Connecticut Demonstration Project: Pavement Preservation on Interstate 95, Towns of Westbrook and Old Saybrook

Final Report
May 2015

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
The Connecticut DOT (CTDOT) initiated a pavement preservation project to resurface a section of I-95. The project limits spanned over 17.8 miles in both the northbound and southbound directions, from mile post 60.65 to mile post 78.45.

The innovative technologies deployed on this project included warm mix asphalt (WMA) and Safety Edge pavement. CTDOT's current standard specification does not allow for the use of WMA or polymer modified binders. Nonetheless, CTDOT is interested in implementing the WMA technology due to its advantages, such as production/compaction of asphalt concrete at reduced temperatures and increased mixture workability especially for polymer modified mixtures. To this end, CTDOT had already constructed five pilot projects that utilized the WMA technology, and the current project will add to CTDOT's experience in implementing WMA for production use.

This project also delivered the first pavement section in Connecticut constructed with Safety Edge. CTDOT has been aware of the benefits of this technology in reducing roadway departure accidents and improving the durability of the outer edge of the pavement. This project will help CTDOT to develop standard guidelines for future projects.

Due to the limited crash history that were available from the locations where Safety Edge was installed, analysis on safety was deemed unnecessary. According to the field observations made by the project staff and the results from a user satisfaction survey, the construction activities resulted in minimal queuing of traffic.

Although some of the Highways for LIFE goals were not fully evaluated, and those for smoothness and noise were not met, the end product was a smooth riding pavement, as indicated by the user survey and a smoothness bonus to the contractor.

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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

CTDOT	Connecticut Department of Transportation
FHWA	Federal Highway Administration
HfL	Highways for LIFE
HMA	Hot mix asphalt
IRI	International Roughness Index
OBSI	Onboard sound intensity
OSHA	Occupational Safety and Health Administration
PDO	Property damage only
RAP	Recycled asphalt pavement
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SRTT	Standard reference test tire
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 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 in a rural area or less than 1.5 miles 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.
    - 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**
  - 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 Connecticut DOT's (CTDOT) demonstration project, which involved 17.8 miles of pavement preservation on I-95. The report presents available project details relevant to the HfL program, including the use of innovative technologies (warm mix asphalt and Safety Edge pavement) and HfL performance metrics measurement where available. The lessons learned during the course of the project are also discussed.

PROJECT OVERVIEW AND LESSONS LEARNED

PROJECT OVERVIEW

The project limits spanned over 17.8 miles of both northbound and southbound I-95, from mile post 60.65 to mile post 78.45. It involved milling and resurfacing of I-95 from Interchange 58 (Route 77) in Guilford to the Baldwin Bridge carrying I-95 over the Connecticut River at Interchange 69 (Route 9) in Old Saybrook.

The innovative technologies deployed on the project were warm mix asphalt (WMA) technology and Safety Edge pavement. CTDOT's current standard specification does not allow for the use of WMA or polymer modified binders. Nonetheless, CTDOT is interested in implementing the WMA technology due to its advantages, such as production/compaction of asphalt concrete at reduced temperatures and increased mixture workability, especially for polymer modified mixtures. To this end, CTDOT had already constructed five pilot projects that utilized the WMA technology, and the current project will add to CTDOT's experience in implementing WMA for production use.

This project also delivered the first pavement section in Connecticut constructed with Safety Edge. CTDOT has been aware of the benefits of this technology in reducing roadway departure accidents and improving the durability of the outer edge of the pavement. This project will help CTDOT to develop standard guidelines for future projects.

HfL Performance Goals

The HfL performance goals for safety and construction congestion were not fully evaluated for this project. Due to the limited crash history that were available from the locations where Safety Edge was installed, analysis on safety was deemed unnecessary. Furthermore, according to the field observations made by the project staff and the results from a user satisfaction survey, the construction activities caused minimal queuing of traffic. The HfL goals for smoothness and noise were not met. However, with an IRI value of 52 inches/mile from the newly paved surface, the project showed a significant improvement in ride quality compared to the old pavement and yielded a smoothness bonus of $205,130 to the contractor.

The available data collected before, during, and/or after construction are summarized below:

- **Safety—**Three crashes involving property damage only (PDO) were observed during the 2-year preconstruction period from January 1, 2009, to December 31, 2011. Due to the limited crash history available from the locations where the Safety Edge was installed, it was determined that further analysis on safety was not warranted. In addition, the OSHA Form 300 was not generated for this project as there were no recorded worker injuries.
- **Construction Congestion—**Due to the amount of traffic on I-95, the construction work was conducted during nighttime hours. Although specific measurements were not taken, only minimal queuing of traffic was observed according to the inspection made by FHWA and the project inspection staff.

- **Quality—** Smoothness and sound intensity test data were collected before and after construction, on 5 miles of the outer lane between exits 58 and 62 in both directions.
    - Smoothness—The IRI values for the existing pavement were 81 inches/mile for the northbound lane and 86 inches/mile for the southbound lane. The IRI values measured from the same limits after resurfacing were 58 inches/mile (a reduction of 23 inches/mile) and 56 inches/mile (a reduction of 30 inches/mile) for the northbound and southbound lanes, respectively. In addition, CTDOT conducted smoothness testing to determine the smoothness pay adjustment for the contractor, which yielded an overall average IRI value of 52 inches/mile. Although this IRI value did not meet the HfL performance goal of 48 inches/mile, it was a significant improvement from the existing pavement, yielding a total smoothness incentive value of $205,130.
    - Noise— The global sound intensity values of the existing pavement were 105.5 dB(A) and 103.9 dB(A) for the northbound and southbound outer lanes, respectively. The corresponding values for the new pavement were 103.7 dB(A) and 103.5 dB(A). Therefore, the reductions in tire-pavement noise were not significant, and the new levels did not meet the HfL goal of less than 96.0 dB(A).
    - Construction quality is not considered a direct goal of the HfL program, but it may have an indirect impact on HfL goals. Detailed mat density results were not provided for this project. However, the contractor received a penalty of $43,220.84 for not meeting the asphalt density specifications and received an asphalt plant bonus of $147,715.55.
- **User Satisfaction—**A user satisfaction survey indicated that the local community was mostly satisfied with the ride quality of the new pavement and CTDOT's traffic control plan to minimize the traffic disruption.

ECONOMIC ANALYSIS

No economic analysis was conducted for this project due to insufficient data. It is noted that the WMA technology is relatively new, and studies on the long-term performance and life cycle costs of WMA pavements are yet to be completed.

LESSONS LEARNED

Following are some of the lessons learned on this CTDOT project:

- CTDOT previously had constructed five WMA projects as part of a pilot study that provided potential benefits and recommendations with regards to the WMA. This project will add to CTDOT's experience on WMA.
- There were difficulties in finding locations that met the criteria for Safety Edge installation. As a result, some of the sections, or at least part of some of the sections, did not seem to warrant placement of the Safety Edge.
- Letting the contractor manufacture his own Safety Edge device attachment helped CTDOT allow room for innovation in the Safety Edge specifications.
- Some of the areas chosen for installation of the Safety Edge had no drop-off with well-established vegetation tight up against the existing pavement edge, or had slightly raised

or upward sloping ground adjacent to the edge of the pavement. The installation of the Safety Edge in these areas did not help significantly in terms of improving driver recovery back onto the pavement surface.

- Dense graded crushed aggregate base as a backing material was found to be somewhat susceptible to erosion. On the contrary, the use of recycled asphalt pavement (RAP) millings was found to have more cohesion over time, and it was recommended that future backing (when re-vegetation is not specified) be done exclusively with RAP.
- CTDOT observed that compaction practices near the edge of the pavement contributed to problems forming the proper shape required for the Safety Edge.
- Lateral displacement was caused by rolling an asphalt mix that is unstable, or tender, and can't support the weight of the compaction equipment. CTDOT also believes that putting well known techniques into practice when rolling unsupported pavement edges may have helped alleviate the problem with deformation of the Safety Edge by lateral displacement.

CONCLUSIONS

This project provided a good learning experience and will add to CTDOT's experience in constructing pavements with WMA technologies. In addition, knowledge was gained on the construction and use of the Safety Edge pavement. Although some of the HfL goals were not fully evaluated, and those for smoothness and noise were not met, the end product was a smooth riding pavement, as indicated by the user survey and the smoothness bonus paid to the contractor.

PROJECT DETAILS

PROJECT DESCRIPTION

Figure 1 shows a map of the project location. The roadway within the limits of pavement preservation carries annual daily traffic ranging from 62,500 to 73,600 vehicles and has a posted speed limit of 65 mph.

The project scope included milling 3 inches of existing pavement from curb to curb and overlaying it with a 1-inch leveling course of hot mix asphalt (HMA) and 2 inches of WMA with PG76-22 polymerized binder or a 5/8-inch ultra-thin HMA pavement on a polymer modified asphalt emulsion. This CTDOT project (no. 0154-01220) was awarded on June 29, 2012, at a cost of $18,175,000. This project was designed under CTDOT's 2012 pavement preservation program.

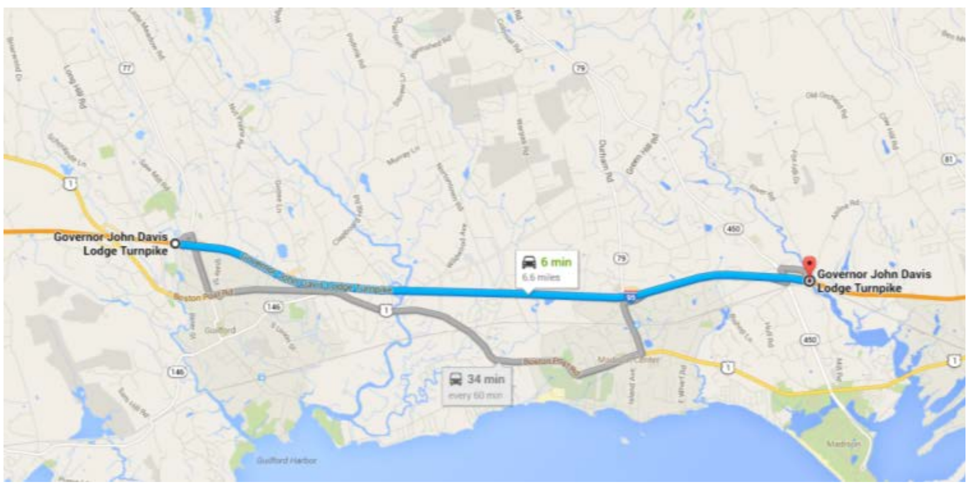


Figure 1. Map. Project location.

The project was divided into three sections:

- **Section I:** I-95 north and south (including adjacent ramps) from the vicinity of Interchange 58 (Route 77) in Guilford to Interchange 65 (Route 153) in Westbrook, a total distance of 12.49 miles (from mile post 60.65 to mile post 73.14).
- **Section II:** I-95 north and south (including adjacent ramps) from the vicinity of Interchange 65 (Route 153) in Westbrook to Interchange 68 (US-1/Springbrook Road) in Old Saybrook, a total distance of 4.59 miles.
- **Section III:** I-95 north and south (including adjacent ramps) from Interchange 68 to the Baldwin Bridge carrying I-95 over the Connecticut River at Interchange 69 (Route 9) in Old Saybrook, a total distance of 0.72 miles (from mile post 77.73 to mile post 78.45).

Table 1 shows the treatments applied to the sections, and figure 2 shows the typical sections for the resurfacing project.

Table 1. Treatments applied to the pavement sections at project location.

Section	Applied Treatment
Sections I and III	3-inch mill and overlay using 1-inch HMA and 2-inch WMA
Section II	5/8-inch ultra-thin HMA pavement on a polymer modified asphalt emulsion

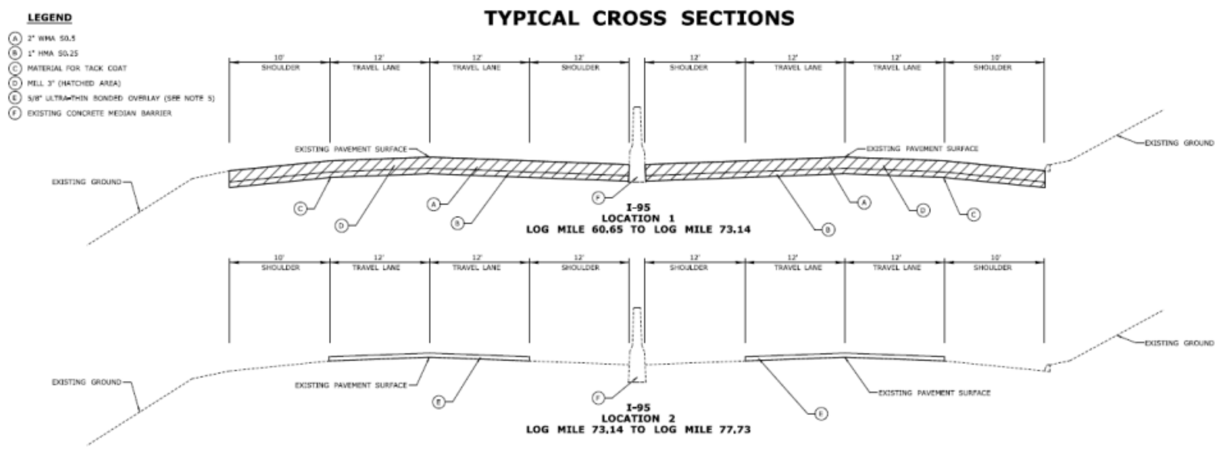


Figure 2. Diagram. Typical cross sections.

Safety Edge was used on Section I to help reduce roadway departure crashes and thereby achieve the HfL performance goal of enhancing safety.

Bid Information

The I-95 pavement preservation project was let on May 23, 2012. The project received four bids ranging from $18,175,000 to $21,767,931.41. The winning bid amount was $18,175,000 and the project was awarded to American Industries Inc.

Table 2. Bid comparisons.

Bidder	Total Bid	Percent of Low Bid
Lowest Bid.	$18,175,000.00	100.00%
2nd Bid	$19,474,472.45	107.15%
3rd Bid	$20,129,578.35	110.75%
Highest Bid	$21,767,931.41	119.77%

Project Schedule

The project construction began in July 2012 and was completed in October 2013. The schedule involved the contractor working from Interchange 63 (Route 81) in Clinton to Interchange 69 (Route 9) in Old Saybrook during 2012 and from Interchange 58 (Route 77) in Guilford to Interchange 63 (route 81) in Clinton during 2013. The Safety Edge was installed in June 2013 at six locations within the 3-inch mill and fill portion of the project. The major project milestones are presented in table 3.

Table 3. Major project milestones.

Event	Date(s)
Contract Award	23-May-2012
Notice to Proceed	30-Jul-2012
Mobilization	30-Jul-2012
Concrete Pavement Reconstruction	13-Aug-2012 to 16-Sep-2012
Safety Edge	29-May-2013 to 02-Jun-2013
Project Completion	Nov-2013

PROJECT INNOVATIONS

Warm Mix Asphalt

In June 2014, Zinke, Mahoney, and Morison submitted a report on WMA to CTDOT, titled *Connecticut Warm Mix Asphalt (WMA) Pilot Projects 2010-2011*[1]. The report reviewed multiple projects constructed across Connecticut during 2010 and 2011 where the research team observed and sampled the different types of WMA that were constructed as part of a pilot project program. The WMA technologies included in the projects included Sasobit®, Evotherm™, Advera®, Double-Barrel® green foamed asphalt, and SonneWarmix™. Placement of the WMA sections was performed satisfactorily for all sections with an observed reduction in heat required to produce the WMA. In addition to the reduced heat, the researchers observed much less smoke from the trucks hauling WMA material. The recommendations of the research team included allowing WMA from the North East Asphalt User Producer Group qualified list to be used by asphalt mix providers if desired, allowing all three types of WMA, and encouraging the reduction in production temperatures without mandating any specific lower temperature. The report also included an analysis of tensile strength ratio testing with a recommendation to allow foamed asphalt material to cool before reheating to fabricate samples.

Mixture Design of Warm Mix Asphalt

Table 4 presents the job mix formulas for HMA, WMA, and the ultra-thin HMA Type B.

[1] Zinke, S., J. Mahoney, and K. Morison. *Connecticut Warm Mix Asphalt (WMA) Pilot Projects 2010-2011*. June 2014. SPR-2269. Connecticut Department of Transportation. Newington, CT.

Table 4. Job mix formula for the three mixtures used in the project.

		HMA	Ultra-Thin HMA Type B	WMA
Mixture #		**4077R**	**N/A**	**4058R-W**
Binder Grade		**PG64-22**	**PG64-22**	**PG76-22**
Percent Binder by Weight	Virgin Binder	5.20	5.10	4.30
Percent Binder by Weight	Total Binder	5.91	5.10	5.00
Target Gradation, Percent Passing Sieve Size	¾ inch	100	100	100
Target Gradation, Percent Passing Sieve Size	1/2 inch	100	94	94
Target Gradation, Percent Passing Sieve Size	3/8 inch	98	46	81
Target Gradation, Percent Passing Sieve Size	#4	69	36	63
Target Gradation, Percent Passing Sieve Size	#8	53	24	51
Target Gradation, Percent Passing Sieve Size	#16	40	19	40
Target Gradation, Percent Passing Sieve Size	#30	29	16	29
Target Gradation, Percent Passing Sieve Size	#50	18	12	18
Target Gradation, Percent Passing Sieve Size	#100	9	9	9

Mixture #		HMA	Ultra-Thin HMA Type B	WMA
		4077R	**N/A**	**4058R-W**
Binder Grade		**PG64-22**	**PG64-22**	**PG76-22**
Target Gradation, Percent Passing Sieve Size	#200	5	5	4
Voids in Mineral Aggregate		15.8	N/A	14.8
Voids Filled with Asphalt		75	N/A	68
Air Voids		4.0%	N/A	4.7%
Mixing Temperature		300 °F	N/A	300 °F
Compaction Temperature		275 °F	N/A	275 °F

Plant Information.

The contractor used one plant to supply all asphalt concrete materials for the project. The plant was located in Jewett City, approximately 35 and 54 miles away from the two ends of the construction area on I-95. Figure 3 is an image of the plant.

Figure 3. Photo. Picture of American Industries plant.

Figure 4 is an image of the Advera WMA additive delivery system at the plant location.

Figure 4. Photo. Cyclonaire injector system for the Advera WMA additive.

WMA Placement

The contractor used a warm mix additive, Advera WMA, on this project. The average mix delivery and laydown temperatures were found to be between 280 °F and 300 °F. The Advera additive was added at a rate of 4 pounds per ton of total WMA mix. The WMA mix was typically placed using a CAT AP655D or CAT AP 1055D paver and a ROADTEC SB-2500 MTV. Compaction was generally achieved through the use of three or four CAT CB54s. Figures 5, 6, and 7 show the paver, MTV, and the roller used on the project, respectively.

Figure 5. Photo. Paving of I-95.

Figure 6. Photo. Roadtec material transfer device.

Figure 7. Photo. Compaction roller.

Table 5 shows the typical weather and temperatures during the construction of HMA and WMA mixtures. The weather was mostly clear, with air temperature ranging from 43 degrees to 80 °F. The mix temperatures measured during construction ranged from 279 to 302 °F for the HMA and 278 to 290 °F for the WMA.

Table 5. Typical weather and temperature.

Mixture	Date	Weather	Air Temp., °F		Mix Temp., °F	
			High	Low	High	Low
HMA	5/14/13	Clear	55	43	291	281
	6/8/13	Clear	70	64	302	279
WMA	6/17/13	Clear	70	62	286	278
	6/30/13	Cloudy	80	75	290	283

Safety Edge

Safety Edge is an installed beveled (typically 30 degrees) or sloped longitudinal pavement edge intended to prevent the drop-off of vehicles from the edge of the bound pavement surface. The Safety Edge allows the vehicle users from veering off, losing control or flipping, and to safely get back to the bound pavement surface. A typical Safety Edge section is shown in figure 8.

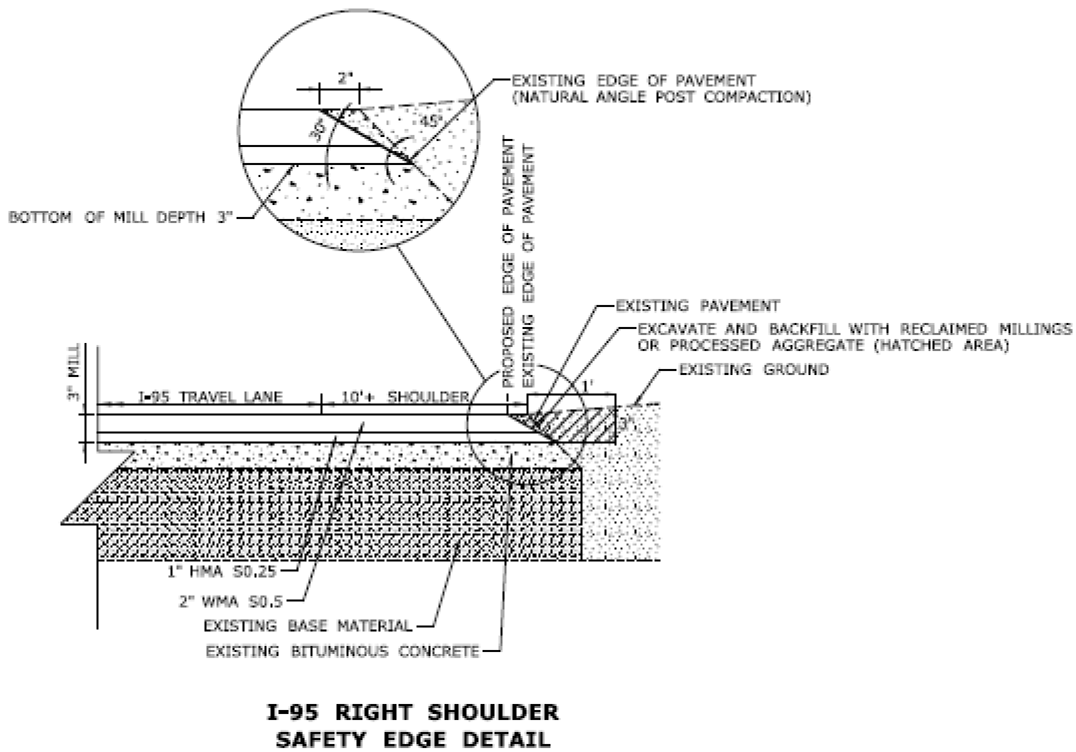


Figure 8. Diagram. Typical section of Safety Edge.

Project Selection for Safety Edge Trial Installation

Although CTDOT had initially considered a project on I-395 in the towns of Griswold and Plainfield for trial installation of Safety Edge, they chose project 154-152 since the project added an additional 6 miles of resurfacing due to an increase in preservation program funding. CTDOT was of the opinion that the HfL grant amount could be best utilized on this larger expanded project. Once the project was granted the Federal funding, the specific locations for the installation of the Safety Edge were finalized.

Safety Edge Install Locations

CTDOT adopted the following criteria for selecting locations to install the Safety Edge:

- The section should not have a closed drainage system (curbing) or guiderail.
- The section should be a minimum length of 1,000 feet.
- The section should have a free draining edge with the adjacent roadside terrain being level with or dropping off away from the edge of the bound pavement surface.

The Safety Edge was installed on the six locations on I-95 as shown in table 6.

Table 6. Install locations for Safety Edge.

Location Number	Direction	Location Detail
1	North	Guilford, Log mile 62.020 – mile 62.240 (1161.6 lf)
2		Madison, Log mile 63.520 – mile 63.730 (1108.8 lf)
3	South	Guilford, Log mile 62.273 – mile 61.925 (1837.4 lf)
4		Guilford, Log mile 63.109 – mile 62.868 (1272.5 lf)
5		Madison, Log mile 64.094 – mile 63.853 (1272.5 lf)
6		Madison, Log mile 64.644 – mile 64.440 (1077.1 lf)

Safety Edge was installed at locations 1 and 3 as a countermeasure to the accidents that had occurred there prior to construction.

The Safety Edge installation was carried out during the night hours in June 2013. The night temperatures during the installation were observed to be in the lower 60's (°F). The Safety Edges were formed only on the 2-inch surface lifts of the pavement sections.

Safety Edge Device

CTDOT's Safety Edge provision allowed the contractor to use any means or device to achieve the "Safety" edge dimensions shown in the detailed drawing. The designer drew the detail based on sample drawings found online.

Four manufacturers' devices were deemed acceptable. However, per the project specifications, there was no binding on the use of specific equipment or devices in forming the required edge. Because the devices were expensive, the contractor opted to manufacture his own Safety Edge device (see figure 9).

Figure 9. Photo. Contractor's self-manufactured Safety Edge device.

The contractor also noted that the installation or removal of the Safety Edge attachment took around 15 minutes. The shortness of each installation location (approximately 1,000 feet) led to these increased installation and removal times for the device. The contractor observed that it took as long or longer to install and remove the device as it did to pave the 1,000-foot section for which it was installed.

After a sit-down review session, a field review was conducted at each of the six installation locations. Each location was reviewed to discuss all aspects of the installation, including unique features, problems, or constructability issues that each location may have had.

Safety Edge Implementation

The following steps were carried out during Safety Edge implementation:

1. Pavement edge/shoulder preparations.
2. Pavement placement.
3. Rolling and compaction.
4. Backing material.
5. Field review of installation locations.

Pavement Edge/Shoulder Preparations. Prior to the Safety Edge installation, the existing edge of the roadway was backed firmly by grass or well packed dirt (patched with weeds). The edge of the roadway shoulder was then scraped back to fully expose the edge of the original pavement. This was followed by cleaning away any encroaching dirt and turf to avoid its interference with the edge of the screed and the installation of Safety Edge.

Pavement Placement. The pavement surface lift, on which the Safety Edge was installed, consisted of a polymer modified, level 3, Superpave dense graded hot mix with a nominal aggregate size of 0.5 inches.

Rolling and Compaction. Figures 10 and 11 show the formation of the Safety Edge prior to backfilling. The contractor did not alter the rolling pattern and compaction techniques when operating the Safety Edge device. Prior to the installation of the backing material, a review was conducted on the six locations where the Safety Edge was installed. The review showed many areas where the roller had shoved the mix laterally toward the edge of the pavement. The following were some of the observations:

- Distortion and maligning in several areas, because of the lateral shoving of the 30 degree slope formed by the Safety Edge.
- Lateral displacement, in some cases, of material by the roller resulting in the eradication of the entire 30 degree slope.
- Distortion, in other cases, of only the top portion of the Safety Edge slope. This distortion could be attributed to the lute reforming the 30 degree edge by pressing the displaced material back against the joint to “reform” the 30 degree slope.
- Edge cracking along about 10 to 15 percent of the length of the installed Safety Edge at most of the locations. The cracking was noted between the very top of the beveled edge to approximately 2 to 3 inches inward from the top of the Safety Edge.

Figure 10. Photo. Formation of Safety Edge prior to backfilling along I-95.

Figure 11. Photo. Close-up of the Safety Edge pavement.

Backing Material. Per the plans, the Safety Edge had to be backed with either reclaimed millings or processed aggregate. The constructability review, conducted on September 9, 2013, indicated that a small portion of the Safety Edge had been backfilled with processed aggregate right after it was installed. Based on the portion's limited performance during a period of approximately 3 months, both the inspection personnel and the contractor felt the need to use reclaimed asphalt millings for better performance of the backing material. In contrast to the processed aggregate that started to experience some loss soon after backfilling, the reclaimed asphalt millings were expected to slightly bind together when placed and compacted.

Field Observations. Some of the observations made by CTDOT on the six locations where Safety Edge was installed include the following (see table 6 for detailed location information):

- Location 1:
    - One-inch leveling course did not utilize the Safety Edge device.
    - Slope of the edge formed on the 2-inch surface lift of polymer modified HMA was found to be greater than 30 degrees.
    - In some areas, the top portion was found to have been shoved by the roller so that it no longer formed a 30 degree ramped edge.
- Location 2: Only about half of the entire length sloped away gently from the edge of the pavement. The other half sloped upward slightly due to the scraping back of the edge of

roadway, thus creating a more abrupt lip at the edge of the pavement than was previously there.

- Location 3: For the last 250 feet in this section, the roadside slope transitioned from level/slight drop-off to an upward facing slope. The project personnel thus decided to not install the Safety Edge for the remaining 250 feet of this location.
- Location 4:
    - There was lateral displacement throughout, and approximately 50 percent top edge cracking was seen.
    - Significant checking of the mat surface was observed. This occurrence could not be attributed to heat checking since the ambient temperatures were reasonably warm.
    - The mix was found to have a slightly finer appearance at this location. Some variations in mix production seemed to result in the mix being more “tender” in this location.
    - It could be safely assumed that the checking of the mat surface, combined with excessive lateral movement, edge cracking, and edge distortion, contributed to problems associated with excessive lateral displacement and cracking of the Safety Edge at this location.
- Location 5: Few areas showed edge cracking from lateral displacement of the mix due to rolling.
- Location 6: Dirt lip formed from scraping back the edge of roadway.

Based on these field observations, the CTDOT review team felt that there were no significant benefits of installing Safety Edge at locations 2, 4, and 6.

DATA ACQUISITION AND ANALYSIS

Connecticut DOT collected project-related data on safety, quality, and user satisfaction before, during, and after construction. The complete set of data needed to determine if this project met the HfL performance goals was not made available for this project. Therefore, only the available data will be presented in this section of the report.

CONSTRUCTION CONGESTION

Per the inspection made by the project staff, along with discussions with project inspection staff, only minimal queuing of traffic was observed during construction.

SAFETY

The CTDOT inspection team noted that four accidents occurred within the work zone during the construction period. These accidents are listed below. Detailed reports for the individual accidents were not made available to the research team.

- 4/18/13 report # 13-00238648.
- 4/26/13 exit 64 utility poles.
- 5/13/13 06:00 n.b.
- 5/16/13 Van vs garrity sweeper.

During the preconstruction period from January 1, 2009, to December 31, 2011, there were a total of three PDO crashes at the project site:

- Two cases where the driver lost control and hit the median jersey barrier (mile post 62.16 northbound and mile post 61.92 southbound).
- One case where the driver lost control and hit the vehicle in the adjacent lane (mile post 61.92 southbound)

Based on the limited crash history available from the locations where the Safety Edge was installed, it was determined that further analysis on safety is not warranted. There were no worker injuries and as such the OSHA Form 300 was not generated for this project.

QUALITY

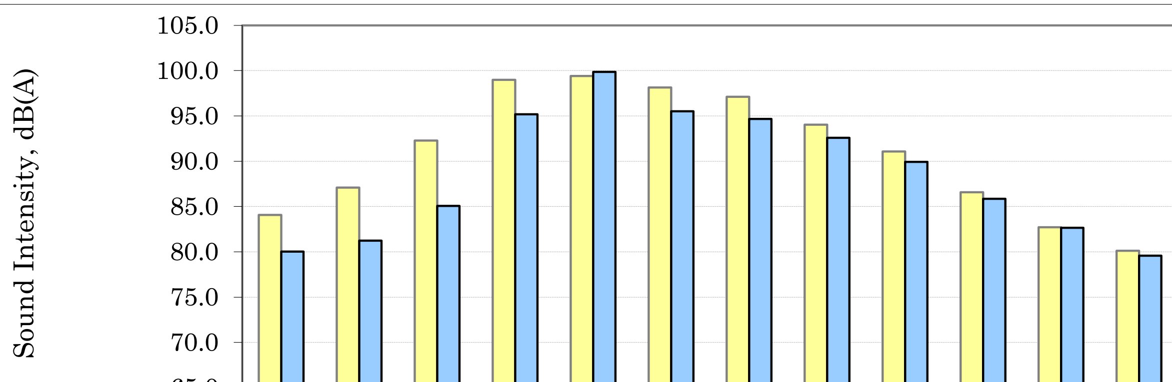
Sound intensity and smoothness test data were collected from 5 miles of the outer lane between exits 58 and 62 in both directions. Comparing these data before and after construction provides a measure of the quality of the finished pavement.

Sound Intensity Testing

Sound intensity measurements were made using the current accepted technique AASHTO TP 76-10, which includes dual vertical sound intensity probes and an ASTM-recommended standard reference test tire (SRTT). Data were collected from the outer lanes of both direction between exits 58 and 62 before and after construction. The sound intensity measurements were recorded and analyzed using an onboard computer and data collection system. Multiple runs were made in the right wheelpath with the two microphone probes simultaneously capturing noise data from the leading and trailing tire/pavement contact areas. Figure 12 shows the dual probe instrumentation and the tread pattern of the SRTT.

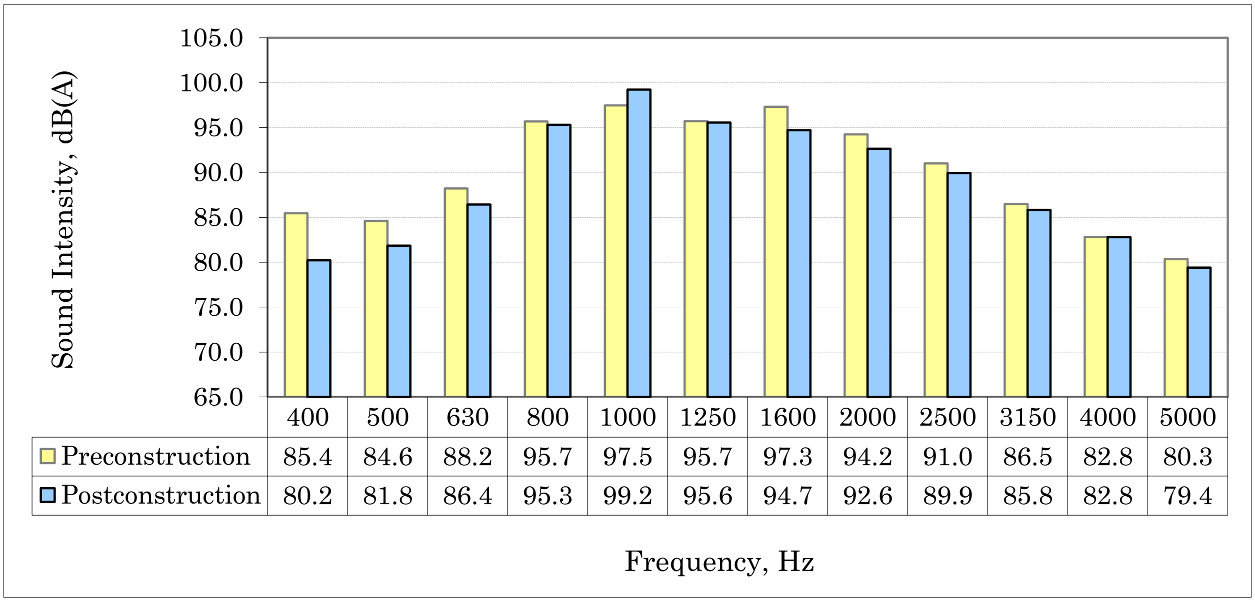
Figure 12. Photo. OBSI dual probe system and the SRTT.

The average of the front and rear sound intensity values was computed to produce a global value. Raw noise data were normalized for the ambient air temperature and barometric pressure at the time of testing. The resulting mean sound intensity levels are A-weighted to produce the sound intensity frequency spectra in one-third octave bands, as shown in figures 13 and 14.



	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Preconstruction	84.1	87.1	92.3	99.0	99.4	98.1	97.1	94.0	91.1	86.6	82.7	80.1
Postconstruction	80.0	81.2	85.1	95.2	99.9	95.5	94.7	92.6	89.9	85.9	82.6	79.6

Figure 13. Chart. Mean A-weighted sound intensity frequency spectra from northbound I-95 before and after construction.



	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Preconstruction	85.4	84.6	88.2	95.7	97.5	95.7	97.3	94.2	91.0	86.5	82.8	80.3
Postconstruction	80.2	81.8	86.4	95.3	99.2	95.6	94.7	92.6	89.9	85.8	82.8	79.4

Figure 14. Chart. Mean A-weighted sound intensity frequency spectra from southbound I-95 before and after construction.

The global sound intensity values of the existing pavement were 105.5 dB(A) and 103.9 dB(A) for the northbound and southbound outer lanes, respectively. The corresponding values for the new pavement were 103.7 dB(A) and 103.5 dB(A). The reduction in the tire-pavement noise was not significant, and the sound intensity levels of the newly constructed pavement surface did not meet the HfL goal of less than 96.0 dB(A).

Smoothness

Smoothness testing was done in conjunction with the sound intensity testing and utilized a high-speed inertial profiler integrated with the test vehicle. Data were collected from both wheelpaths and averaged to produce an IRI value. A low value is an indication of better ride quality (i.e., smoother road). Figure 15 is an image of the test vehicle showing the profiler positioned in line with the right rear wheel. Figure 16 graphically presents the IRI values for the preconstruction and newly constructed pavement. From the smoothness testing conducted between exits 58 and 62 of I-95, the IRI values for the existing pavement were found to be 81 inches/mile for the northbound lane and 86 inches/mile for the southbound lane. The IRI values measured from the same limits after resurfacing were determined to be 58 inches/mile and 56 inches/mile for the northbound and southbound lanes, respectively.

Figure 15. Photo. High-speed inertial profiler mounted behind the test vehicle.

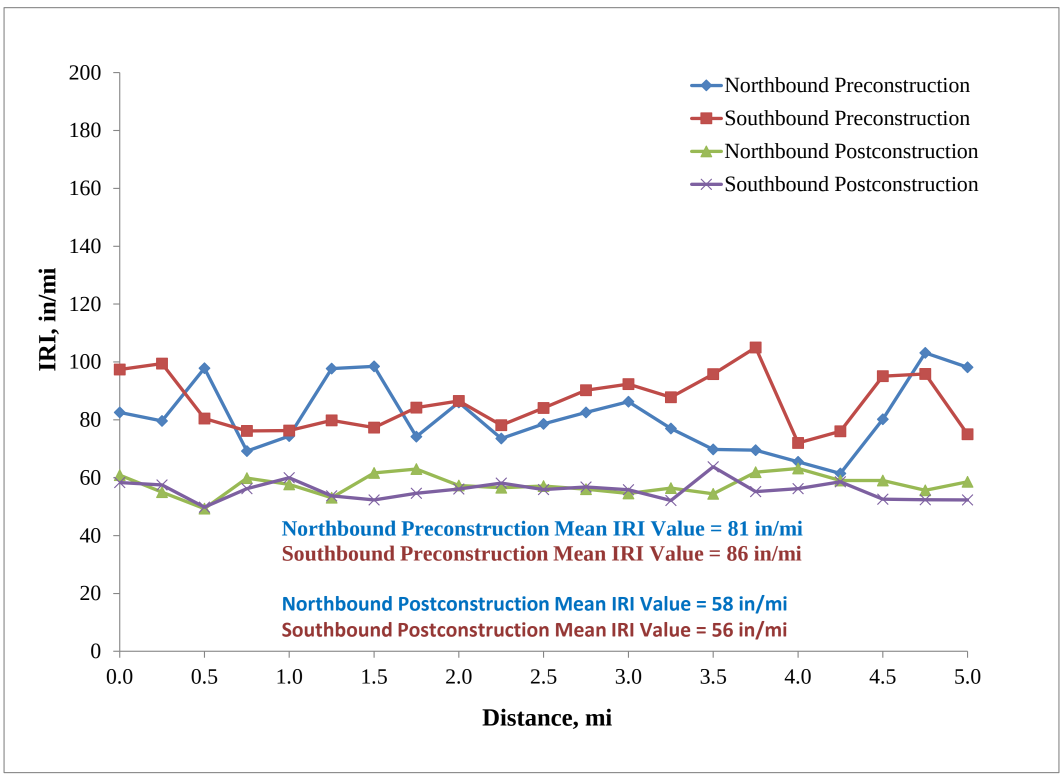


Figure 16. Graph. Mean IRI values before and after construction.

In addition to the above, CTDOT conducted IRI testing on the resurfaced pavement to determine the smoothness incentive/disincentive for the contractor. The resulting IRI values are shown in figures 17 and 18. The overall average IRI for the entire project was 52 inches/mile, which does not meet the HfL performance goal.

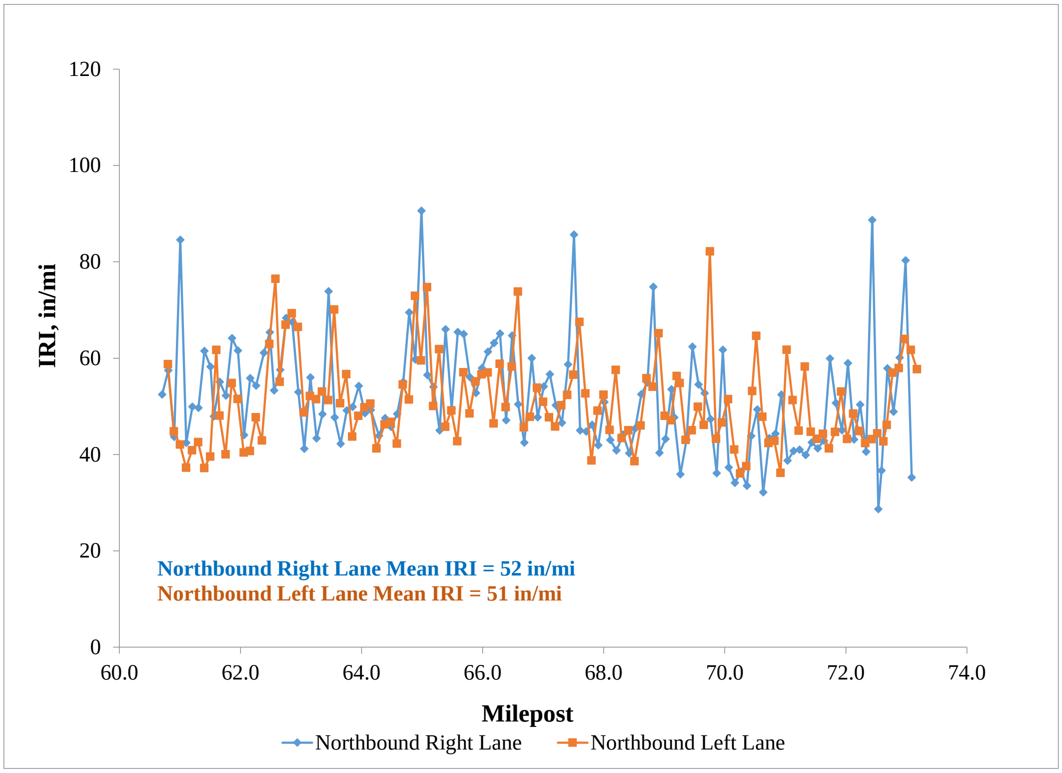


Figure 17. Graph. Mean IRI values from northbound I-95.

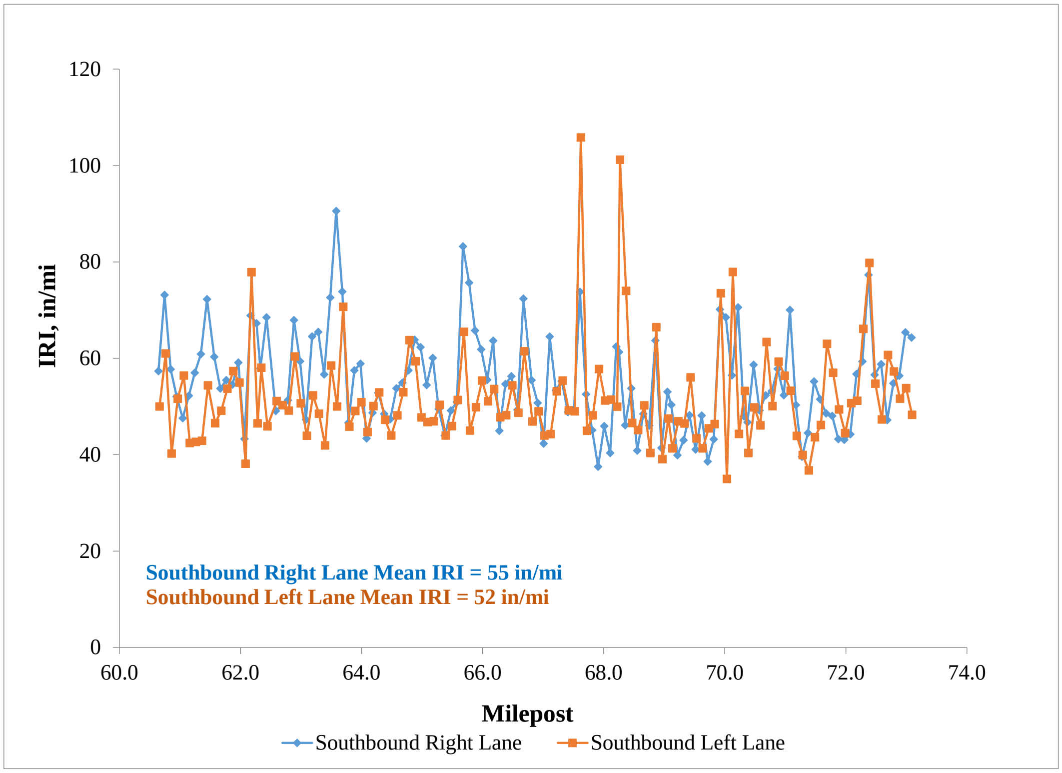


Figure 18. Graph. Mean IRI values from southbound I-95.

The smoothness pay adjustment was applied only to the surface lift of all mainline pavement where the total HMA/WMA thickness is 3 inches. In other words, areas that received a total asphalt thickness of less than 3 inches, such as bridge transition areas and underpasses, were excluded from determining the smoothness adjustment. Table 7 shows the pay factors and the pay adjustments calculated for each lane. The total incentive due to the contractor was $205,130.

Table 7. Summary of pay factor and smoothness pay adjustment.

Direction	Lane	Tons	IRI (inches/mile)	Average Pay Factor (%)	Pay Adjustment
North	Right	9,928	52	6.30	$50,027
	Left	9,927	51	7.18	$57,051
South	Right	9,931	55	5.29	$42,041
	Left	9,928	52	7.05	$56,011
Project Total		39,714	52	6.46	$205,130

Mat Density, Asphalt Content, and Aggregate Gradation

Mat density results were not provided for this project. However, a penalty of $43,220.84 was assessed because the contractor did not meet the asphalt density specifications. An asphalt plant bonus of $147,715.55 was also awarded to the contractor.

User Satisfaction

The CTDOT conducted a public survey to evaluate user satisfaction with the current project. The survey consisted of seven questions that focused on the following:

- Familiarity with pavement preservation.
- Preference between less frequent but longer duration construction projects or more frequent but quicker projects.
- Familiarity with WMA technology.
- Ride quality and turnaround time to repave the “ground off” surface.
- Ride quality of the new pavement compared to the pavement before construction.
- Traffic disruption during construction of this project.

A total of 18 responses were received. The complete survey results are provided in appendix A. The following are the conclusions drawn from the survey results:

- Residency – Of the 18 respondents, 10 provided their residency information, and all were from Connecticut.
- Duration of construction – 50 percent of the respondents preferred more frequent construction with shorter duration. Twenty-eight percent preferred the other, while the remaining 22 percent did not show any preference.
- Familiarity with WMA – 61.1 percent of the respondents were familiar with or had at least heard of the WMA technology. The remaining 38.9 percent of the responders had never heard of WMA.

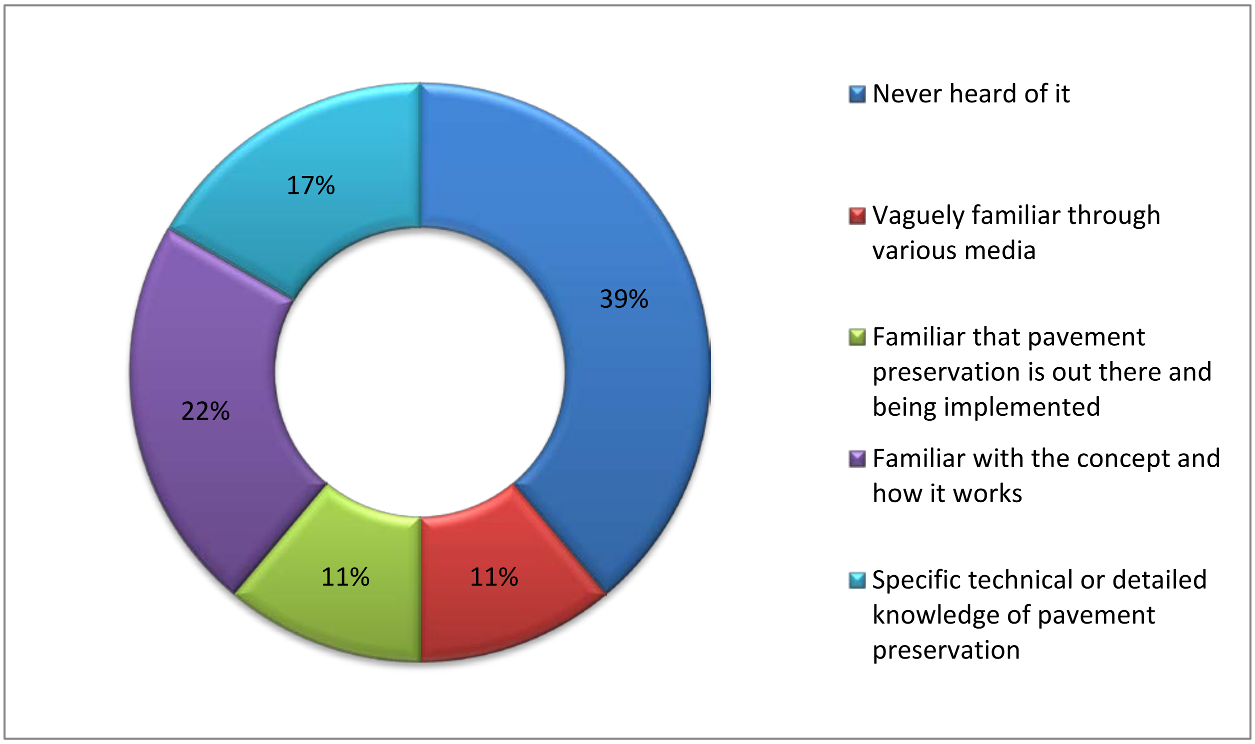
- Ground off surface – 41.1 percent of the responders indicated that the ground off surface provided worse ride quality, and 52.9 percent responded that the turnaround time to repave the ground off surface was adequate.
- Ride quality of new pavement – 70.6 percent of the responses showed that the new pavement rides smoother than the old pavement.
- Minimizing traffic disruption – 83.3 percent of the responders were satisfied with CTDOT's traffic control plan to minimize the disruption.

The HfL performance goal for user satisfaction is to achieve a 4-plus rating on a Likert scale of 1 to 7. However, the CTDOT's answer options were adjectival and were different for each question. Therefore, the survey results were not converted to a Likert scale.

APPENDIX A: USER SATISFACTION SURVEY

This appendix includes the results of the user satisfaction survey. A total of 18 responses were received. Ten respondents provided information on their residency, and all were from Connecticut. The responses are summarized on a question-by-question basis.

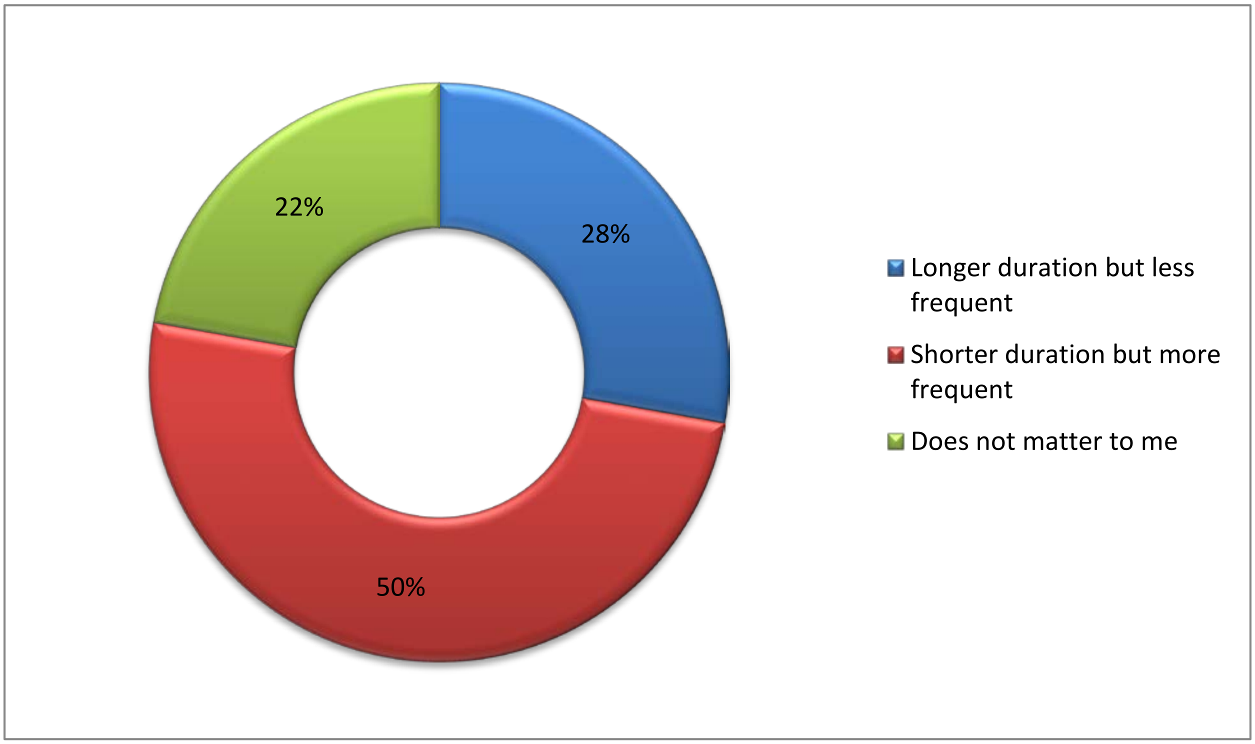
Question 1. How familiar are you with Pavement Preservation?



Answer Options	

Figure 19. Chart and Table. Response to Question 1.

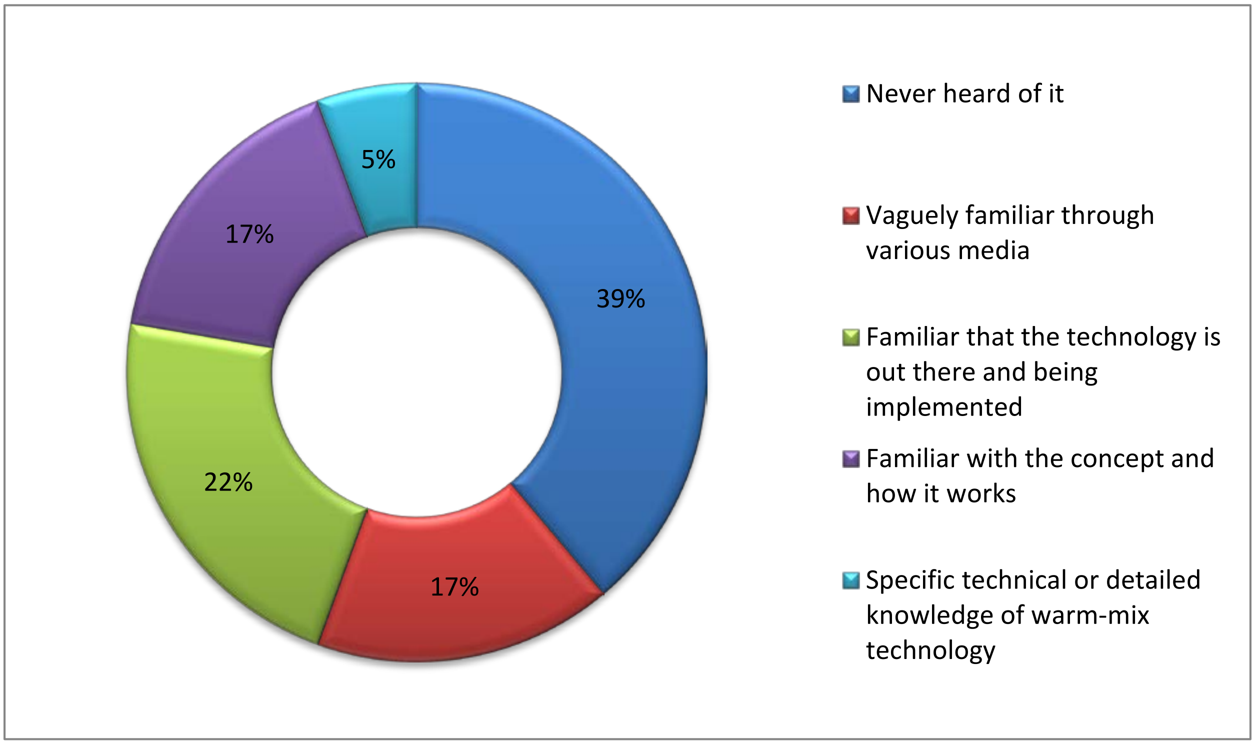
Question 2. For roads that you travel often, do you prefer less frequent but longer duration projects (1-2 year of road construction every 13-15 years) or more frequent but quicker projects (2 weeks to 2 months of road construction every 10-12 years)?



Answer Options	**Response Percent**	**Response Count**
Longer duration but less frequent	27.8%	5
Shorter duration but more frequent	50.0%	9
Does not matter to me	22.2%	4
answered question		**18**
skipped question		**0**

Figure 20. Chart and Table. Response to Question 2.

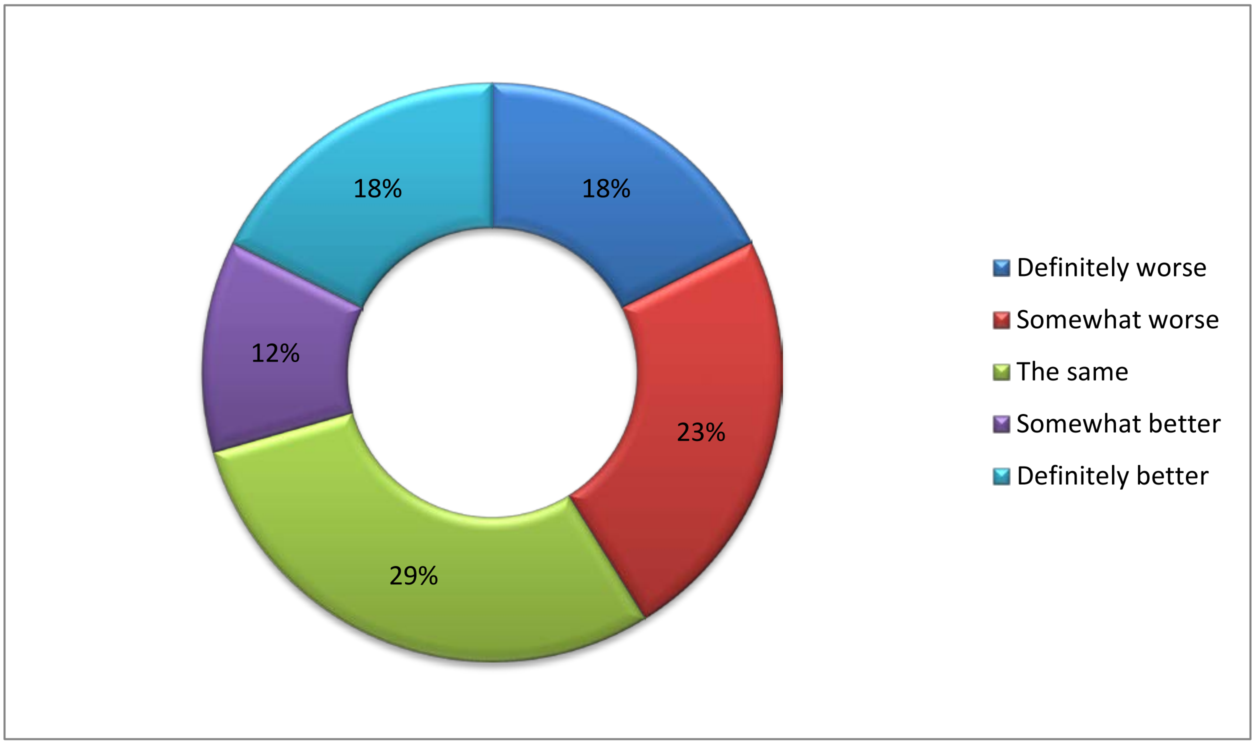
Question 3. This project incorporated warm mix asphalt (WMA) technology. WMA is similar to traditional hot mix asphalt but it is 25 to 100 degrees cooler than the normal production pavement temperature. How familiar are you with the WMA technology?



Answer Options	Response Percent	Response Count
Never heard of it	38.9%	7
Vaguely familiar through various media	16.7%	3
Familiar that the technology is out there and being implemented	22.2%	4
Familiar with the concept and how it works	16.7%	3
Specific technical or detailed knowledge of warm-mix technology	5.6%	1
answered question		**18**
skipped question		**0**

Figure 21. Chart and Table. Response to Question 3.

Question 4. In areas where the existing pavement was "ground off" (top 3 inches removed), how would you rate the ride quality of the "ground off" surface before the surface was repaved compared to other similar state paving jobs?

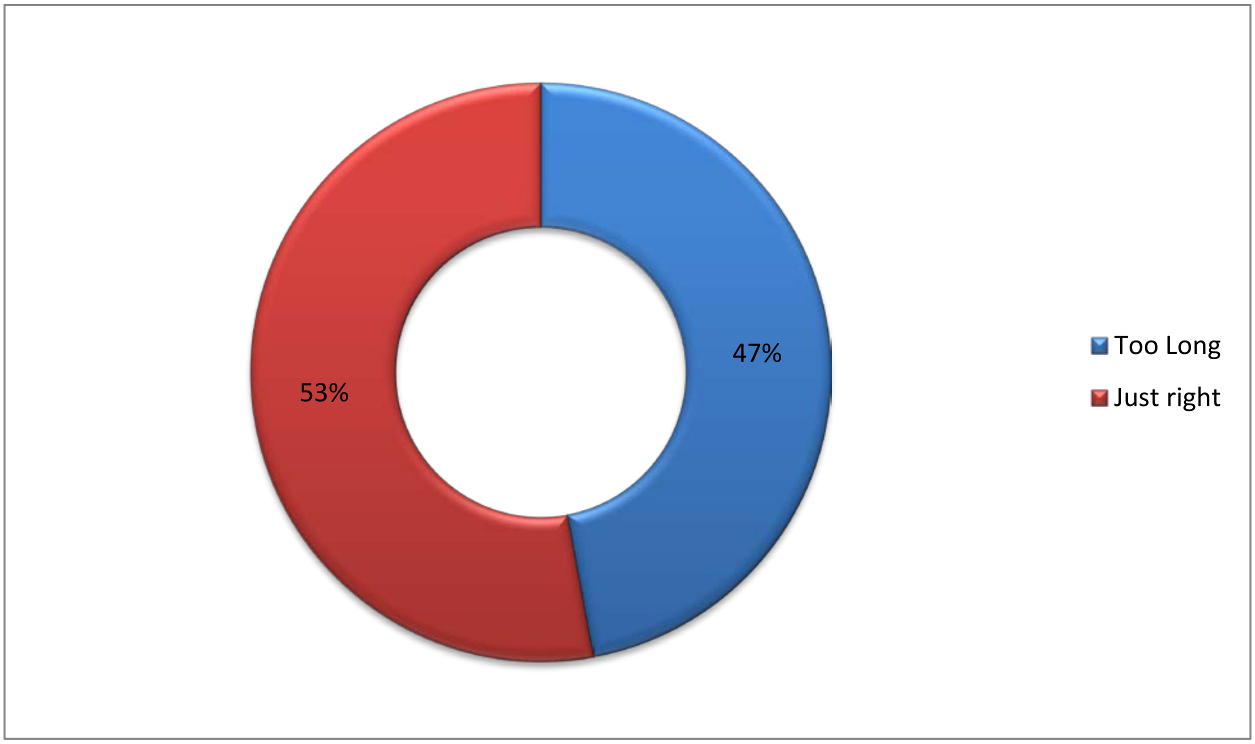


Answer Options	Response Percent	Response Count
Definitely worse	17.6%	3
Somewhat worse	23.5%	4
The same	29.4%	5
Somewhat better	11.8%	2
Definitely better	17.6%	3
Please Explain,		1
answered question		**17**
skipped question		**1**

Number	Explained Comments
1	Smooth ride from on ramps to off ramps and throughout the pavement

Figure 22. Chart and Table. Response to Question 4.

Question 5. In areas where the existing pavement was ground off (top 3 inches removed), how would you rate the turnaround time to repave the roadway?

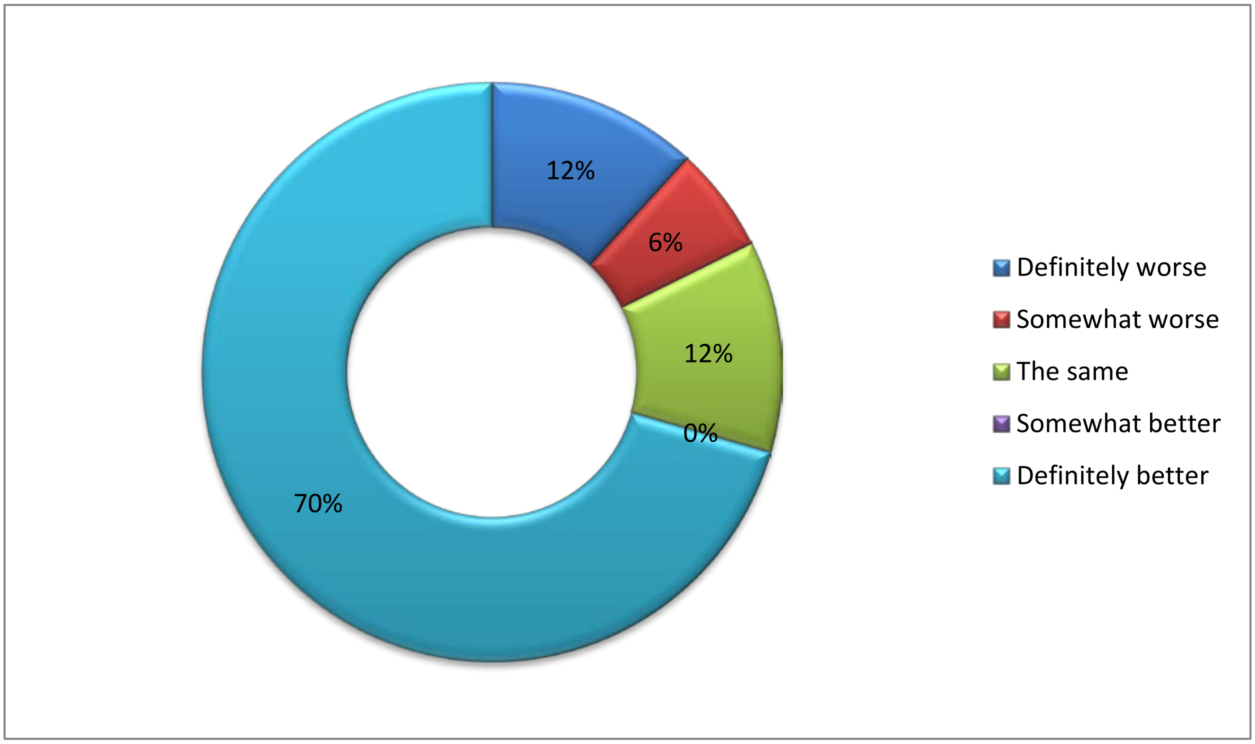


Answer Options	Response Percent	Response Count
Too Long	47.1%	8
Just right	52.9%	9
Please Explain,		4
answered question		**17**
skipped question		**1**

Number	Explained Comments
1	It's supposed to happen in the same work cycle, not over a period of days or more.
2	faster than I thought it would be
3	when they pave the roads why does it take so long to put down final striping?
4	Quicker the better, seemed to be 3weeks to a month

Figure 23. Chart and Table. Response to Question 5.

Question 6. How would you rate the ride quality of the new pavement compared to the previous pavement before construction?

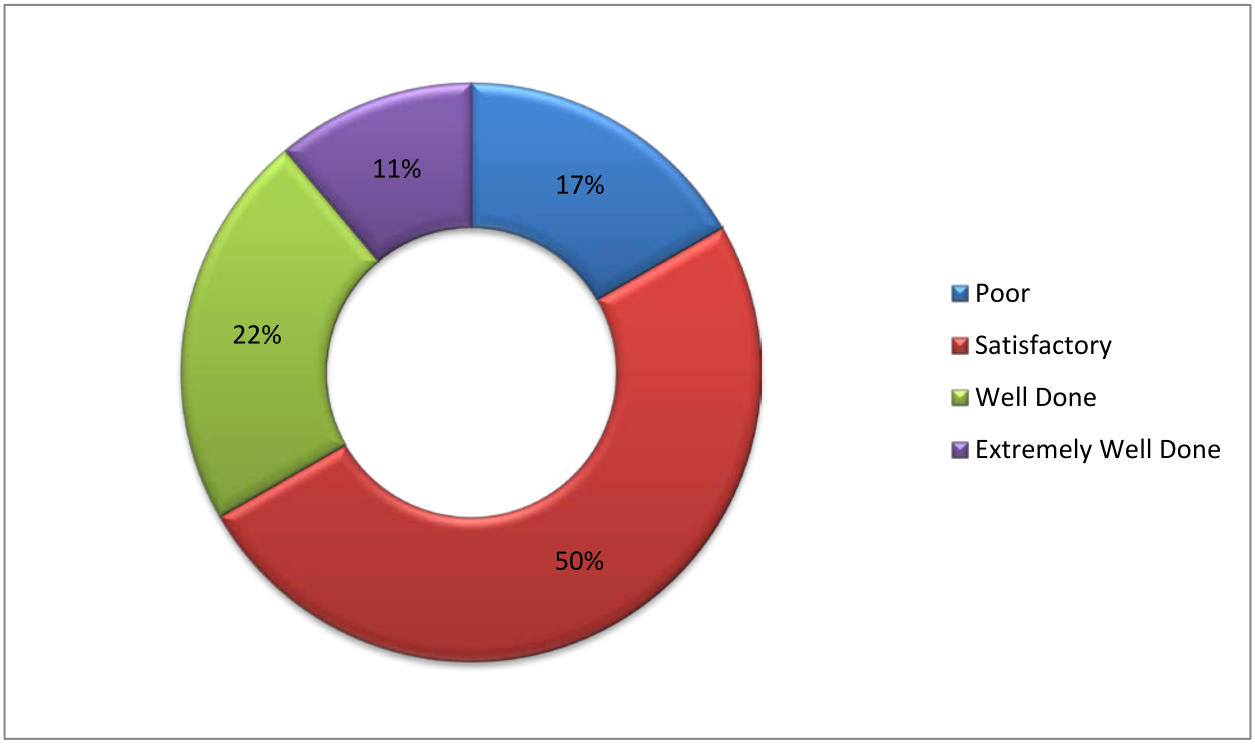


Answer Options	Response Percent	Response Count
Definitely worse	11.8%	2
Somewhat worse	5.9%	1
The same	11.8%	2
Somewhat better	0.0%	0
Definitely better	70.6%	12
Please Explain,		1
answered question		**17**
skipped question		**1**

Number	Explained Comments
1	this section of 95 needed to be repaved for a long time

Figure 24. Chart and Table. Response to Question 6.

Question 7. How would you rate the Department of Transportation in minimizing the traffic disruption during construction of this project?



Answer Options	Response Percent	Response Count
Poor	16.7%	3
Satisfactory	50.0%	9
Well Done	22.2%	4
Extremely Well Done	11.1%	2
If you answered Poor, please describe how DOT can minimize this disruption		1
	answered question	**18**
	skipped question	**0**

Number	Explained Comments
1	I doubt you'll please anyone considering it is always going to be inconvenient.

Figure 25. Chart and Table. Response to Question 7.