condition can occur in a few years after construction and require premature maintenance or rehabilitation. The infrared scanner technology is being used to ensure these conditions are identified on a real time basis during the paving operation.

IR technology is recommended as part of the SHRP2 *Technologies to Enhance Quality Control on Asphalt Pavements (R06C)* product. IR technology is recommended as part of the SHRP2 *Technologies to Enhance Quality Control on Asphalt Pavements (R06C)* product. Field demonstration projects were completed to demonstrate the use and effectiveness of an infrared (IR) asphalt pavement scanner for control of asphalt mixture temperature uniformity, and to confirm the short and long term benefits of the IR technology, which are listed below:

- Short or near-term benefits:
    1. More uniformly constructed hot and warm-mix asphalt layers
    2. Higher or more uniform in-place field density

3. Reduced discrepancies between contractor and agency test data, or data to explain possible discrepancies between the contractor and agency test data
4. Provide near real-time results that facilitate immediate corrective actions to paving practices

- Long-term benefit:

1. Longer lasting pavements with lower maintenance costs

The purpose of this document is to overview the deployment of the infrared scanner technology for improving the uniformity of the HMA mat during construction.

Field Demonstration Projects

Ten field demonstration projects were completed as part of the Infrared Scanner deployment efforts. The Pave-IR Scan™ system was used on ten field demonstration projects included in the SHRP II program. The agencies that participated in the field demonstrations included: Alabama DOT, Alaska DOT, Eastern Federal Lands of FHWA, Illinois DOT, Maine DOT, Missouri DOT, New Jersey DOT, North Carolina DOT, Virginia DOT, and West Virginia DOT. This section of the report describes the ten field demonstration projects and identifies the data collected within each of the projects. Table 1 provides a listing and specific project details for each project.

Densities were monitored by quality control personnel to ensure adequate densities were being obtained by the compaction operation. Cores of the asphalt concrete mat were also taken on every project, as part of the quality assurance program being administered by the agency and/or contractor. As part of the deployment projects, a non-nuclear density gauge was used to measure the relative density across and along specific areas of the mat, as well as in specific locations with different mat temperatures.

Table 1. Field Demonstration Projects and Asphalt Concrete Layers Monitored with the Pave-IR Scan™ System

Project	Facility	Type	Layer Type	Thickness, in.
Alabama DOT	Secondary Arterial	Mill and Overlay	Wearing Surface	1.5
Alaska DOT	Runway	Reconstruction	AC Base	3.0
	Taxiway		Binder Course	3.0
Eastern Federal Lands	Principle Arterial	New Construction	AC Base	3.0
			Intermediate	2.5
Illinois DOT	Secondary Arterial	Mill and Overlay	Wearing Surface	1.5
	Interstate	Mill and Overlay	Wearing Surface	1.5
Maine DOT	Interstate	Mill and Overlay	Wearing Surface	2.0
Missouri DOT	Interstate	Mill and Overlay	Wearing Surface	1.75
New Jersey DOT	Principle Arterial	Mill and Overlay	Wearing Surface	1.75

Table 1. Field Demonstration Projects and Asphalt Concrete Layers Monitored with the Pave-IR Scan™ System

Project	Facility	Type	Layer Type	Thickness, in.
North Carolina DOT	Interstate	Reconstruction	Wearing Surface	1.5
Virginia DOT	Collector	Mill and Overlay	Wearing Surface	2.0
West Virginia DOH	Primary Arterial	New Construction	Drainage Layer	4.0
			AC Base	3.0

Alabama DOT Project

The Alabama Department of Transportation (ALDOT) conducted a demonstration project along state route AL 202 in Anniston, Alabama in May 2017. Table 2 lists the contacts or individuals that were present during the field demonstration for this project.

Table 2. Contacts for the Alabama DOT Demonstration Project

Lyndi Blackburn	ALDOT	BlackburnL@dot.state.al.us	334-206-2203
Sergio Rodriguez	ALDOT	RodriguezS@dot.state.al.us	334-206-2204
Harold Von Quintus	ARA	hvonquintus@ara.com	512-694-1511
Joseph Reiter	ARA	jreiter@ara.com	217-356-4500
Steve Cooper	FHWA	Stephen.Cooper@dot.gov	720-963-3722
Kristy Harris	FHWA	Kristy.Harris@dot.gov	334-274-6361

The demonstration project was performed on AL 202 between I-20 and CR 109/Bynum Leatherwood Rd. For the field demonstration sections observed by project personnel May 18 and 25, 2017, paving was performed on AL 202 from Bynum Leatherwood Rd. to Bynum Blvd; approximately 1.5 miles. The southbound inside, travel, lane was paved as two separate control strips during the field observation nights starting at Bynum Leatherwood Rd. Data were collected with the Pave-IR Scan and software on May 18, and May 26, 2017 along AL-202 near Anniston, AL. Figure 2 shows the locations of the two ALDOT AL-202 paving sections included in the field demonstration project.

The asphalt concrete mixture was delivered to the project using end-dump discharge trucks, as shown in figure 3. The asphalt batching plant was less than 10 miles haul distance to any point along the project. The asphalt concrete mixture was dumped into a Roadtec material transfer device. A Roadtec rubber-tired paver was used to place the mixture on the surface, both of which are shown in Figure 4. Noncontact sensors were used to control the longitudinal grade or profile of the mixture being placed. Overall, Mid-South Paving Inc., the contractor participating in the demonstration project, used excellent practice in placing the asphalt concrete mixture.

The rehabilitation strategy for the segment of AL 202 during the field demonstration project involved placing a 1.5 in. asphalt concrete surface layer. The existing roadway had been milled in previous weeks and was followed by a surface treatment that was allowed to cure for at least 72 hours. For the first control strip the overlay was placed directly on the surface treatment with no preparations outside of sweeping the surface. During the second control strip paving night on May 25 a tack coat was placed on the previous surface prior to paving.

Compaction of the mix was achieved using one Hamm steel-drum roller in the breakdown position, with a Sakai steel-drum roller in the finish roller position. The breakdown roller was used in the vibratory and static settings, with the finish roller in the static setting. During the paving of the first control strip the rollers were having difficulty with the mix moving around during most rolling patterns and were creating a non-uniform surface visually. On the second night of paving the addition of the tack coat, the only paving variable changed that was observed, made it much easier for the roller crew to adjust the roller pattern to achieve density. Figure 5 shows the rollers used on the project. Cores were taken at random locations for acceptance of the mixture on the night of paving to determine if the control strip was acceptable. The results of this control strip on May 18 produced unsatisfactory results, with cracking and material loss evident the following day. The second night of control strip paving produced a satisfactory final surface.

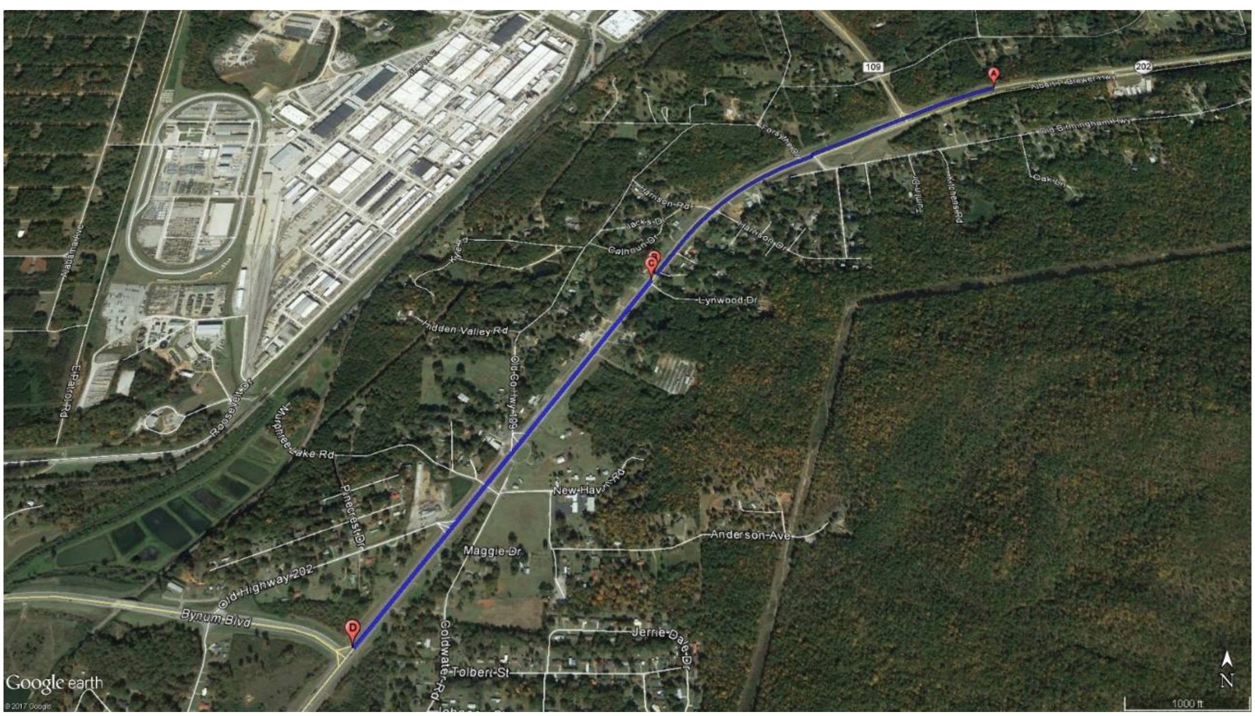


Figure 2. Location of Alabama DOT Field Demonstration Project showing Paths #1 and #2 of the Paver.

Figure 3. End-Dump Trucks Delivering Mixture to the Alabama Paving Site.

Figure 4. Roadtec Paver and Roadtec Material Transfer Vehicle Used to Place the Mixture.

Figure 5. Hamm Roller Used in the Breakdown, and Sakai Roller Used in the Finish Rolling Position to Compact the Asphalt Concrete Mixture.

Alaska DOT Project

The Alaska Department of Transportation and Public Facilities (ADOT&PF) Infrared (IR) demonstration project was conducted at the Ted Stevens Anchorage International Airport (see figure 2). This airfield project was selected by the Alaska DOT for the demonstration project because of its size and location. Table 3 lists the contacts or individuals that were present during the field demonstration for this project.

The demonstration project started on June 15 and continued through June 18. This project included the reconstruction the existing flexible pavement along selected runways and taxiways. Granite Construction was the paving contractor. Five asphalt concrete layers were placed as part of the reconstruction, which are listed and identified in table 4. Only the upper asphalt treated base layer was monitored with the Pave-IR Scan system.

Table 3. Contacts for the Alaska Demonstration Project

Richard Giessel	Alaska DOT	Richard.giessel@alaska.gov	907-269-6244
Stephan Saboundjian	Alaska DOT	Steve.saboundjian@alaska.gov	907-269-6214
Steve Ayers	Granite Construction	Stephen.ayers@gcinc.com	907-344-2593
Paul Angerhofer	MOBA	pangerhofer@moba.de	770-634-0058
Harold Von Quintus	ARA	hvonquintus@ara.com	512-694-1511
Paul Dalbey	ARA	pdalbey@ara.com	217-356-4500
Monica Jurado	FHWA	Monica.jurado@dot.gov	720-963-3722

Table 4. Pavement Structure for the Alaska Demonstration Project

Layer #	Layer Description	Lift Thickness, inches	IR Scanner Used to Monitor Mix Temperatures
1	Wearing Surface	2	No
2	Binder Course	3	Yes
3	Intermediate Course	2	No
4	Asphalt Concrete Base	3	Yes
5	Asphalt Concrete Base	3	No
	Total	13	

The mixture was delivered to the project using bottom-dump trucks, as shown in figure 3. Use of the bottom-dump trucks allowed continuous, non-stop paving along the runway. A windrow elevator was used to pick up the mixture and place it in a Caterpillar rubber-track paver. Non-contact sensors were used to control the longitudinal grade or profile of the mixture being placed.

Three steel wheel rollers were used to compact the mixture: two were Dynapac vibratory rollers used in the breakdown and intermediate positions, and the third was a Caterpillar roller operated in the static mode for finish rolling. The Dynapac rollers used in the breakdown and intermediate positions were Intelligent Compactor (IC) rollers and equipped with GPS devices to ensure uniform coverage. In addition, both IC rollers were equipped with accelerometers to monitor the response of the mixture under compaction, but were not being used to make compaction decisions. The two Dynapac rollers used the same rolling pattern, while the Caterpillar roller was only used to remove any roller marks left by the intermediate roller. The two Dynapac rollers each made two coverages over the mat.

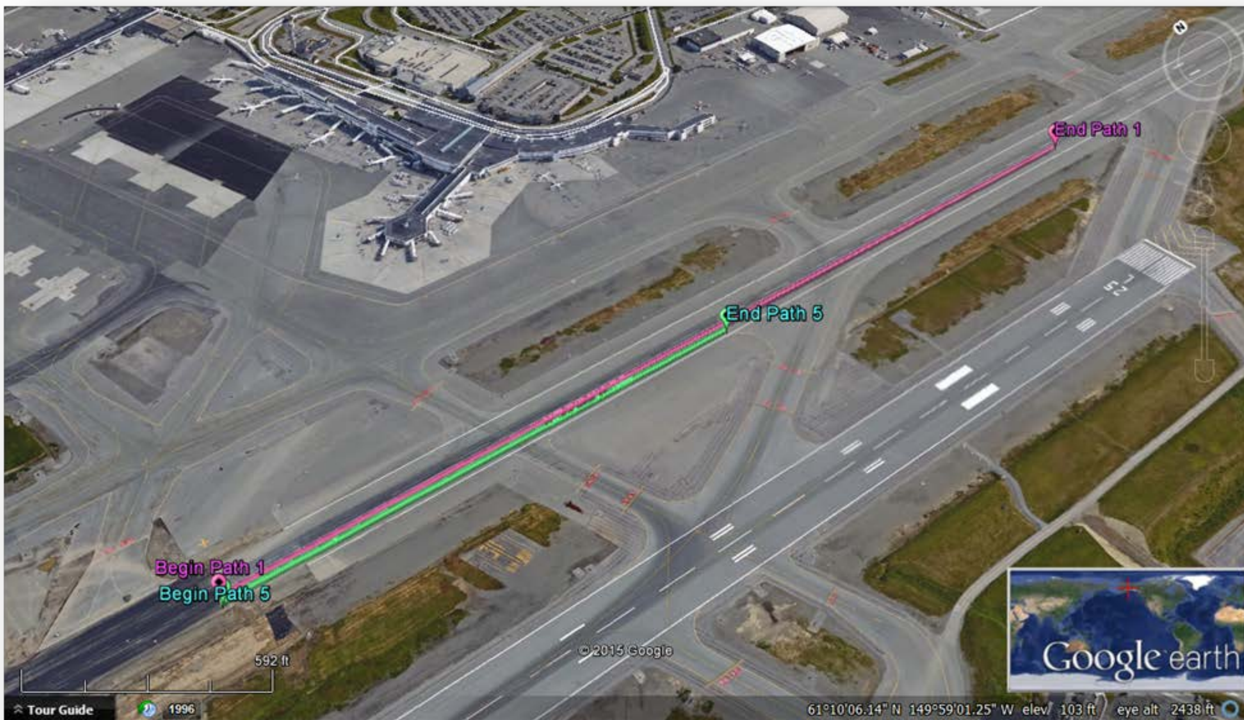


Figure 6. Location of Alaska DOT Field Demonstration Project showing Paths #1 and #5 of the Paver.

Figure 7. Bottom-Dup Truck Delivered Mix to Alaska Paving Site.

Data was collected with the Pave-IR scanner and software for ADOT&PF on June 16 and 17, 2015 (Tuesday and Wednesday) at the Ted Stevens Anchorage International Airport (TSAIA). Complete pulls were made along the main runway on June 16. On June 17, Granite Construction started paving cross over taxiways and turnarounds for which the pull distance was short so it was decided not to collect the Pave-IR data on these segments. Data was to be collected on projects in other regions within Alaska, but the use of the Pave-IR was confined to the Anchorage area or region until the 2016 construction season. Data was collected during the 2016 construction season but that information and data were unavailable for use in this report.

Eastern Federal Lands Project

Starting June 23, 2015, Eastern Federal Lands Highway Division (EFL) began a demonstration project along US 1 in the area of Fort Belvoir, VA to test the effectiveness of using an infrared (IR) scanner on a pavement rehabilitation and reconstruction project. The complete construction project on US 1 is from SR 235 in Mount Vernon, VA to SR 638 in Pohick, VA. Table 5 lists the contacts for this project.

Table 5. Contacts for the Eastern Federal Lands Demonstration Project

Mike Dallaire	EFL-FHWA	Michael.Dallaire@dot.gov	571-434-1573
Robert Hinman	EFL-FHWA	Robert.Hinman@dot.gov	703-948-3555
Steve Deppmeier	EFL-FHWA	Steve.Deppmeier@dot.gov	703-404-6292
Paul Angerhofer	MOBA	pangerhofer@moba.de	770-634-0058
Harold Von Quintus	ARA	hvonquintus@ara.com	512-694-1511
Joseph Reiter	ARA	jreiter@ara.com	217-356-4500
Steve Cooper	FHWA	Stephen.Cooper@dot.gov	720-963-3722

MOBA – MOBA Mobile Automation AG
ARA – Applied Research Associates, Inc.
FHWA – Federal Highway Administration

The demonstration continued over several weeks, on different sections of a reconstruction project, to widen and increase the number of lanes on US 1 (see figure 4). The areas under investigation also included a small section of SR 286 where it intersects US 1.

The demonstration project focused on newly constructed segments of US 1 southbound located at the southern end of the Davison Army Airfield runway. The project included placing 14 inches of total asphalt on the mainline section of US 1. Three base lifts (4in on 3in on 3in) and one intermediate lift (2.5in) were placed during the construction phases observed as part of the demonstration project (see table 6); with a final lift to be placed following milling nearer to completion of the project, when the technology may not be available. Paving operations were observed on June 24 and 25, and all field data were collected during the same time frame.

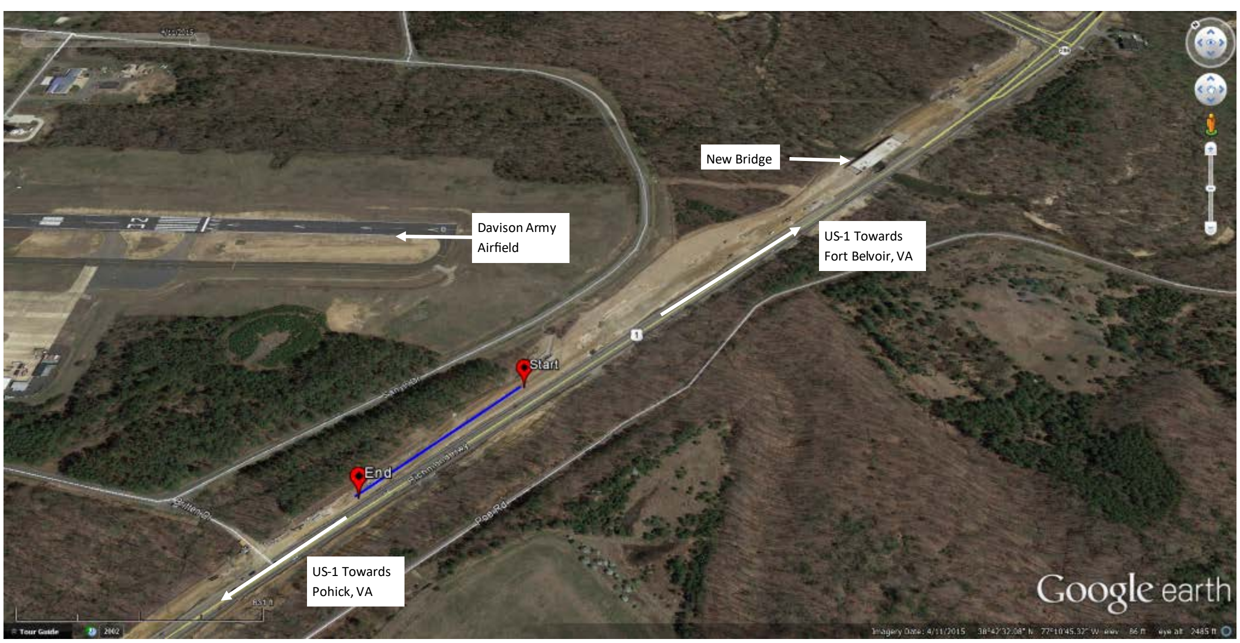


Figure 8. Eastern Federal Lands US 1 Project Location

Table 6. Pavement Structure for the Eastern Federal Lands Demonstration Project

Layer #	Layer Description	Lift Thickness, inches	IR Scanner Used to Monitor Mix Temperatures
1	Wearing Surface	1.5	No
2	Intermediate Course	2.5	Yes
3	Asphalt Concrete Base	3	No
4	Asphalt Concrete Base	3	Yes
5	Asphalt Concrete Base	4	No
	Total	14	

The asphalt concrete mixture was delivered to the project using end-dump discharge trucks, as shown in Figure 9. The haul time was between 45 minutes and two hours due to the location of the asphalt plant in Manassas, VA, and traffic conditions near the project site. This lead to inconsistent delivery of material and frequent stops in paving shown in the data analysis presented in later sections. A Blaw Knox® rubber-tracked paver was used to place the mixture on the surface.

A material transfer device was not used in this location due to the issues with material delivery and short paving pulls. However, the paving contractor anticipates using a material transfer device for the final surface course. The paving contractor, Branscome Paving, intended to use the Pave-IR scanner to establish a baseline of their current paving practices, then to adjust their practices to determine the impacts to thermal segregation. This should improve their overall paving practices to provide more consistent temperature in the future.

Figure 9. End-Dump Trucks Delivering Mixture to the EFL Paving Site

The paving performed for the demonstration project was new construction on US 1. The aggregate base was in place and proof rolling was performed prior to paving. Base asphalt paving began with a 4-inch initial base using 3 pulls to create the full width three lane roadway. A second base lift over all lanes, and one pull of the third lift in the outside lane were completed on the first day of the demonstration project. On the second day, the final lift of base was completed and 2.5 inches of intermediate was placed.

Each lift was compacted using three separate rollers, with a tack coat applied between each lift. The compacting operations began with a Hamm HD+120 oscillatory breakdown roller, a Caterpillar CB434D as an intermediate roller, and a steel double drum finish roller.

Nuclear densities were monitored by quality control personnel to ensure adequate densities were being obtained by the compaction operation. Cores were also taken at random locations for acceptance of the mixture.

Illinois DOT Project

From June 29 to July 28, 2015, the Illinois Department of Transportation (IDOT) conducted a demonstration project on IL 116 and I-155 near Peoria, IL. The demonstration project, near Peoria, IL, was performed on both IL 116 and I-155 to provide two different roadway types for demonstrating the IR scanner technology (see figures 6 and 7). Table 5 lists the contacts for this project.

On IL 116 paving was completed in both the East and West directions between Farmington and Hanna City, IL. The section of I-155 was paved in the North and South directions from Townline Rd. south to the Tazewell County line. On IL 116 the surface was milled before a 1.5-inch overlay was placed. For I-155 the project involved the milling and replacement of 1.5 inches of surface asphalt concrete.

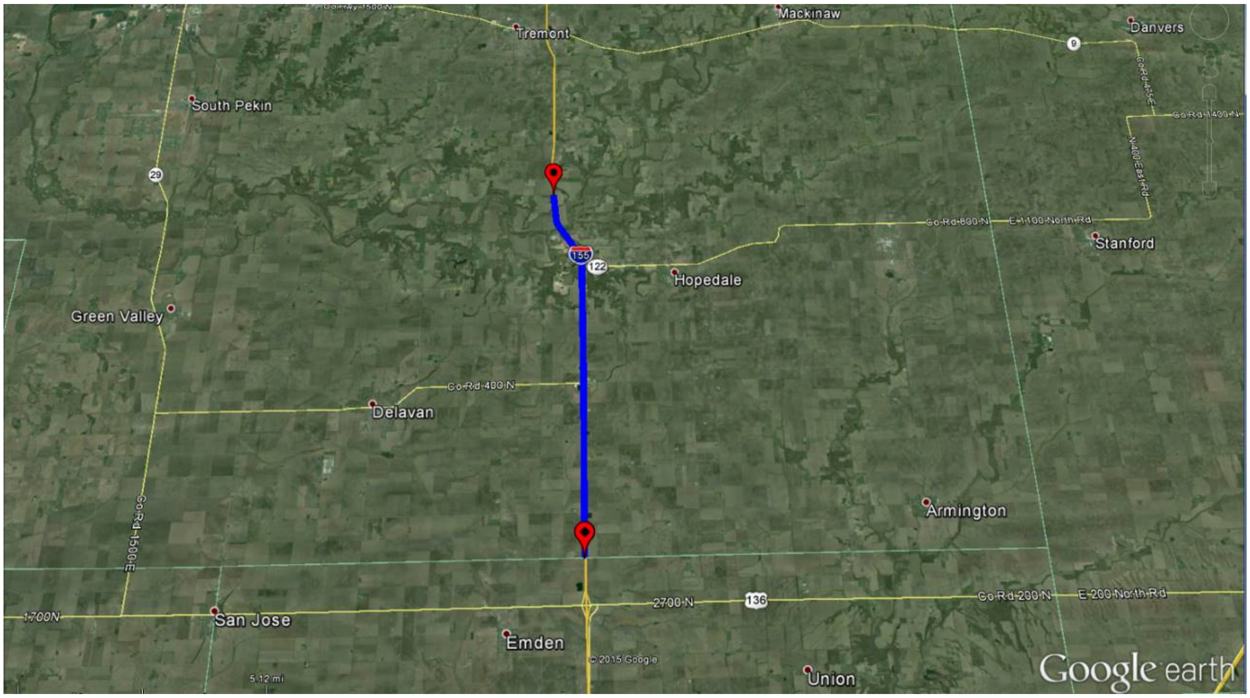


Figure 10. Illinois I-155 Project Location

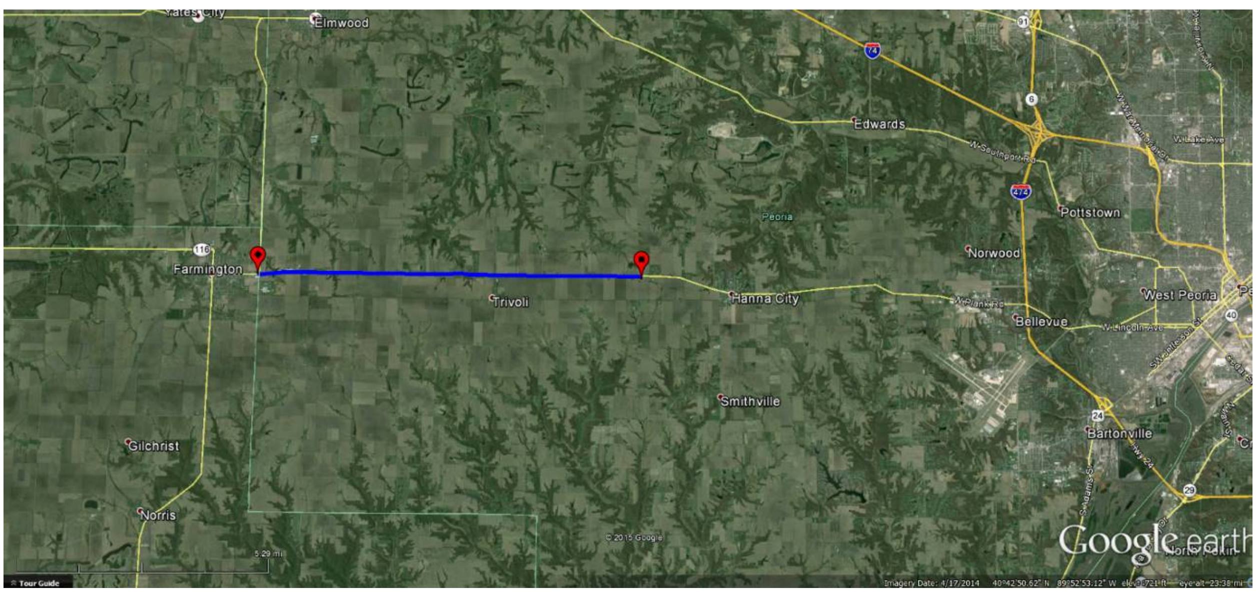


Figure 11. Illinois IL-116 Project Location

The asphalt concrete mixture was delivered to the project using end-dump and flow-boys or horizontal discharge trucks. The asphalt concrete mixture was dumped into a Roadtec material transfer device for the I-155 project, while no MTV was used for the IL 116 project. A Terex® rubber-tracked paver was used to place the mixture along the I-155 project, while a Caterpillar rubber-tracked paver was used along the IL 116 project. Figure 8 shows the mixture being delivered to the Caterpillar paver on the IL 116 project. United Contractors Midwest (UCM), the paving contractor, installed water nozzles in front of the rubber-track to reduce mix and tack coat pick up. Figure 9 shows the water nozzle set up with spraying water on the track. Although located in Peoria, IL the asphalt batching plant was less than twenty miles haul distance to the northern end of the project. Noncontact sensors were used to control the longitudinal grade or profile of the mixture being placed. Overall, United Contractors Midwest (UCM), the contractor participating in the demonstration project, used excellent practice in placing the asphalt concrete mixture.

Table 7. Contacts for the Illinois Demonstration Project

Tom Zehr	IDOT	thomas.zehr@illinois.gov	217-524-7268
Jim Trepanier	IDOT	james.trepanier@illinois.gov	217-782-9607
Paul Angerhofer	MOBA	pangerhofer@moba.de	770-634-0058
Harold Von Quintus	ARA	hvonquintus@ara.com	512-694-1511
Paul Dalbey	ARA	pdalbey@ara.com	217-356-4500
Padraig O'Shea	UCM	padraig.oshea@ucm.biz	309-925-2721
Steve Cooper	FHWA	Stephen.Cooper@dot.gov	720-963-3722
Brian Pfeifer	FHWA	Brian.Pfeifer@dot.gov	217-492-4281

MOBA – MOBA Mobile Automation AG
ARA – Applied Research Associates, Inc.
UCM – United Contractors Midwest, Inc. (R.A. Cullinan & Son, Inc.)
FHWA – Federal Highway Administration

Figure 12. End-Dump Truck Delivering Mixture to Caterpillar Paver on the IL 116 Project

Figure 13. Water Nozzle Installed in Front of the Rubber-Track to Reduce Mix and Tack Coat Pick-Up along the IL 116 Project

The rehabilitation strategy for the segment of IL 116 included milling the existing asphalt concrete wearing surface and placing a new 1 in. asphalt concrete wearing surface. The rehabilitation strategy on I-155 included milling the existing surface and replacing with a XX in. binder course and a 1.5 in. wearing course. Tack coat was placed on all milled or previous surfaces prior to paving.

Three rollers were used to compact the mixtures: a Caterpillar CB54 vibratory breakdown roller, and two Hamm HD120 oscillatory rollers as intermediate and finish rollers.

Nuclear densities and uncompacted material sampling were monitored by quality control personnel to ensure adequate densities were being obtained by the compaction operation. Cores were also taken at random locations for acceptance of the mixture.

Maine DOT Project

The Maine Department of Transportation (DOT) infrared (IR) demonstration project was conducted along I-95. The demonstration project started at the Canadian border in the southbound lanes on September 15th and continued through September 28th, 2015. Figures 10 and 11 show the location of the two project segments included in the field demonstration project.

The project included placing a 2-inch overlay over the existing asphalt concrete surface. Paving operations were observed on September 16th and 17th. All field data were collected during the same time frame. Table 5 lists the contacts for this project.

The asphalt concrete mixture was produced in a drum mix plant with dual gates under the storage silo for loading the trucks to reduce the potential for truck-to-truck segregation at the paving site when unloading the trucks. Multiple dumps were used to load the larger trucks to fill the trucks where mixture was placed along the entire bed of the truck.

The mixture was delivered to the project using end-dump and flow-boys or horizontal discharge trucks. The asphalt concrete mixture was dumped into a Weiler material transfer device. A Caterpillar® rubber-tired paver was used to place the mixture on the surface. Figure 12 shows the overall delivery-paving operation. Noncontact sensors were used to control the longitudinal grade or profile of the mixture being placed. Overall, Lane Construction used excellent practice in placing the asphalt concrete mixture.

The rehabilitation strategy for the segment of I-95 included milling the existing asphalt concrete wearing surface and placing an asphalt concrete base and binder layers and wearing surface. An IRS-1 tack coat was placed on the milled surface while a Craftco low modulus crack sealer was placed along the longitudinal construction joint between the two southbound lanes of I-95.

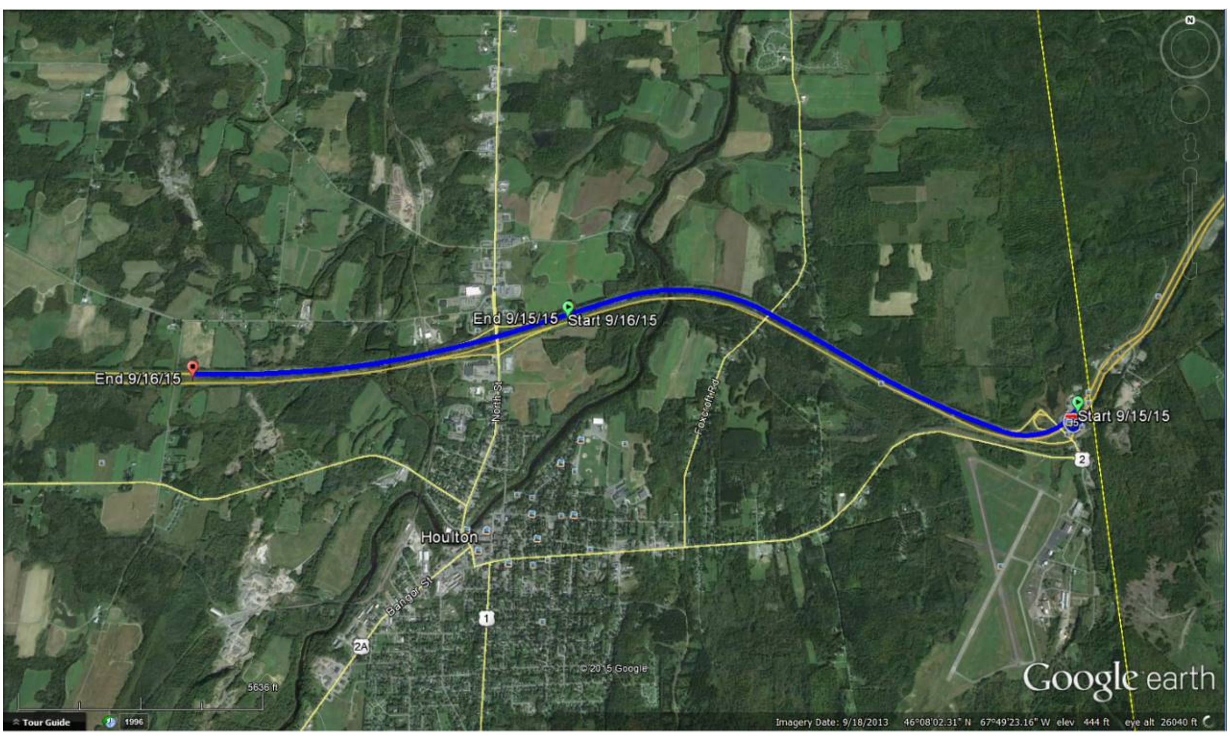


Figure 14. Maine I-95 Project Location; Segments Placed on September 15th and 16th

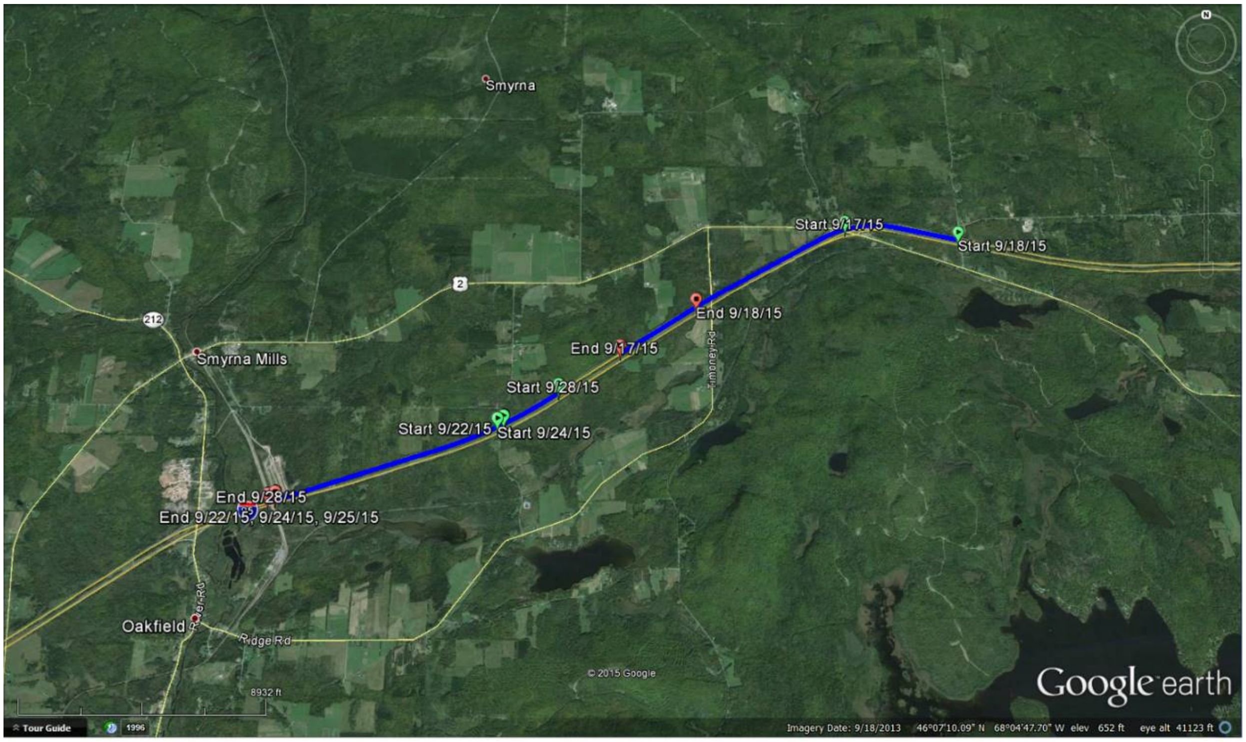


Figure 15. Maine I-95 Project Location; Segments Placed on September 18th to 28th

Table 8. Contacts for Maine Demonstration Project

Dale Peabody	Maine DO	Dale.peabody@maine.gov	207-624-3305
Bruce Yeaton	Maine DOT	Bruce.yeaton@maine.gov	207-431-1223
Ulrich Amoussou-Guenov	Maine DOT	Ulrich.amoussou-guenov@maine.gov	207-624-3277
Jon Bither	Consultant	jacmbither@gmail.com	207-538-5048
Paul Angerhofer	MOBA	pangerhofer@moba.de	770-634-0058
Harold Von Quintus	ARA	hvonquintus@ara.com	512-694-1511
Paul Dalbey	ARA	pdalbey@ara.com	217-356-4500
Steve Cooper	FHWA	Stephen.Cooper@dot.gov	720-963-3722

ARA – Applied Research Associates, Inc.
FHWA – Federal Highway Administration

Figure 16. Paving Operation Used along the Maine I-95 Project

Five rollers were used to compact the mixture: a Caterpillar, Volvo, and Ingersoll-Rand steel wheel vibratory rollers, a Hamm steel wheel oscillatory roller, and a Caterpillar rubber tired roller. Two of the steel wheel rollers were used in the breakdown position in echelon, while the other two steel wheel rollers were used as finish rollers. The combination of breakdown and finish rollers changed during paving operations on different days. The Caterpillar rubber tired roller was used in the intermediate position.

Densities were monitored by quality control personnel to ensure adequate densities were being obtained by the compaction operation using the Pavement Quality Indicator (PQI) non-nuclear density gauge. Cores were also taken at random locations for acceptance of the mixture.

Missouri DOT Project

From August to September 2015, the Missouri Department of Transportation (MoDOT) conducted a demonstration project along I-29 in St. Joseph, MO. The demonstration project, in

St. Joseph, MO, started just south of the intersection of I-29 and I-229 and continued to a location just south of the intersection of I-29 and US 169 (see figure 13). Only the northbound direction of I-29 was scheduled for rehabilitation in 2015, with the southbound direction scheduled for rehabilitation in 2016.

The project included placing a 1.75-inch overlay over a milled asphalt concrete surface. Paving operations were observed on September 1 and 2, and all field data were collected during the same time frame. Table 5 lists the contacts for this project.

The asphalt concrete mixture was delivered to the project using end-dump and flow-boys or horizontal discharge trucks. Although located in Elwood, KS the asphalt batching plant was less than ten miles haul distance to any point along the project. The asphalt concrete mixture was dumped into a Roadtec material transfer device. A Terex® rubber-tracked paver was used to place the mixture on the surface. Figure 14 shows the overall delivery-paving operation. Noncontact sensors were used to control the longitudinal grade or profile of the mixture being placed. Overall, Herzog Construction, the contractor participating in the demonstration project, used excellent practice in placing the asphalt concrete mixture.

The rehabilitation strategy for the segment of I-29 included milling the existing asphalt concrete wearing surface and placing the asphalt concrete binder layer (SP048F) and wearing surface (SP125B). A tack coat was placed on the milled or previous surface prior to paving. Special milling was completed at the beginning and ends of bridges to maintain proper elevation transitions.

Three rollers were used to compact the mixture: a Bomag BW284 breakdown roller, a Sakai GW750-2 rubber tired intermediate roller, and a Hamm HD1480 oscillatory finish roller. Nuclear densities and uncompacted material sampling were monitored by quality control personnel to ensure adequate densities were being obtained by the compaction operation. Cores were also taken at random locations for acceptance of the mixture.

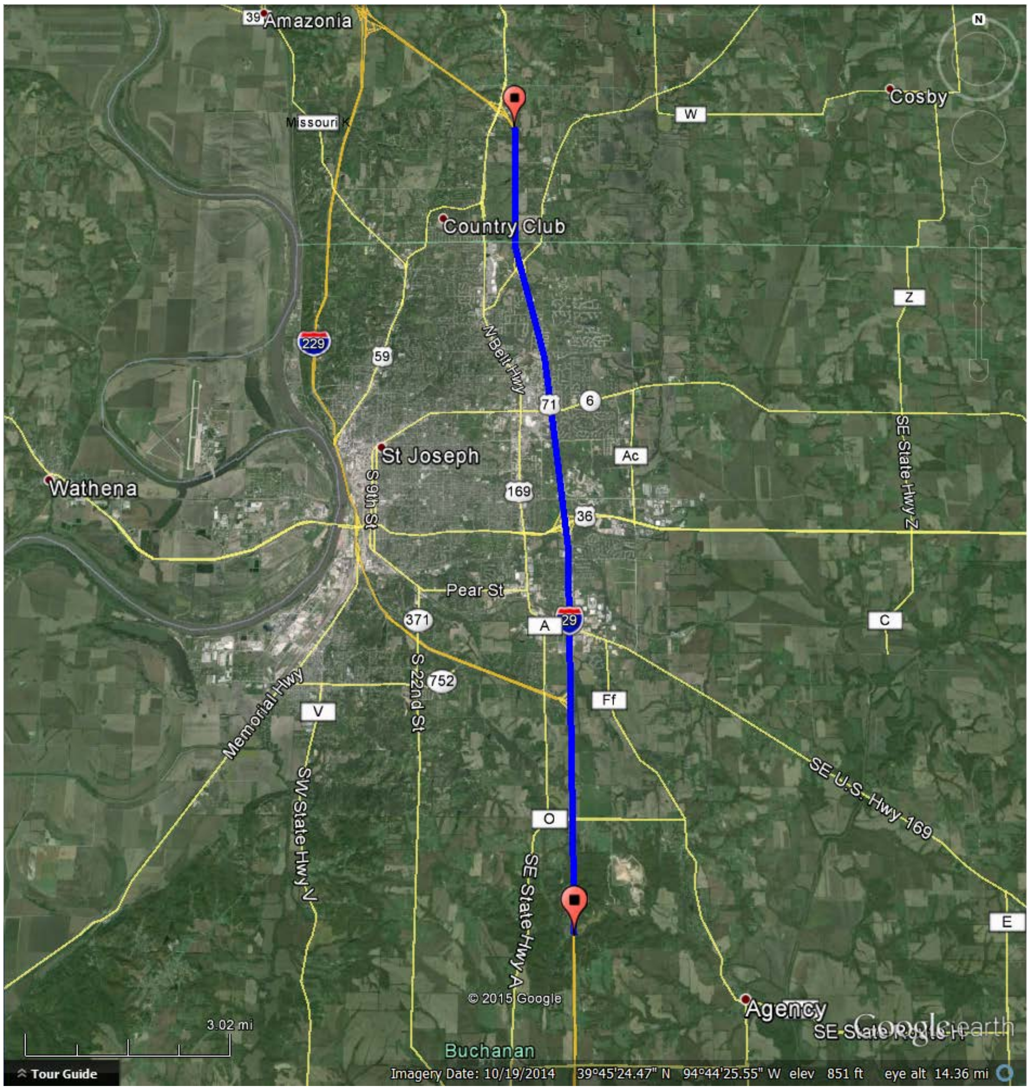


Figure 17. Missouri I-29 Project Location.

Table 9. Contacts for Missouri Demonstration Project

Bill Stone	MoDOT	William.Stone@modot.mo.gov	573-526-4328
Dan Oesch	MoDOT	Daniel.Oesch@modot.mo.gov	573-751-8608
James Gillespie	MoDOT	James.Gillespie@modot.mo.gov	660-646-3218
Paul Angerhofer	MOBA	pangerhofer@moba.de	770-634-0058
Harold Von Quintus	ARA	hvonquintus@ara.com	512-694-1511
Joseph Reiter	ARA	jreiter@ara.com	217-356-4500
Steve Cooper	FHWA	Stephen.Cooper@dot.gov	720-963-3722
Mike McGee	FHWA	Mike.Mcgee@dot.gov	573-638-2608

MOBA – MOBA Mobile Automation AG
ARA – Applied Research Associates, Inc.
FHWA – Federal Highway Administration

Figure 18. Paving Operation Used along the Missouri I-29 Project.

New Jersey DOT Project

From October 14 to October 21 2015, the New Jersey Department of Transportation (NJDOT) conducted a demonstration project along US 130 near North Brunswik, NJ. The demonstration project, from milepost 72.68 to milepost 83.58, runs from US 1 in North Brunswick to Main St. in Cranbury Township (see figure 15). Only the northbound direction of US 130 was scheduled for rehabilitation as part of the demonstration.

The project included placing a 1.75-inch overlay over a milled asphalt concrete surface. Paving operations were observed on September 1 and 2, and all field data were collected during the same time frame. Table 5 lists the contacts for this project.

The asphalt concrete mixture was delivered to the project using end-dump discharge trucks. The asphalt concrete mixture was dumped into a Roadtec material transfer device. A Caterpillar® rubber-tracked paver was used to place the mixture on the surface. Figure 16 shows the overall delivery-paving operation. Noncontact sensors were used to control the longitudinal grade or profile of the mixture being placed. Overall, Trap Rock Industries, the contractor participating in the demonstration project, used excellent practice in placing the asphalt concrete mixture.

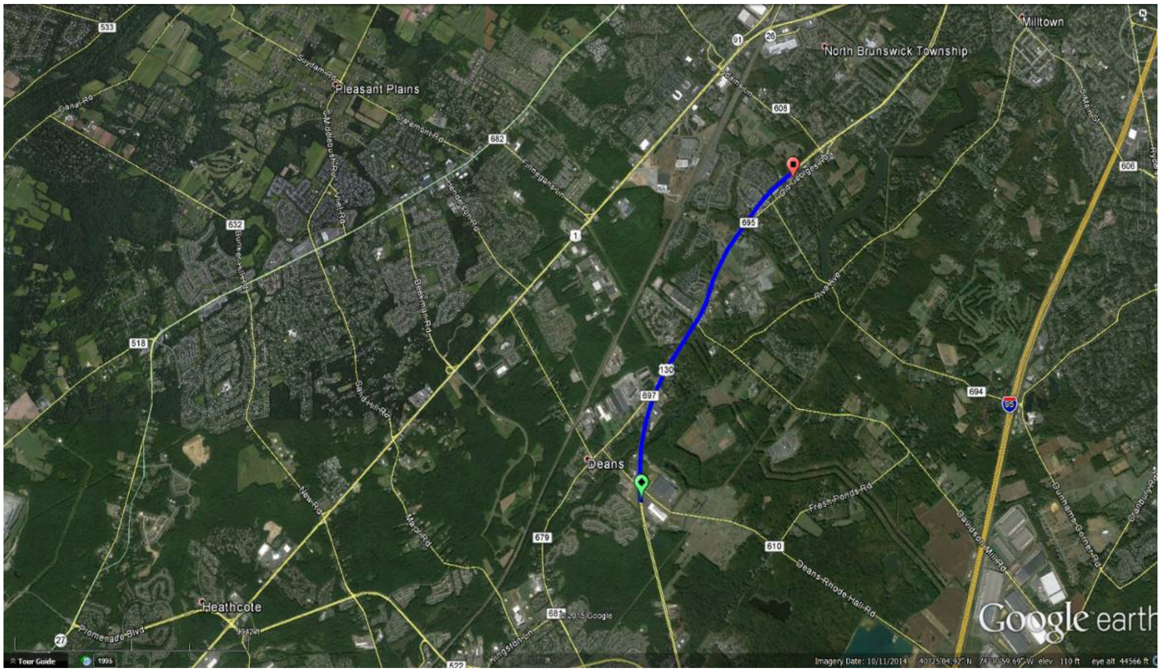


Figure 19. New Jersey US 130 Project Location

Table 10. Contacts for New Jersey Demonstration Project

Stevenson Ganthier	NJDOT	Stevenson.ganthier@dot.state.nj.us	609-530-4445
Robert Blight	NJDOT	Robert.blight@dot.state.nj.us	609-530-4445
Brian Tobin	Rutgers University	btobin@rci.rutgers.edu	848-445-2961
Paul Angerhofer	MOBA	pangerhofer@moba.de	770-634-0058
Harold Von Quintus	ARA	hvonquintus@ara.com	512-694-1511
Joseph Reiter	ARA	jreiter@ara.com	217-356-4500
Steve Cooper	FHWA	Stephen.Cooper@dot.gov	720-963-3722
Kostas Svamas	FHWA	Kostas.Svamas@dot.gov	609-637-4208

MOBA – MOBA Mobile Automation AG
ARA – Applied Research Associates, Inc.
FHWA – Federal Highway Administration

The rehabilitation strategy for the segment of US 130 included milling the existing asphalt concrete wearing surface and placing an asphalt concrete base layer and an SMA wearing surface. An edge sealer and tack coat was placed on the milled or previous surface prior to paving. The same sealing and tack pattern was continued on all surfaces that would come into contact with the new asphalt concrete paving materials.

Three Caterpillar steel drum rollers were used to compact the mixture, all CB-534Ds. Two of the rollers were used as breakdown rollers, and one was used as a finishing roller. The two breakdown rollers were fitted with intelligent compaction (IC) systems, which the researchers at Rutgers University are using to compare to the IR data.

Nuclear densities were monitored by quality control personnel to ensure adequate densities were being obtained by the compaction operation. Cores were also taken at random locations for acceptance of the mixture.

Figure 20. Paving Operation Used along the New Jersey US-130 Project Location.

North Carolina DOT Project

In May 2016, the North Carolina Department of Transportation (NCDOT) conducted a demonstration project along I-40 in Raleigh, NC. The demonstration project in Raleigh, NC, was performed as part of the I-40/440 FORTIFY Stage II reconstruction effort on 11.5 miles of interstate highway (see figure 17). The Stage II project extends from US 1/64 to I-440 on I-40; on the South side of Raleigh.

For the field demonstration section observed by project personnel May 25, 2016, paving was performed on I-40 from 0.75 miles west of the Lake Wheeler Rd. overpass to the Lake Dam Rd.

overpass; approximately 1.5 miles. Westbound lane 2 and 8 ft. of lane 3 were paved for a total width of 19 ft. during the field observation. Table 5 lists the contacts for this project. Table 8 lists the contacts for the North Carolina project.

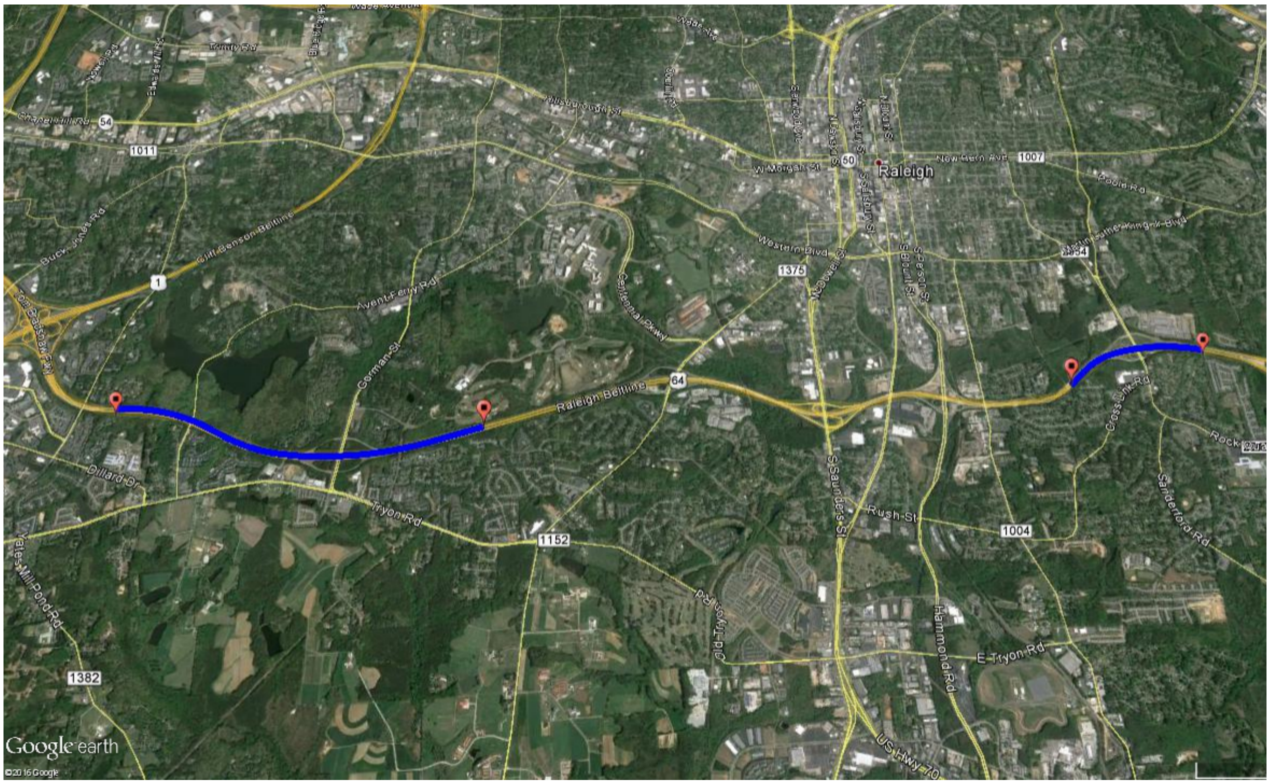


Figure 21. North Carolina I-40 Project Locations

The asphalt concrete mixture was delivered to the project using end-dump discharge trucks. The asphalt batching plant was less than 10 miles haul distance to any point along the project. The asphalt concrete mixture was dumped into a Roadtec material transfer device. A Caterpillar® rubber-tracked paver was used to place the mixture on the surface. Figure 18 shows the overall delivery-paving operation for the project. Noncontact sensors were used to control the longitudinal grade or profile of the mixture being placed. Overall, Granite Construction, the contractor participating in the demonstration project, used excellent practice in placing the asphalt concrete mixture.

Table 11. Contacts for North Carolina Demonstration Project

Nilesh Surti	NCDOT	nsurti@ncdot.gov	919-707-2403
Paul Angerhofer	MOBA	pangerhofer@moba.de	770-634-0058
Harold Von Quintus	ARA	hvonquintus@ara.com	512-694-1511
Joseph Reiter	ARA	jreiter@ara.com	217-356-4500
Steve Cooper	FHWA	Stephen.Cooper@dot.gov	720-963-3722
Jim Phillips	FHWA	Jim.Phillips@dot.gov	919-747-7018

MOBA – MOBA Mobile Automation AG
ARA – Applied Research Associates, Inc. (Subject Matter Expert for the Project)
FHWA – Federal Highway Administration

Figure 22. Paving Operation Used along the North Carolina I-40 Project.

The reconstruction strategy for the segment of I-40 during the field demonstration project involved placing a 1.5 in. asphalt concrete surface layer. A tack coat was placed on the previous surface prior to paving.

Compaction of the mix was achieved using two Volvo and two Caterpillar steel-drum rollers in the breakdown, intermediate, and finish roller positions. The breakdown and intermediate rollers were used in the vibratory setting, with the finish roller in the static setting. The various rollers were used in each position due to equipment breakdowns and maintenance. However, no matter the configuration of specific rollers, the crew was able to adjust the roller pattern to achieve density. Cores were taken at random locations for acceptance of the mixture on the day following paving.

Virginia DOT Project

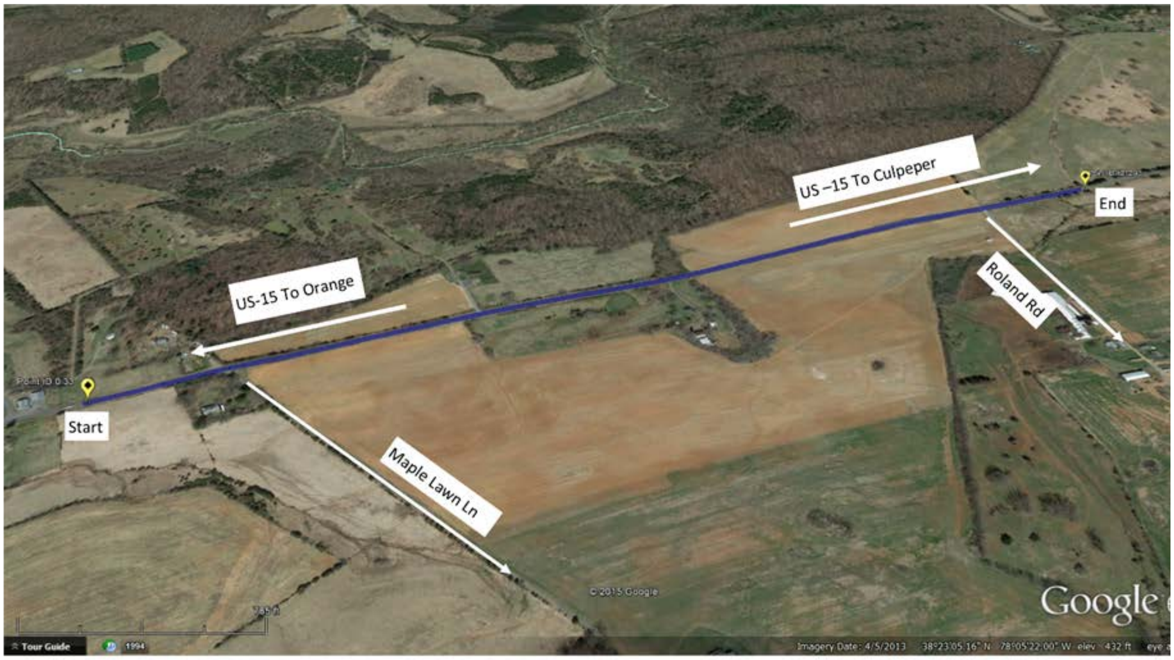
In July 2015, the Virginia Department of Transportation (VDOT) conducted a demonstration project on US Route 15 South of Culpeper, VA. The demonstration project started at the intersection of US 15 and CR 649 and ended at the intersection of US 15 and CR 648 to the South, approximately 2 miles total length (see figure 19). Paving began in the southbound lanes on July 21, 2015, and continued through July 25, 2015. Paving operations were observed July 21 and 23 by the project team. The project included placing a new specification, 50 gyration, 2-inch overlay of an existing asphalt concrete surface. All field data were collected during the same time frame. Table 5 lists the contacts for this project.

The asphalt concrete mixture was produced in a counter flow drum plant less than five miles from the North end of the paving site. The specific mixture used for the project was part of a special specification study using 50 gyration mixtures to attempt to increase the asphalt content of the resulting roadway. As such, VDOT personnel performed a coring study alongside the IR demonstration project to determine the effects of both changes to their current paving materials and processes. These research cores were used as additional testing points for analyzing the relationship of the IR, core density, and non-nuclear field density data.

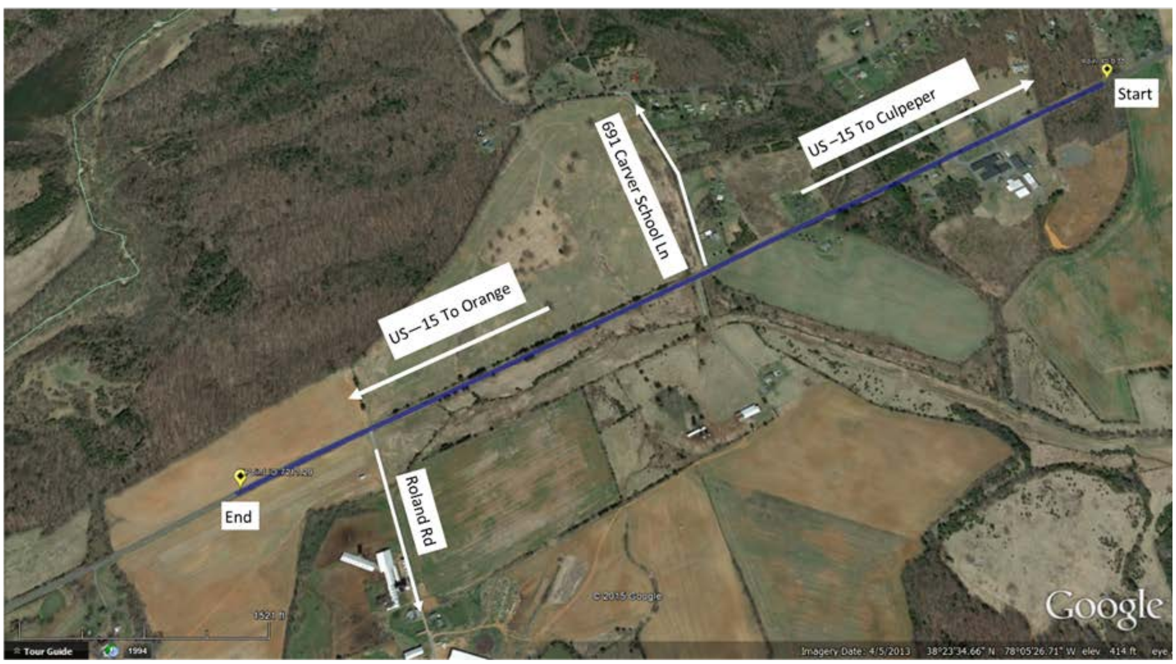
The mixture was delivered to the project using end-dump trucks. The asphalt concrete mixture was dumped into a Roadtec material transfer device. A Caterpillar® rubber-track paver was used to place the mixture on the surface. Figure 20 shows the overall mixture delivery-paving operation used along the US-15 rehabilitation project. Noncontact sensors were used to control the longitudinal grade or profile of the mixture being placed. Overall, Chemung Contracting, the contractor used to assist in the demonstration project, used excellent practice in placing the asphalt concrete mixture.

The rehabilitation strategy for the segment of US 15 included only the placement of an asphalt concrete overlay surface. A trackless tack coat was placed on the in-service surface prior to placing the new asphalt concrete mat.

Two rollers were used to compact the mixture: one Caterpillar CB54 breakdown roller, and one Hamm HD 90 finish roller. The contractor’s nuclear density gauge was not functional for the US 15 operation, so quality control and acceptance for compaction were based on square plugs that were cut from the newly placed mat. In addition, cores were taken for a VDOT study on the special specification asphalt concrete mixture.



(a) July 23 northbound US 15 paving



(b) July 21 southbound US 15 paving

Figure 23. Virginia US 15 Project Location

Table 12. Contacts for the Virginia Demonstration Project

Kevin McGhee	VDOT	Kevin.McGhee@VDOT.Virginia.gov	207-624-3305
Ed Dalrymple	Chemung Contracting	EDalrymple@dalholding.com	540-829-7203
Paul Angerhofer	MOBA Inc.	pangerhofer@moba.de	770-634-0058
Harold Von Quintus	ARA	hvonquintus@ara.com	512-694-1511
Joseph Reiter	ARA	jreiter@ara.com	217-356-4500
Steve Cooper	FHWA	Stephen.Cooper@dot.gov	720-963-3722

MOBA – MOBA Mobile Automation AG
ARA – Applied Research Associates, Inc.
FHWA – Federal Highway Administration

Figure 24. Delivery-Paving Operation Used along the Virginia US-15 Project.

West Virginia DOT Project

In July 2016, the West Virginia Department of Transportation (WVDOT) conducted a demonstration project on the new construction project on State Route 10 in Logan, WV. The demonstration project in Logan, WV, was performed as part of the new construction realignment of State Route 10. The new roadway runs along the western/southern banks for the Guyandotte River, whereas the current alignment of SR 10 runs on the eastern/northern banks of the river (see figure 21).

Figure 25. West Virginia State Route 10 Project Locations

The field demonstration section observed by project personnel was approximately one half mile south of the new SR 10 bridge over the Guyandotte River; across from McConnell, WV. The demonstration project observed a small section of the construction project from July 26 to July 28, 2016. Following the demonstration project WVDOT continued IR scanner temperature data collection on SR 10 on August 3 and August 4, 2016. Table 5 lists the contacts for this project.

Table 13. Contacts for the West Virginia Demonstration Project

Michael Pumphrey	WVDOT	Michael.E.Pumphrey@wv.gov	304-206-8625
Joey Farrell	Jobsite Technologies	farrell.joey@gmail.com	941-460-0250
Harold Von Quintus	ARA	hvonquintus@ara.com	512-694-1511
Joseph Reiter	ARA	jreiter@ara.com	217-356-4500
Steve Cooper	FHWA	Stephen.Cooper@dot.gov	720-963-3722
Hamilton Duncan	FHWA	Hamilton.Duncan@dot.gov	304-347-5329

ARA – Applied Research Associates, Inc. (Subject Matter Expert for the Project)
FHWA – Federal Highway Administration

The asphalt concrete mixture was delivered to the project using end-dump discharge trucks. Most of the trucks arrived on site untarped, but when a truck was observed to be tarped the observed average temperature was generally 10-15 degrees higher than the untarped trucks. The asphalt batching plant was less than 15 miles haul distance to any point along the project. A Wirtgen Group Voegle rubber-tired paver was used to place the mixture on the surface. Figure 22 shows the overall mixture delivery-paving operation used along the State Route 10 construction project. An MTV was added to the paving operation, but after the initial field demonstration project and data collection had been completed. Noncontact sensors were used to control the longitudinal grade or profile of the mixture being placed. Overall, West Virginia Paving (WV Paving), the contractor participating in the demonstration project, used good practice in placing the asphalt concrete mixture.

Figure 26. Mixture Delivery-Paving Operation used along the State Route 10 Project

The construction strategy for the segment of SR 10 during the field demonstration project involved placing a 4-inch open graded drainage base on a geosynthetic filter fabric July 26. On July 27 and July 28, a 3-inch asphalt concrete base layer was paved over the drainage base without tack to preserve the properties of the drainage base. Figure 23 shows the placement of the drainage base on the geosynthetic, and the base paving on the drainage base layer.

Figure 27. Placement of Drainage Base on the Geosynthetic Fabric along State Route 10

Compaction of the mix was achieved using two Volvo steel-drum rollers in the breakdown and finish roller positions. The breakdown roller was used in the static then vibratory settings, with the finish roller in the vibratory then static settings. The rolling pattern of each of the rollers was adjusted using a QC process with a nuclear gauge, and the crew was able to adjust the roller pattern to achieve density.

Cores were taken in select locations to compare the IR scanner temperature results with the QC nuclear gauge, a PQI non-nuclear density gauge, and standard pavement coring. Full analysis of the comparison results are provided in the analysis section. Error! Reference source not found. shows the density measuring devices used, coring of the first pass of base paving, and a core location with visible suspected end-of-load segregation. The core in the location of suspected end-of-load segregation does not exhibit the same water runoff as the other cores indicating it likely has a higher void content with larger pores, likely due to segregation.

On August 3 and August 4, 2016 WV Paving paved a second base layer and included a material transfer vehicle (MTV) as part of the paving operation. WVDOT sent the raw data to the project team to be included in the analysis to provide additional data comparisons to paving without the MTV.

Data AnalysEs and Observations from Field Demonstration Projects

The IR data for all of the field demonstration projects were provided in a ".txt" format which included the raw temperature data collected from the Pave-IR system. An analysis of the txt file was completed on all projects to determine the temperature differentials relative to the three categories established in PP-80. This chapter of the report summarizes the analyses completed and compares the results between all of the field demonstration projects.

Temperature Differential Defined

The variable used for the segregation criteria is adopted from the specification developed by the Texas Department of Transportation (TxDOT), i.e., Tex-244-F, which defines the temperature differential, Tdiff, as the following:

$$T_{\text{diff}} = T_{98.5} - T_{1.0} \tag{1}$$

Where $T_{98.5}$ and $T_{1.0}$ are the 98.5 and 1.0 percentiles obtained from the distribution of the temperature data, respectively. A graphical schematic of the temperature differential is provided in figure 24. Tex-244-F also requires the above temperature differential be calculated for each 150-foot segment for evaluation of thermal segregation.

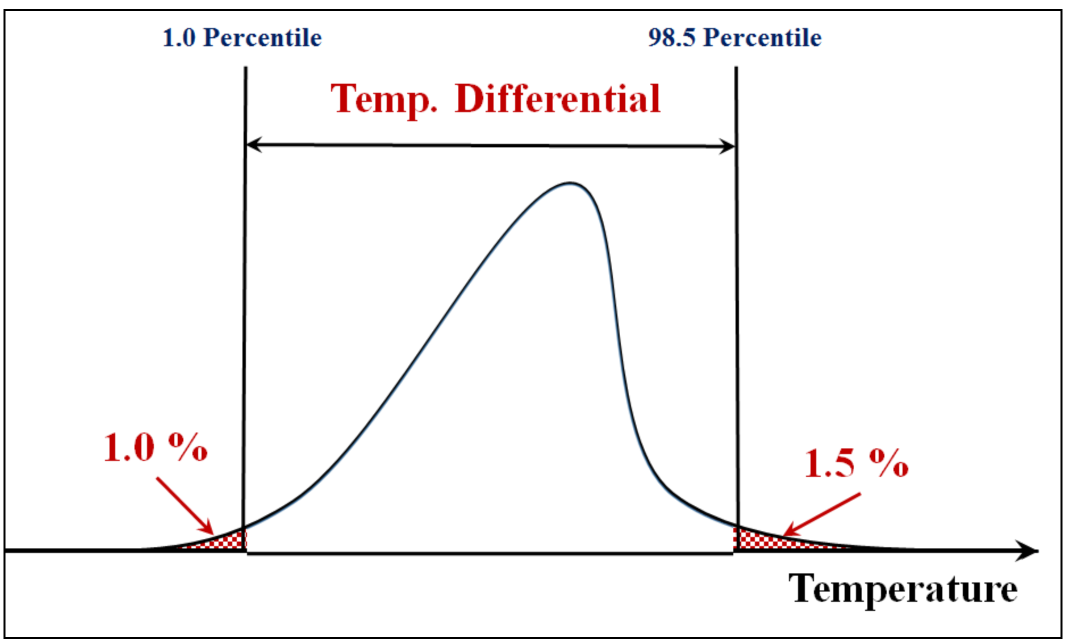


Figure 28. Schematic for the Definition of Temperature Differential.

According to the proposed AASHTO specification for Pave-IR, the presence and severity of the thermal difference (referred to in the specification as thermal segregation) is defined as the following:

- T_{diff}, ≤ 25°F: No thermal difference
- 25°F < T_{diff}, ≤ 50°F: Moderate thermal difference
- 50°F < T_{diff}, : Severe thermal difference

Unprocessed Temperature Data

The distribution of the raw temperature data was determined for all projects. Figures 25.a and 25.b show an example from the Alaska DOT field demonstration project for paths 1 and 5, respectively. Also shown in the figure is the basic statistics obtained from the raw data: standard deviation, maximum, minimum, 1.0 and 98.5 percentiles, and the temperature differential.

Figure 25 indicates that the mat temperature is mostly between 280 °F and 320 °F. Both distributions exhibit a long tail towards the lower temperature range, with a second peak observed at approximately 120°F for path 1 and 160°F for path 5. In addition, the maximum temperature recorded by the PaveIR system for path 5 was found to be 953.6°F. It is clear that some of these high and low temperature values are not representative of the asphalt mat temperature.

While it is difficult to explain the reason behind such an extremely high temperature in the data, it is suspected that the lower temperature is mainly due to: (1) the temperature measured towards (or outside) the paving edge, (2) temperature recorded during paver stops, and/or (3) human interference (i.e., the system measuring the temperature of a person in between the IR sensor and the pavement). These findings suggest that the raw data needs to be filtered to eliminate any extraordinary temperature readings, which is discussed in the following section.

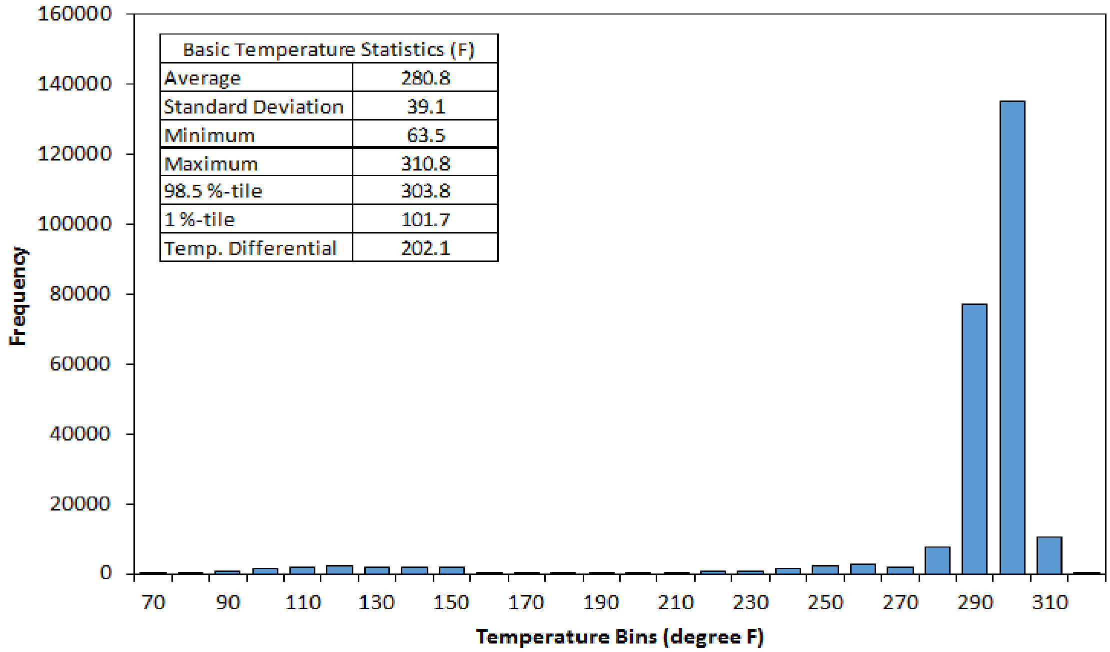
Prescreening of Temperature Data

To eliminate any invalid temperature readings shown in the above section of the report, both thermal profiles from paths 1 and 5 were pre-screened using the following criteria the first two of which are adopted from Tex-244-F.

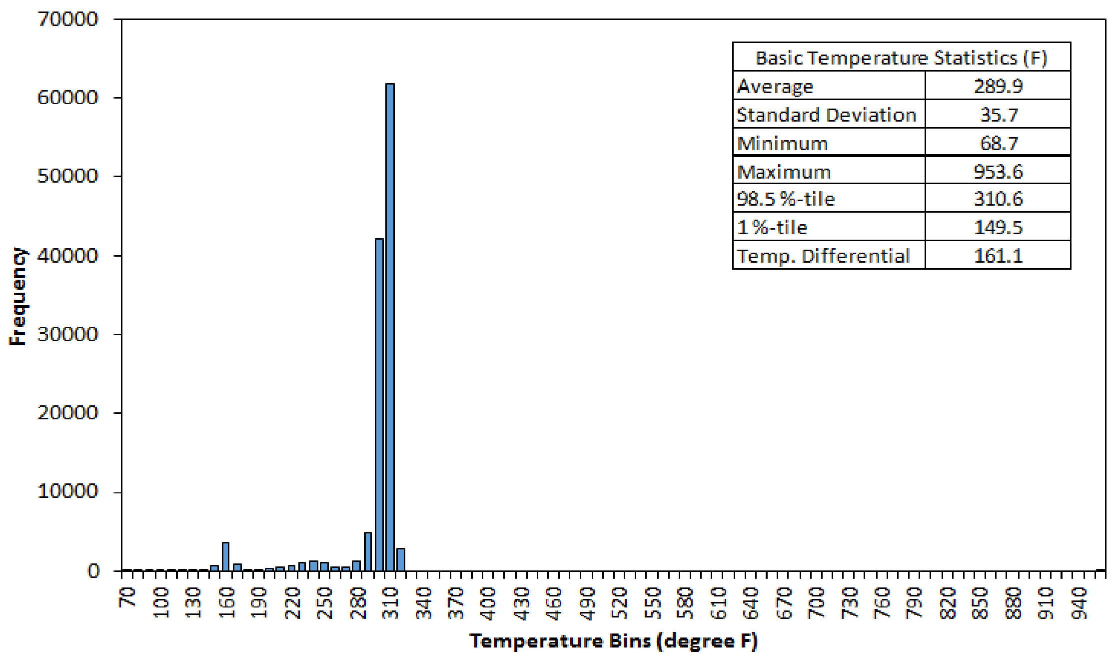
1. Eliminate temperature measurements within 1 to 2 feet of the edge of the uncompacted mat: To meet this criterion, the first three scan points from each edge of the mat were eliminated from the analysis. These scan points are:

a. Scan points 1, 2, and 3 located at 0 ft., 0.8 ft., and 1.6 ft., respectively, from the northern edge of mat.

b. Scan points 27, 26, and 25 located at 0 ft., 0.8 ft., and 1.6 ft., respectively, from the southern edge of mat.



(a)



(b)

Figure 29. Unprocessed Temperature Distribution for (a) Path 1 and (b) Path 5 during the Alaska DOT Field Demonstration Project.

The Pave-IR Scan system includes an Auto Edge Detect feature. The feature uses a set of variables to monitor the mat. The first variable is the scanner height or distance from the sample point to the scanner head. This distance is an important variable used by the Pave-IR system to calculate the measurement width and to determine the scanner head angle change necessary to achieve 10-inch (25 cm.) lateral increments between the readings. Taking into account any offset from the center of the machine, the operator enters a paving width sufficient to ensure the entire mat is monitored. With these variables entered into the Pave-IR project details, the system uses a temperature threshold of 176 °F (80 °C) to determine what readings are on the hot asphalt concrete mat and what are outside the edges of the mat. Any readings below 176 °F are considered outside the edges of the mat and are not used in the temperature difference calculations.

1. Eliminate locations of paver stops greater than 10 seconds: The raw thermal profiles were examined and locations identified where the paver stopped for more than 10 seconds. These locations are summarized in Table 2. Per Tex-244-F, the thermal profile between 2 feet behind and 8 feet in front of (in the direction of paving) each of these areas were eliminated from the analysis. ADOT&PF, however, does not delete the stops from the analysis. As such, the analysis was completed with and without the paver stops.
2. Eliminate temperature readings below 170°F or above 400°F: This criterion is to remove any temperature readings influenced by other potential interferences such as human interference and any random error associated with data collection.

Figures 26 to 39 show the distribution of the processed temperature data from the ten field demonstration projects.

Post-Processing of Temperature Data

Following the pre-screening procedure outlined above, a temperature contour plot was generated from the remaining data for further evaluation. To be consistent with Tex-244-F, the entire path was broken down into segments of 150 feet in length, and the segments were numbered from SG1 to SG24, with SG1 being the first 150-foot segment at the beginning (west end) of paving. Tex-244-F recommends that all paver stops greater than 1 minute in duration be removed from the processed temperature data for establishing the number of sections within the different temperature differential categories. Table 10 summarizes the analysis of the temperature differentials for excluding and including the paver stops. As shown, the use of the MTV and/or belly dump trucks significantly reduced the number of sections with temperature differentials exceeding 50 °F.

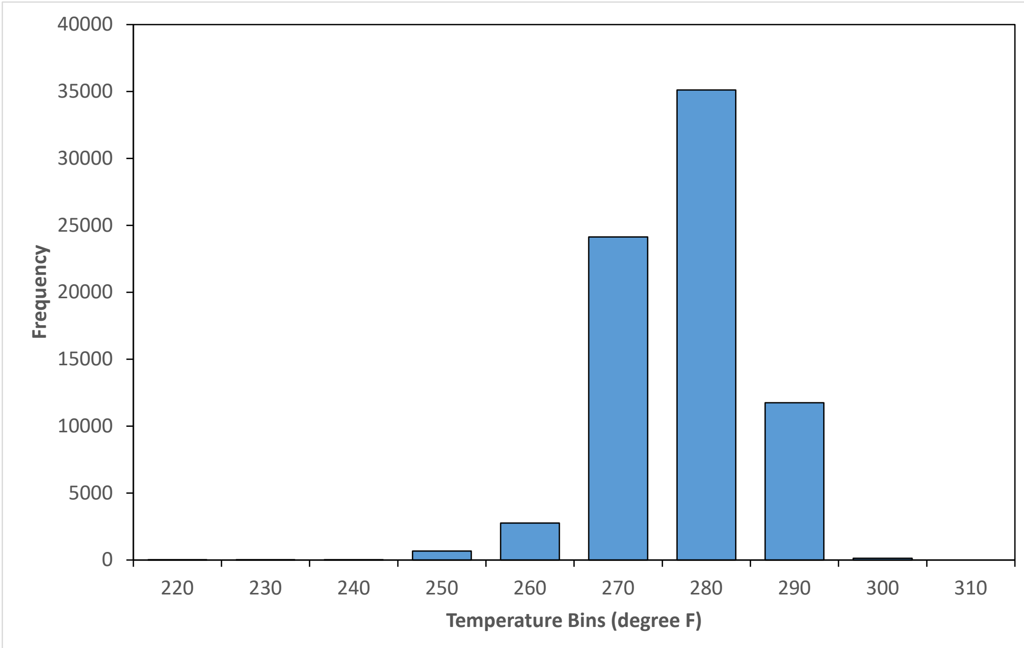


Figure 30. Processed Temperature Distribution for Path 1 on May 18, 2017; Alabama Field Demonstration Project.

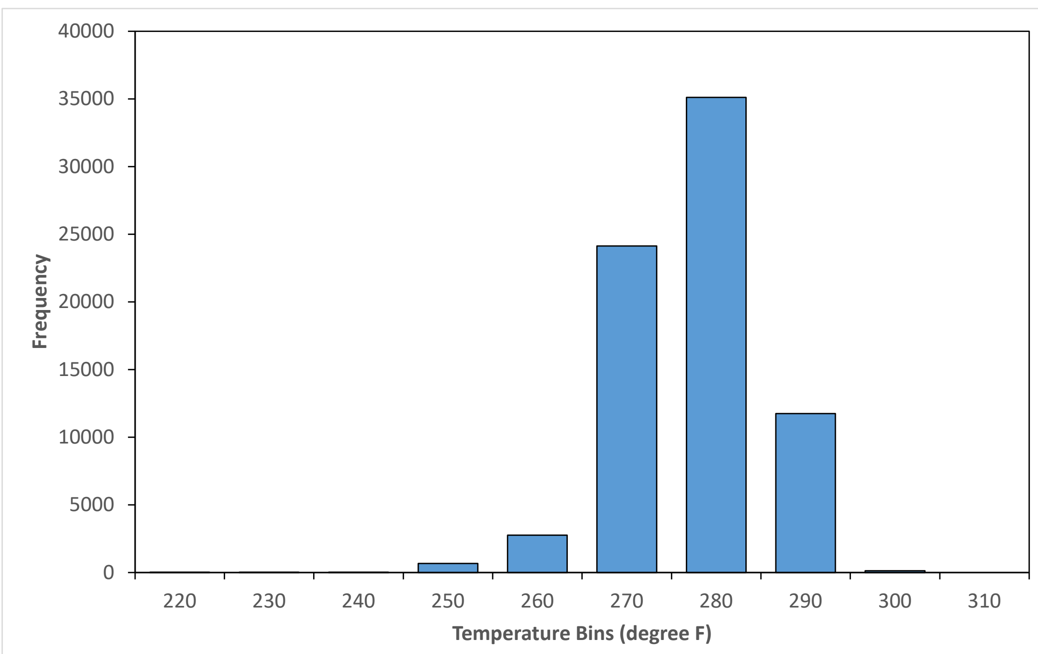


Figure 31. Processed Temperature Distribution for Path 2 on May 26, 2017; Alabama Field Demonstration Project.

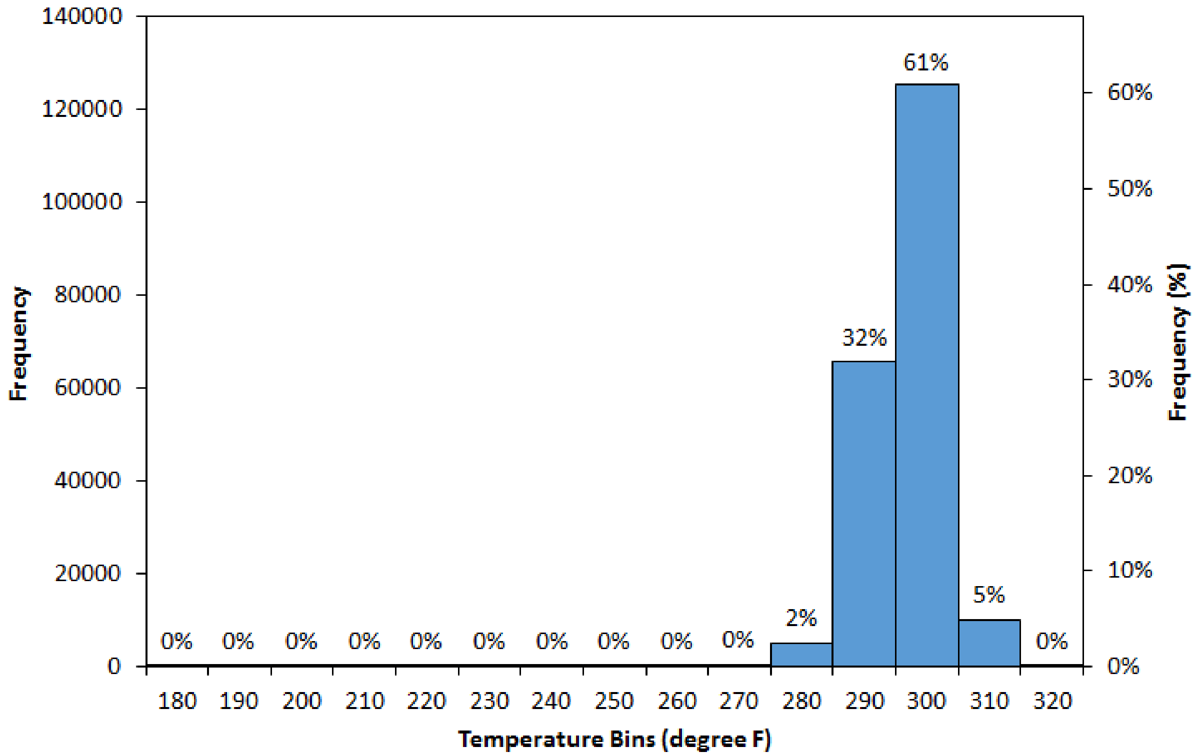


Figure 32. Processed Temperature Distribution for Path 1; Alaska Field Demonstration Project.

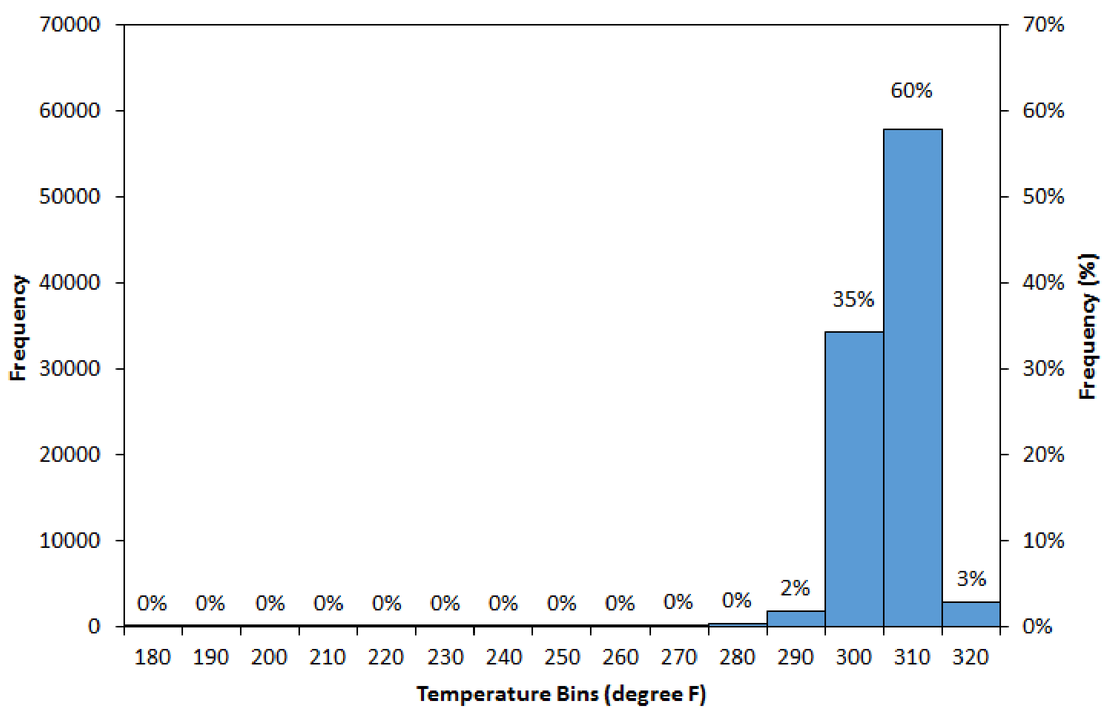


Figure 33. Processed Temperature Distribution for Path 5; Alaska Field Demonstration Project.

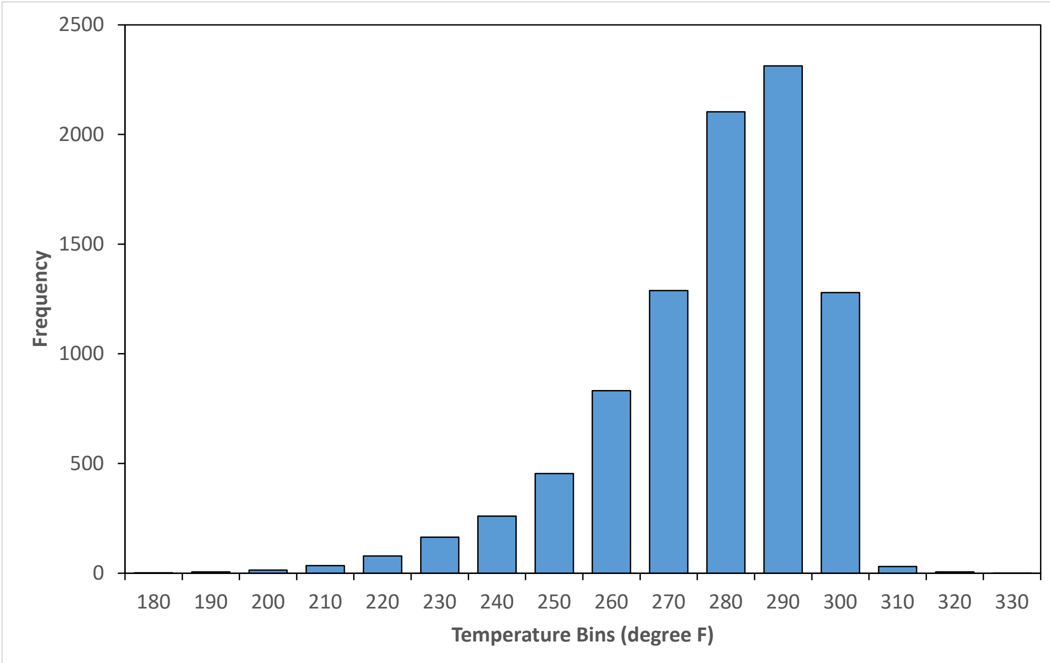


Figure 34. Processed Temperature Distribution, Lift 2 – Right Lane; Eastern Federal Lands Field Demonstration Project.

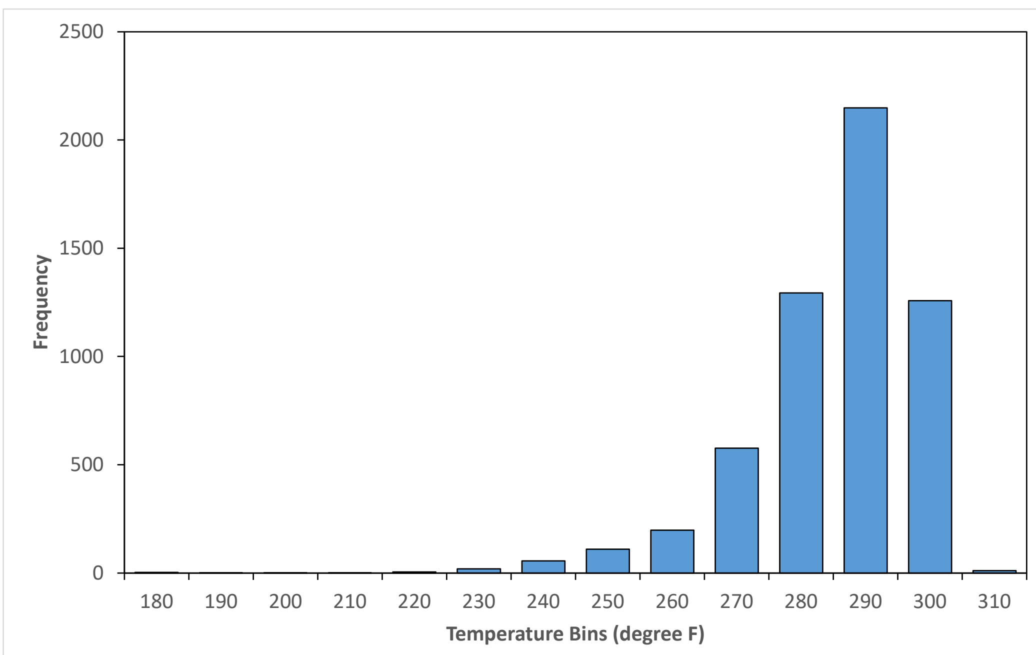


Figure 35. Processed Temperature Distribution, Lift 2 – Center Lane; Eastern Federal Lands Field Demonstration Project.

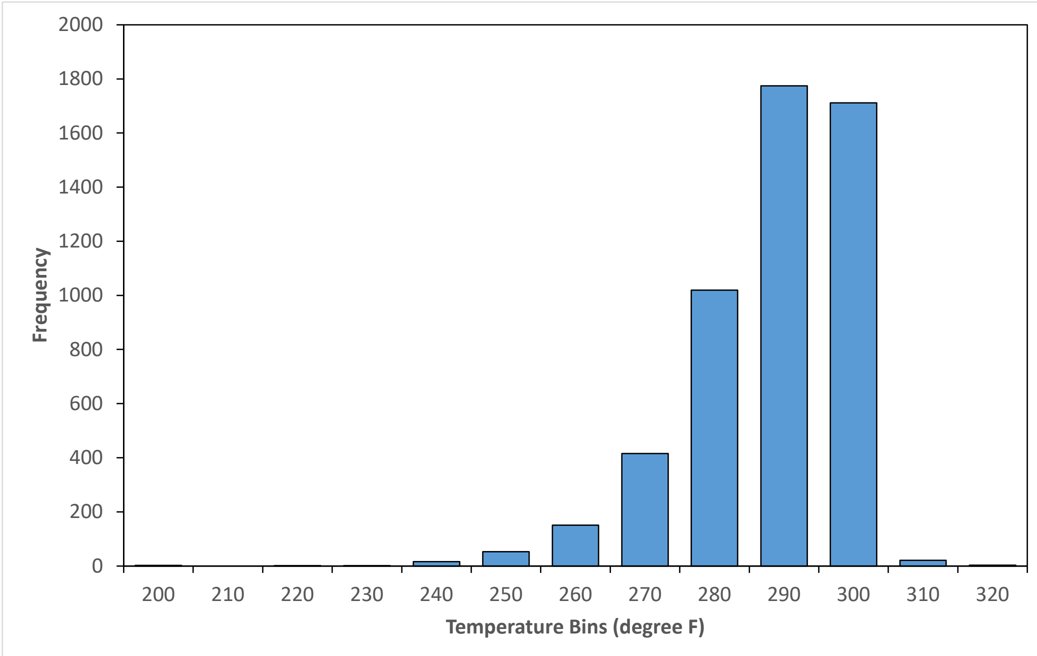


Figure 36. Processed Temperature Distribution, Lift 2 – Left Lane; Eastern Federal Lands Field Demonstration Project.

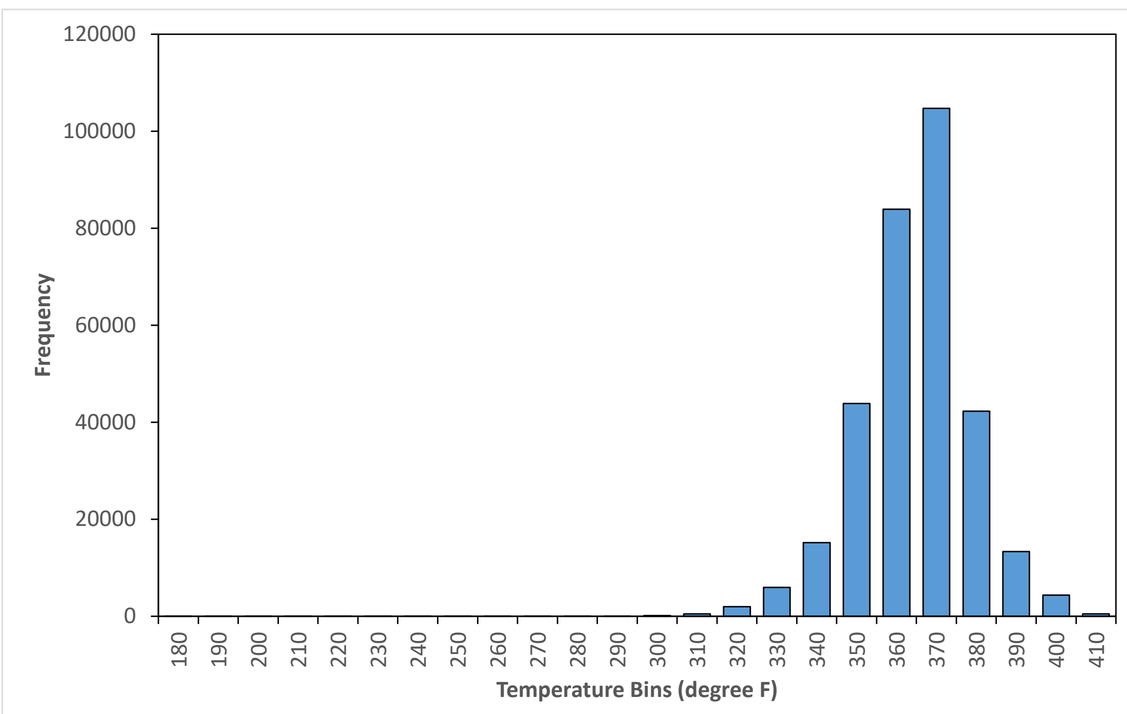


Figure 37. Processed Temperature Distribution, I-155; Illinois Field Demonstration Project.

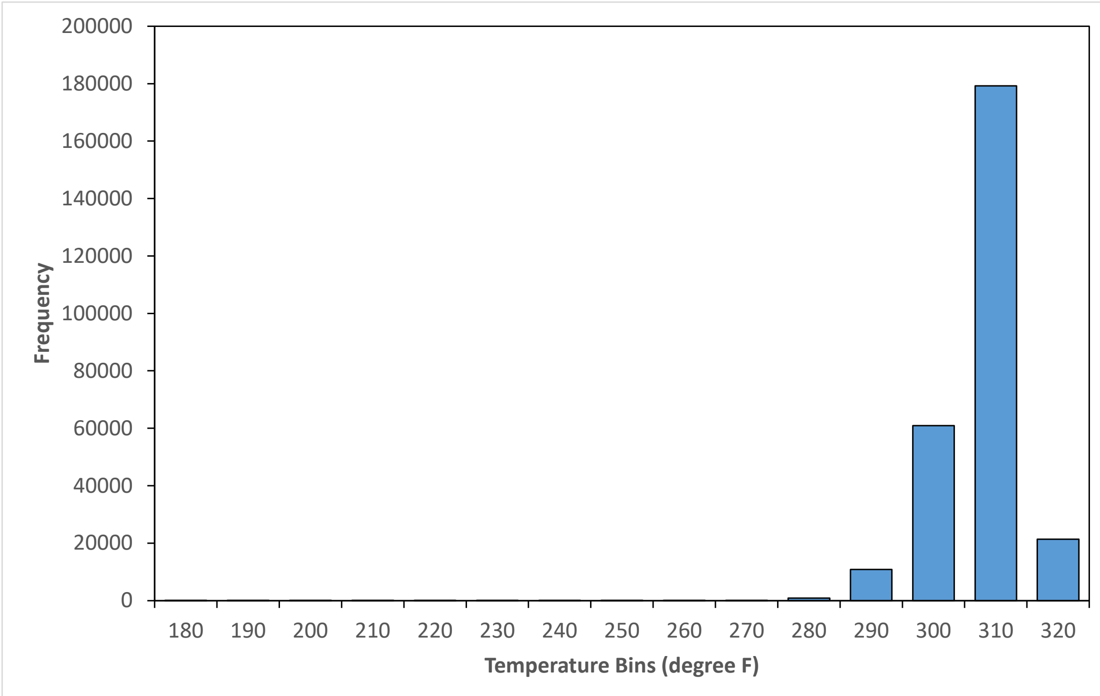


Figure 38. Processed Temperature Distribution, I-95; Maine Field Demonstration Project.

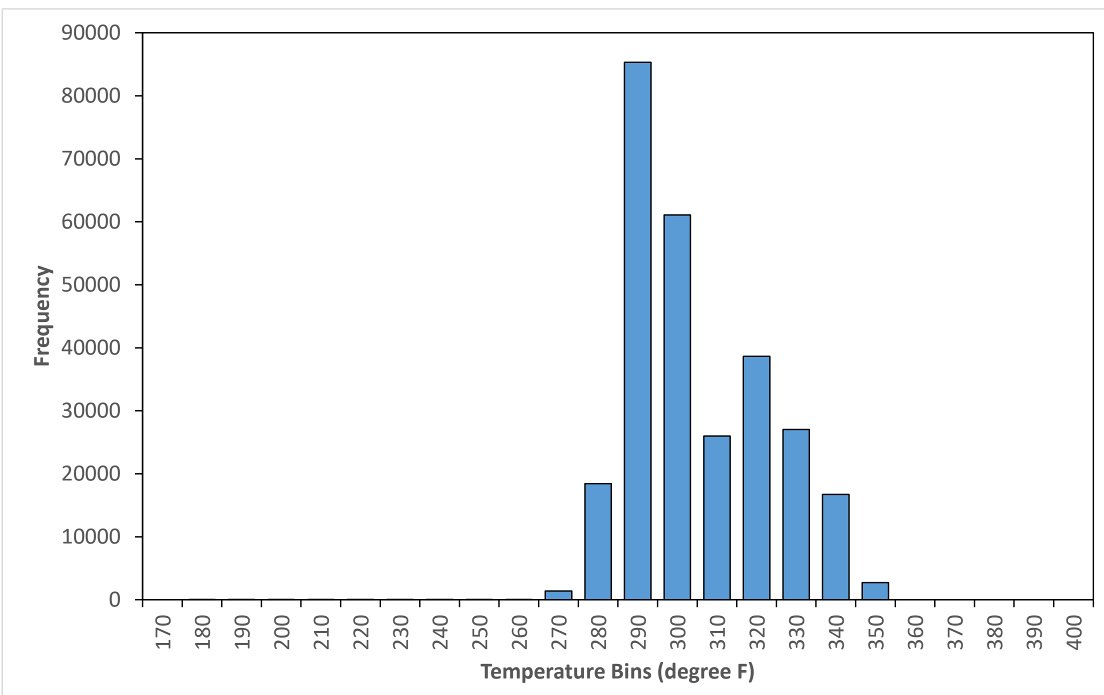


Figure 39. Processed Temperature Distribution, I-29; Missouri Field Demonstration Project.

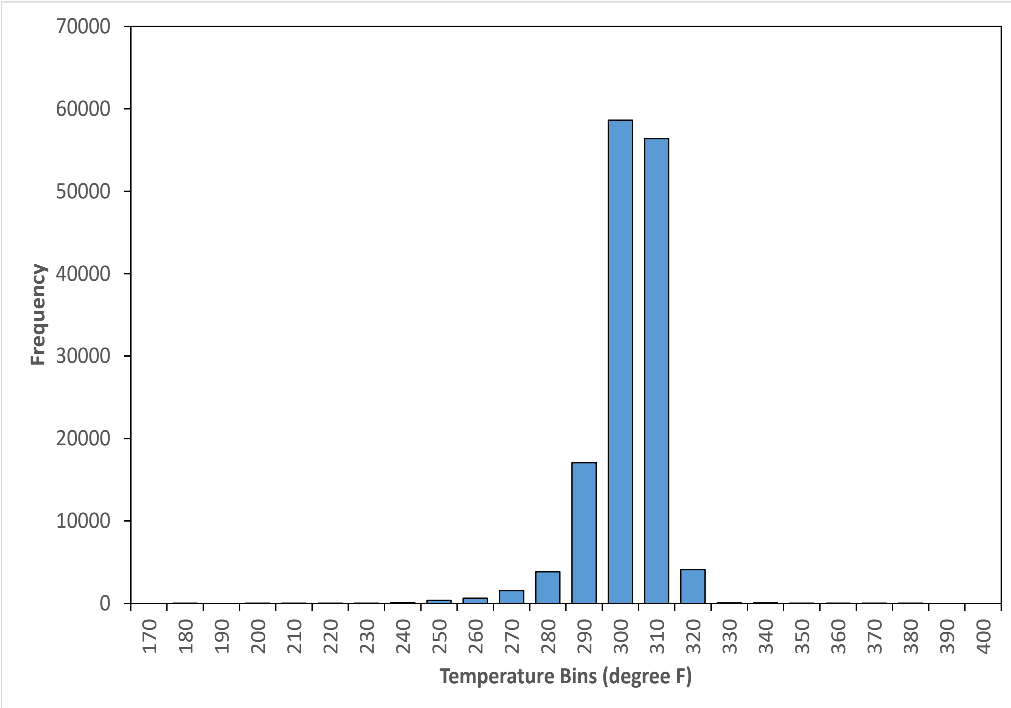


Figure 40. Processed Temperature Distribution, US-130; New Jersey Field Demonstration Project.

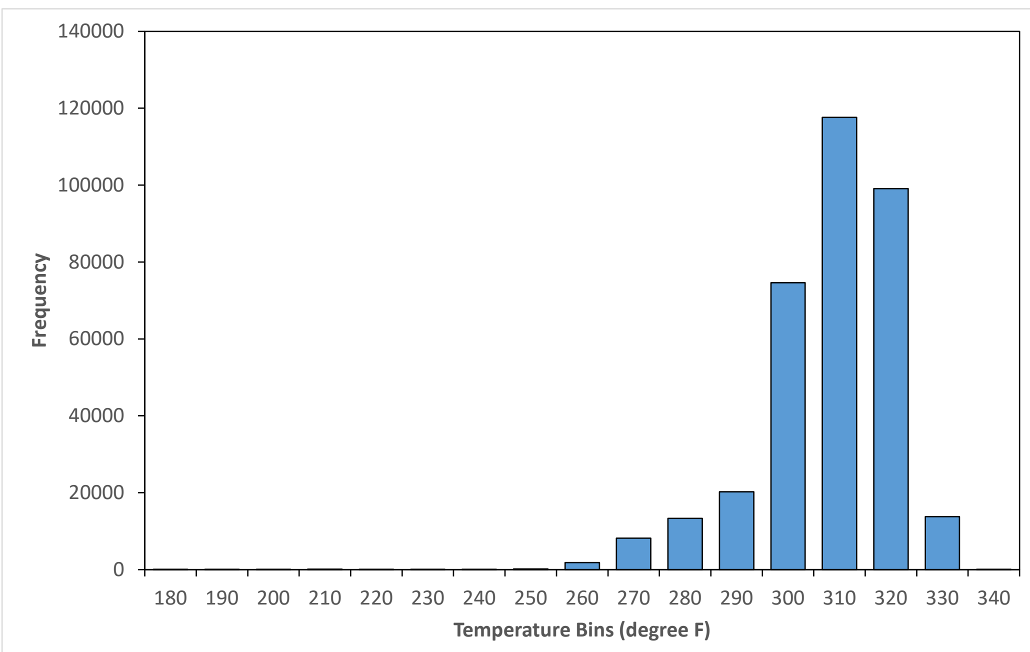


Figure 41. Processed Temperature Distribution, I-40; North Carolina Field Demonstration Project.

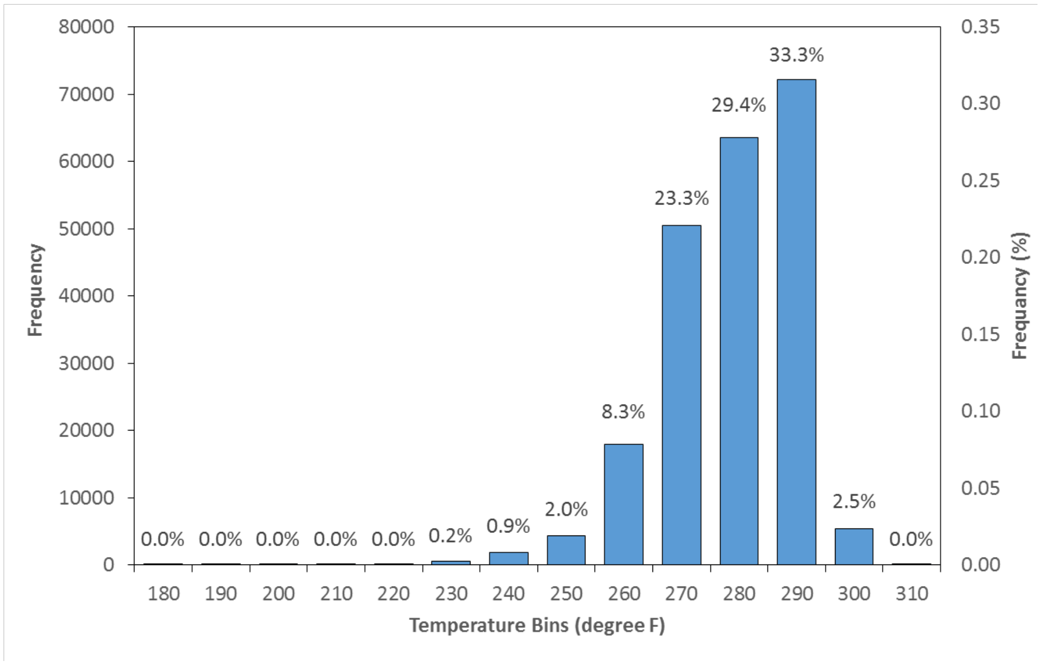


Figure 42. Processed Temperature Distribution, Southbound SR-15; Virginia Field Demonstration Project.

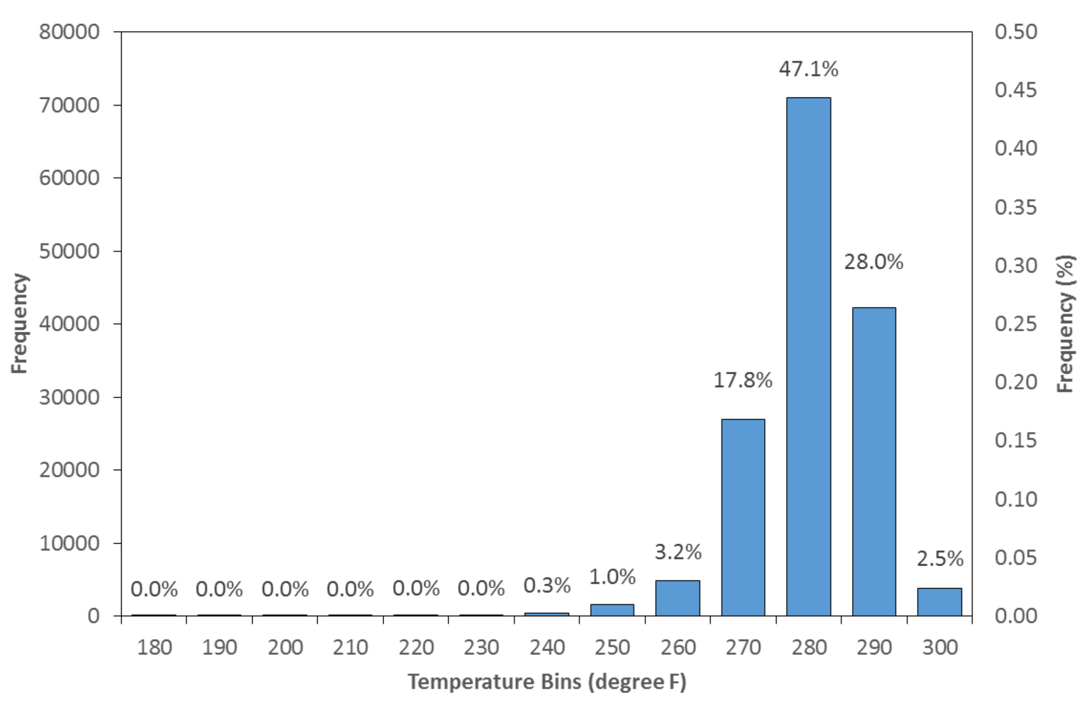


Figure 43. Processed Temperature Distribution, Northbound SR-15; Virginia Field Demonstration Project.

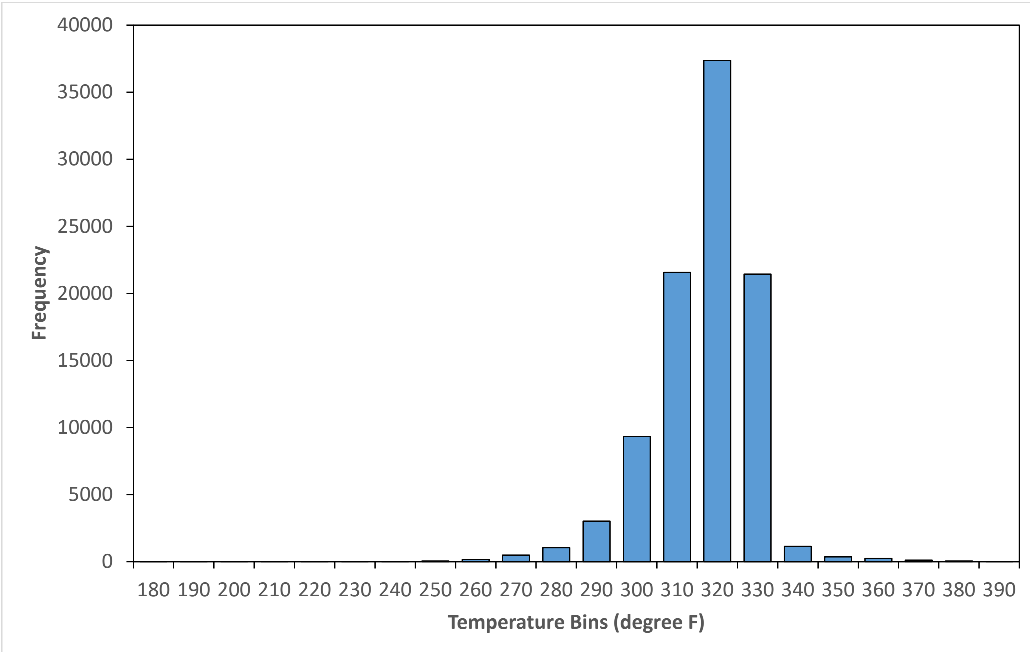


Figure 44. Processed Temperature Distribution, SR-10; West Virginia Field Demonstration Project.

Table 14. Summary of Results from the Field Demonstration Projects; Percentage of Sections within the Different Temperature Differential Categories

Paver Stops	Total Number of Increments	Number of Increments within Temp. Regimes			Thermal Streaking
		Minor	Moderate	Severe	
Alaska DOT Project					
Excluded	36	27	9	0	None
Included	36	22	8	6	None
Maine DOT Project					
Excluded	579	546	25	8	None
Included	579	494	56	29	None
Virginia DOT Project					
Excluded	84	72	10	2	None
Included	84	71	9	4	None
Eastern Federal Lands					
Excluded	108	2	24	82	None
Included	108	2	16	90	None
New Jersey DOT Project					
Excluded	262	188	49	25	None
Included	262	163	43	56	None
Missouri DOT Project					
Excluded	816	648	135	33	None
Included	816	440	170	206	None
North Carolina DOT Project					
Excluded	126	95	24	7	None
Included	126	79	24	23	None
West Virginia DOH Project; without MTV					
Excluded	99	0	74	25	None
Included	99	0	58	41	None
West Virginia DOH Project; with an MTV					
Excluded	159	133	19	7	None
Included	159	104	47	8	None
Illinois DOT Project					
Excluded	1,520	218	761	541	None
Included	1,502	196	708	598	None
Alabama DOT Project					
Excluded	48	34	14	0	None
Included	47	34	11	2	None

Table 15. Effect of Delivery Method on Percentage of Sections within the Different Temperature Differential Categories

Project	Delivery Truck Type	MTV Included	Percent Severe Temp. Differentials	Thermal Streaking
Alaska	Bottom-Dump	Windrows	17	None
Missouri	End Dump & Flow Boys	Yes	25	None
Alabama	End Dump	Yes	4	None
Maine	End Dump	Yes	5	None
New Jersey	End Dump	Yes	21	None
Virginia	End Dump	Yes	5	None
North Carolina	End Dump	Yes	18	None
West Virginia	End Dump	Yes	5	None
East Federal Lands	***End Dump***	***No***	***83***	***None***
Illinois	***End Dump***	***No***	***40***	***None***
West Virginia	***End Dump***	***No***	***41***	***None***

NOTE: The projects in italics and bold did not include a Material Transfer Vehicle during the placement of the asphalt concrete layer and had a significantly higher percent of severe temperature differentials.

Application of Pave-IR Scan™ in Quality Assurance Programs

The Pavement Quality Index (PQI) non-nuclear density gauge was used to measure or estimate the mat density at locations where temperature differential was observed or suspected based on the Pave-IR temperature contours and visual inspection. The PQI density test locations vary based on the type of testing. For the specific field demonstration project, the location of the PQI density points were determined at random and in areas where significant temperatures were recorded by the Pave-IR scanner.

The data were segregated into three groups, depending on how quality control procedures being used by the paving contractor: (1) contractor was using a nuclear or non-nuclear density gauge to ensure mat density exceeded minimum value before moving to the next roller section in real time, (2) contractor was using a density gauge for monitoring mat density after finish rolling, and (3) contractor was not monitoring densities during the rolling process. Figure 45 shows the relationship between COV of the mat temperatures and COV of the measured densities. As shown, as the variation increased in mat temperatures, the variation in mat densities correspondingly increased.

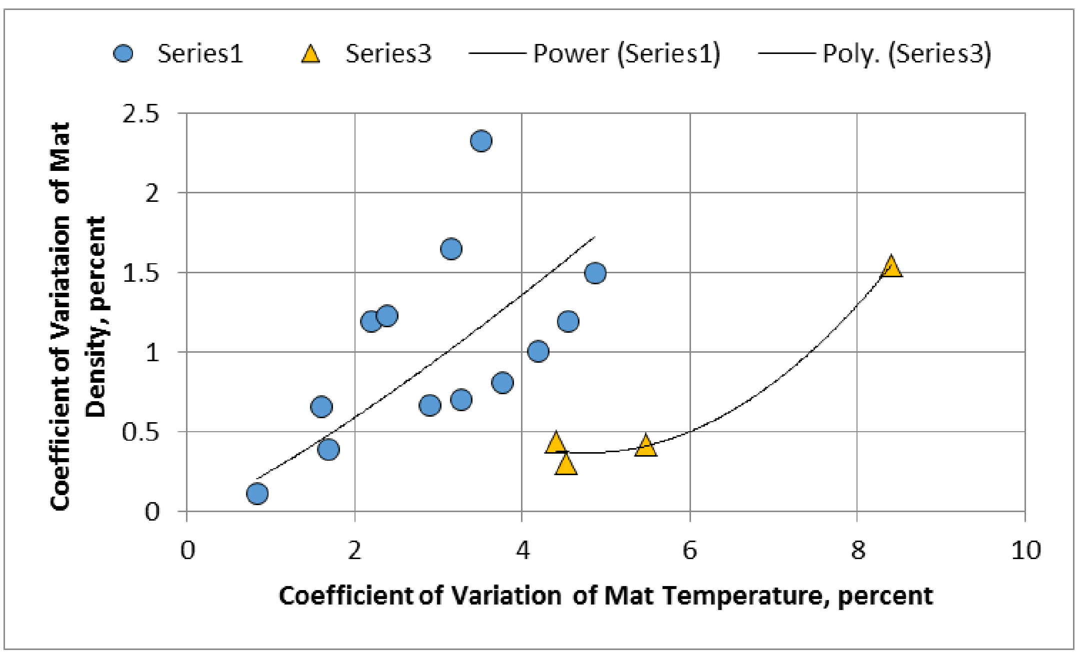


Figure 45. Coefficient of Variation of Mat Density as related to Coefficient of Variation of Mat Temperature.

The relationship in figure 45 shows the importance of controlling density through the control of mat temperature. This becomes important for any percent within limits specification or in other words, controlling the risk of the contractor for being penalized on density.

Infrared Workshops Summary and Assessment

Ten workshops were held over a period of 2 years as part of the infrared scanner technology deployment. The objectives of the R06C – Infrared (IR) Workshop were to:

1. Discuss the value added by using IR technology (what it is, why should you care, how does it affect your bottom line, how do you get there).
2. Present a summary of the results from the field demonstration projects. The workshops were targeted both to contractor and agency personnel.

Table 16 lists the workshops and other outreach activities that were completed for this deployment. This chapter of the report summarizes the results from the workshop and comments made by agency and contractor personnel that were involved in the field demonstration projects.

Table 16. Workshops and Other Outreach Activities on Application of Infrared Technology

Location/Host Agency	Type	Date	Comment	Number of Participants
Anchorage, Alaska	Workshop	11/14/2015	Pilot Workshop	10
Anchorage, Alaska	Presentation	11/15/2015	Outreach Activity at the Alaska Asphalt Summit	80
Richmond, Virginia	Workshop	4/24/2016	Combined workshop between EFL and VDOT.	45
Rutgers University, New Jersey	Presentation	2/15/2016	Outreach Activity during multiple Topics	75
Springfield, Missouri	Showcase	6/1/2016 & 6/2/2016	Showcase delivered over a 2-day period.	80
Charleston, WV	Workshop	3/1/2017	Two ½ workshops were delivered back to back.	90
Charleston, WV	Presentation	3/2/2017	Outreach Activity at the WV Asphalt Paving Conference	120
Springfield, Illinois	Workshop	3/7/2017	Held in conjunction with Illinois Asphalt Paving Conference	42
Raleigh, NC	Workshop	3/22/2017	Workshop to overview the field demonstration project	48
Alabama	Workshop	NA	Scheduled for completion on August 30.	NA
Las Vegas, NV	Workshop	6/1/2017	Non-participating agency in the field demonstration projects	33

The presentations delivered at the workshops of the participating agencies in the field demonstration projects are summarized below.

1. Introduction to Infrared Technology: What is it and Why is it Needed?

The focus of this first presentation was to provide a brief background and history on the infrared technology in terms of how it is being used to provide more uniform and longer lasting mats. In addition, the presentation defined various terms and factors, and laid the foundation for the latter presentations. It also identified where we are to date with infrared technology and how we got there.

2. Equipment and Software Demonstration; Getting Real Time Information for Decision Making

The focus of this session was to provide an overview of the equipment and software, including: setting up the equipment, calibration, data acquisition, getting started, and monitoring mat surface temperatures. Key points included: showing how simple the equipment is to use, it does not interfere with the paving operations or screed operators, and getting real time data to make decisions during the paving operation.

3. Data Analyses and Findings: What was learned from the Demonstration Project; Outcome and Lessons Learned from the Demonstration and Other Projects

The session started with an overview of the field demonstration project, in terms of the paving operations. It also included a summary of the data collected during the demonstration project and how the decisions made on the project were influenced by the real time monitoring of the mat placement temperatures. The final part of this session was to provide a summary of the data and how it will likely affect the performance of the mat.

4. Agency's Perspective as an Acceptance Tool

The lead agency staff person gave the next presentation that focused on the DOT's perspective on using and implementing the Infrared technology. The presentation included some points and advantages of the technology to ensure a high uniformity of the mat based on the results from the demonstration project, as well as how the agency plans to implement the technology in the short-term.

5. Contractor's Perspective as a Quality Control Tool

The lead contractor staff person gave the contractor's perspective of using the Infrared technology and equipment. This presentation included an overview of the contractor's points and advantages of the technology to minimize penalties and maximize incentive, as well as, how a contractor uses the IR data is used to make decisions in real time.

6. Implementation Strategies (A Focus on Agency Use):

The presentation focused on the specifications used by the lead agencies and overviewed the products from this project to assist in the implementation process. The presentation was separated into two portions relative to implementation which are listed below.

a) Products and Application of Products
- Case Studies from Demonstration Projects
- Updated Specification: Improving the Mat.
- Trouble Shooting Guide

b) Lead Agency Strategies/Specifications
- Example: Specifications and QA Plan/Strategies
- Lessons Learned

7. Discussion Session with Questions and Answers

The agency lead staff person was the moderator for this session of the workshop. The original focus of this session was to have a type of round table discussion on the advantages and limitations of the Pave-IR Scan system and implementing the equipment in day to day use, as well as, answer any additional questions from the participants. However, most of the discussion on implementation relative to the agency and contractor's use was completed during the previous session on the Contractor's Perspective as a QC Tool.

8. Presentation and Demonstration of Ground Penetrating Radar

This final session was delivered by GSSI. The presentation provided an overview of the ground penetrating radar (GPR) relative to the equipment's capability and use.

Workshop assessment forms were distributed during each of the workshops to obtain feedback from the participants. The workshop assessment form consisted of 10 questions, which are included in Appendix A. Figure 18 provides a summary of the comments and ratings received from all workshops combined.

A workshop assessment form was distributed to the participants. The following is a summary of the workshop evaluation or assessment received from the participants that attended the workshop. The rating used for each question varied from 1 to 10 with the definition for each shown below.

<table>
<tr><td colspan="10">Rating Number</td><td rowspan="3">Overall Rating</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td colspan="3">No Knowledge</td><td colspan="3">Moderate Knowledge</td><td></td><td colspan="3">Extensive Knowledge</td></tr>
<tr><td colspan="10">1. What was your subject knowledge level of the infrared scanner techniques prior to this workshop?</td><td>5.1</td></tr>
</table>

2. What was your subject knowledge level of the infrared scanner techniques after this workshop?	**7.6**

On the average, the participants had a moderate knowledge of the IR scanner technology and found that they learned more from the workshop. Several individuals had an extensive knowledge prior to the workshop as well, but in nearly every case participant knowledge increased following the workshop.

Rating Number										Overall Rating
1	2	3	4	5	6	7	8	9	10	
Low									High	
3.a How would you rate the effectiveness of the overall workshop content?										**7.8**
3.b How would you rate the effectiveness of the peer presentations, successes, and challenges?										**8.2**

Rating Number										Overall Rating
1	2	3	4	5	6	7	8	9	10	
Strongly Disagree							Strongly Agree			
4.a This workshop provided me with a better understanding of IR Scanner Technology.										**8.3**
4.b I understand how the IR scanner strategies can benefit my agency and program.										**7.7**
4.c I found the format of the workshop encouraged active participation.										**8.3**
4.d My participation in this workshop was worthwhile.										**8.3**
7. My expectations for what I would learn in the event were met.										**8.0**
8. The presenters delivered clear information.										**8.3**

The following figures are a summary of the numerical rating provided from the participants attending the workshops. This summary does not include the participants that attended via a remote location. Based on the ratings, it appears the objectives of the workshop and expectations of the participants prior to attending the workshop were met.

Figure 46. Assessment of Workshops.

The following is a list of the questions that were asked the workshop participants to initiate discussion at each workshop, as well as the response from the participants.

1. What were the most important ideas you learned from the workshop?
• How specs. are implemented. • The feedback from contractors. • Real time thermal information can help connect issues on the daily operation. Help isolate problem areas. Temperature differentials are higher for B101 layers. • Details regarding QA implementation. • Contractor perspective. • Overall. • Better understanding contractors' concerns (and VAA) and thoughts related to IRVSE and specs. • Contractors' perspective. Hearing from VDOT & EFL on their experiences. • How states are looking to implement in QC/QA. • Could be a great training tool for our employees/paving crews. • How IR has been implemented in some DOTs. • I like to learn about new techniques. • Predominant benefit is a QC tool, but might not be worth cost to contractors. • General discussions of need and possible specification. • How temperature correlates to segregation. • This technology is more appropriate for QC than acceptance. • How this technology can allow real-time adjustments to paving operations to improve uniformity. • Concept on how to apply. • That the IR scanner would make a good tool for contractors. • Benefits of Pave-IR and how to use or not use it in specifications. • How contractors would use. • Alternative options to obtain consistent temperature.
2. Are there questions or issues you wished the workshop had addressed that it didn't?
• Would IR spec. be cost effective? • No. • Why does Texas paper recommend ignoring outside 2'? • No. • More information about benefits to a contractor. • How did full implementation affect unit pricing in states that are using full time? It is important for agency personnel to know the impact of cost to their overall program so they can make an informed decision. Is it worth a 10-20% increase in unit pricing? • What are the costs (Agency & Contractor) to implement Pave IR? What are the benefits? ROI? • I am not convinced that the IR was responsible for the pavement improvements in the various states discussed. I would need some data to evaluate all of the changes that affect density, (MTV, Mix Design, etc.) • If density is good, do I care about temperature differentials? • Yes. • No. • Not really. • Cost implementations. Particularly in states that have implemented IR technology.

• Any previous specs. (from 40 years ago, etc.) that once addressed the issues this new technology helps to identify, e.g.: requiring three dumps to load trucks – no mention of this. • Can the draft evaluation from selected states be shared?
3. What else could the FHWA do to support you or your agency in the learning more about the SHRP2 Infrared Scanner innovations?
• n/a • n/a • On-site demonstrations. • Data management. • Continue to reach out and ask questions – good dialogue today. • Be very careful about using the IR scanner to develop a specification – should be used only as a tool. • Demo projects with other contractors. • Train more. • Should be part of a broader asphalt ME design, placement, compacting, QC/QA, performance discussion. • Provide reports documenting pilot projects and lessons learned. • Nothing. • Lessons learned from other states.
4. What else could AASHTO do to support you or your agency in learning more about the SHRP2 Infrared Scanner innovations?
• n/a • n/a • Webinars for dissemination lower/broader in the organization. • More training. • Continue to reach out and ask questions – good dialogue today. • Be very careful about using the IR scanner to develop a specification – should be used only as a tool. • Make a unit available to other contractors. • Should be part of a broader asphalt ME design, placement, compacting, QC/QA, performance discussion. Needs to be part of a holistic discussion of asphalt performance. • Best practices, pilot specifications. • Nothing. • Information sharing.
5. Please provide us with additional comments, feedback, or ideas related to this event or future SHRP2 events.
• I would like to see what MIX types (i.e., AC content) is used in states that use IR spec. • Industry comments/opinions ran on too long – took from other (more positive) participants. • See number 10. • Good program – nice job. • Build in a morning break. • Pave IR should be a tool for evaluating performance, not an agency QA requirement.

Comments from contractor and agency personnel relative to using the Pave-IR Scan™ are listed below:

1. Improves communication between plant and paver personnel to reduce the temperature differential to the lowest value possible. The paving contractor was able to cut the temperature differential in half on a couple of the field demonstration projects simply by adding delivery trucks and/or using a material transfer vehicle.
2. The visual image or display of the temperature differential on the monitor is undisputable in terms of variation in densities or percent compaction. Paver personnel, as well as contractor management personnel start to take notice on what field-plant activities increase and decrease the temperature differential.
3. It is a good forensic tool to investigate reasons or troubleshoot for low and/or non-uniform mat density.
4. Monitoring the temperature differentials on a lot by lot basis for quality control purposes, determines when the paving contractor needs to take some type of action to reduce the temperature differentials.
5. Use of the IR scanner definitely reduces the risk of being penalized for low percent compaction by the agency. If the temperature differential in above 15ºF, the risk of being penalized by the agency increases.
6. It removes the guess work and subjective opinions from identifying mixture segregation.
7. Nearly 100 percent of the mat surface is inspected, so the concern of basing a decision to penalize a contractor is not based on just a few random samples.
8. The Pave-IR ScanTM system can be used to resolve disputes between the contractor and agency related to the mat uniformity in terms of density and segregation. More importantly it can serve as a benefit to both the agency and contractor in terms of defining potential causes of low density and high variability in the density measurements.
9. Provides a reduction in future (short and long-term) maintenance costs. Projects or areas with severe temperature differentials will exhibit premature cracking and raveling.
10. Use of tarps: On the West Virginia field demonstration project, end-dump trucks were used to deliver the asphalt concrete mixture to the paving site. Some of the tarps were in good conditions and covered the entire truck bed while others were ripped and provided little to no protection of the asphalt concrete mix. The paver operator observed a large temperature differential and lower temperature of the mix in those trucks with ripped and damaged tarps in comparison to those trucks with tarps in good condition and properly placed over the entire truck bed. The paver operator communicated the increase in

temperature differentials and lower mix temperatures to the truck drivers and requested that all tarps in poor condition be repaired to cover the entire truck bed.