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Field Monitoring of Experimental Hot Mix Asphalt Projects Placed in Massachusetts

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16. Abstract

Since 2000, Massachusetts has been involved with numerous field trials of experimental hot mix asphalt mixtures. These experimental mixtures included several pilot projects using the Superpave mixture design methodology, utilization of warm mix asphalt technologies, asphalt rubber mixtures, latex or polymer modified asphalt mixtures, and reflective crack relief layer mixtures. All these types of mixtures are placed to achieve a longer service life and specific outcomes in terms of performance of the pavement.

The research team solicited input from MassDOT to identify projects that were of interest for monitoring. Twelve projects were identified for inclusion in the study. For each project, a plan was developed to monitor the experimental mixture performance. Ultimately, it was decided that condition data (distresses, rutting, cracking, roughness, etc.) would be measured periodically during the duration of this project to monitor project performance.

Generally, based on the monitoring plan and associated thresholds for condition indices, the experimental mixtures placed at the selected projects have provided acceptable performance in terms of cracking, rutting, and ride quality. Furthermore, it is suggested that a final specification be developed for mixtures exhibiting acceptable performance.

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Field Monitoring of Experimental Hot Mix Asphalt Projects Placed in Massachusetts

Final Report

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The Project Team would like to acknowledge the efforts of Edmund Naras, Pavement Management Engineer, MassDOT, and Gregory Doyle, Construction Quality Engineer for FHWA Massachusetts Division. The Project Team would also like to acknowledge the MassDOT district materials engineer in each of the five districts for their efforts in obtaining data for each of the projects monitored.

Disclaimer

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Executive Summary

This study of the Field Monitoring of Experimental Hot Mix Asphalt Projects Placed in Massachusetts was undertaken as part of the Massachusetts Department of Transportation (MassDOT) Research Program. This program is funded with Federal Highway Administration (FHWA) State Planning and Research (SPR) funds. Through this program, applied research is conducted on topics of importance to the Commonwealth of Massachusetts transportation agencies.

Since 2000, Massachusetts has been involved with numerous field trials of experimental hot mix asphalt (HMA) mixtures. These experimental mixtures included several pilot projects using the Superpave mixture design methodology, utilization of warm mix asphalt (WMA) technologies, asphalt rubber (AR) mixtures, latex or polymer modified asphalt mixtures, and reflective crack relief layers (RCRL) mixtures. All these types of mixtures are placed to achieve a longer service life and to achieve a specific outcome in terms of performance of the pavement. Examples of a specific outcome can include better distress resistance, easier placement or construction.

Because of their experimental nature, these types of mixtures placed on field projects require evaluation and monitoring to determine if they achieved the desired performance outcome. These evaluations require many years and cannot be conducted over a short period of time. Ultimately, these evaluations and monitoring will determine if an experimental mixture was successful enough for further use and full-scale implementation. Thus, the primary goal of this project was to monitor the performance of MassDOT selected experimental mixtures placed at varying times since 2000 over an extended period.

At the onset of this project, the research team solicited input from MassDOT to identify projects that were of interest for monitoring. A total of 12 projects were identified for inclusion in the study. The primary reason for monitoring each project was different, but included evaluating technologies (warm mix asphalt, crumb rubber, polymer, etc.), evaluating new pavement preservation strategies (ultra-thin bonded overlay, elastomeric friction courses, etc.), crack mitigation methods (stress absorbing membrane interlayer, pavement reinforcement systems, etc.), and evaluating reduced gyratory compactive effort for Superpave mixtures. For each selected project, a significant effort was undertaken to collect all available data regarding the project from MassDOT. This included all bid/contract documents, material specifications, plant reports, construction quality assurance data, ride quality, and distress data.

For each selected project, a plan was developed to monitor the performance of the experimental mixture. Ultimately, it was decided that condition data (distresses, rutting, cracking, roughness, etc.) would be measured periodically throughout the duration of this project to monitor project performance. The condition data was collected using standardized techniques by the MassDOT Pavement Management Section over the life of each selected project and more importantly in the same manner for each project. This allowed for a more consistent and less biased evaluation of the performance evaluation of each project while also

allowing for a future project-to-project comparison if so desired. Four condition indices with associated thresholds for acceptable performance were calculated at specific time intervals for each selected project.

A detailed summary of all the relevant data and condition evaluations for each project is provided in this report. Generally, based on the monitoring plan and associated thresholds for condition indices, the experimental mixtures placed at the selected projects have provided acceptable performance in terms of cracking, rutting, and ride quality. Furthermore, it is suggested if these projects continue to provide acceptable performance that a final specification be developed so the same strategies can be used in the future.

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List of Acronyms

APA	Asphalt Pavement Analyzer
AR	Asphalt Rubber
ARGG	Asphalt Rubber Gap Graded
CMCR	Chemically Modified Crumb Rubber
DI	Distress Index
EFC	Elastomeric Friction Course
GGSMA	Gap Graded Stone Matrix Asphalt
G_{sb}	Bulk Specific Gravity of Compacted Specimen
G_{mm}	Maximum Theoretical Specific Gravity
HMA	Hot Mix Asphalt
IRI	International Roughness Index
JMF	Job Mix Formula
LTMF	Laboratory Trial Mix Formula
N_{design}	Superpave Design Gyratory Compactive Effort
OGFC	Open Graded Friction Course
PCI	Pavement Condition Index
PGAB	Performance Grade Asphalt Binder
PSI	Present Serviceability Index
QA	Quality Assurance (Includes both Contractor QC and MassDOT Acceptance Activities)
QC	Quality Control (Contractor Testing Results)
RCRL	Reflective Crack Relief Layer
RI	Rutting Index
SAMI	Stress Absorbing Membrane Interlayer
SBR	Styrene Butadiene Rubber
SSC	Superpave Surface Course
SIC	Superpave Intermediate Course
UTBO	Ultra-Thin Bonded Overlay
VFA	Voids Filled with Asphalt
VMA	Voids in Mineral Aggregate
WMA	Warm Mix Asphalt

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1.0 Background

Massachusetts has been involved with numerous field trials of experimental hot mix asphalt (HMA) mixes. These types of mixes have included but are not limited to Superpave, warm mix asphalt (WMA), asphalt rubber (AR), and reflective crack relief layers (RCRL) mixes.

In 2000, Massachusetts placed its first Superpave pilot projects utilizing the Superpave mix design method. In total, there have been seven experimental pilot projects utilizing Superpave mix designs conducted in three different districts in the state. Beyond these Superpave mixes, Massachusetts has placed several pilot projects to evaluate new and existing technologies in HMA. In 2005, the first WMA mix trial was conducted in the state in MassDOT Highway Division District 4. Since that time, new HMA mixes have been developed and placed around the state that incorporate new WMA additives.

Each of these experimental projects has been placed to evaluate a specific technology or design methodology. These evaluations cannot be made over a brief period. Hence, the goal of this project was to monitor the performance of these experimental HMA mixes to fully evaluate their performance in the field.

The performance was measured through a series of field procedures. These procedures quantified the performance of each mix and the changes in their performance over time. Furthermore, construction data and site information of each project was documented.

This data will aid Massachusetts in determining if full-scale implementation of these design methodologies and technologies is cost-effective in the long term. Overall, it is anticipated that well-performing technologies could be separated from poor-performing ones, thus leading to better decisions for future infrastructure decisions. Ultimately, this will lead to a better use of shrinking infrastructure funding.

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2.0 Research Objectives

The objectives of this study were to:

- Identify the experimental HMA mixes that have been placed and are scheduled to be placed in Massachusetts.
- Catalog the relevant material properties and performance for each mix at the time of production and placement.
- Monitor each mix in the field at periodic intervals. Monitoring should include field survey of distress and calculation of relevant Pavement Condition Index (PCI), as well as collection of field core samples at selected locations for further laboratory testing.
- Develop a comparative measure to evaluate the effectiveness of each HMA mix versus time in terms of distress and loss of structural efficiency.
- Evaluate the mixes in terms of the developed comparative measures.
- Generate a database with all the relevant preconstruction, construction, and post-construction data. Data will include site location, virgin material characteristics, Contractor, temperature, density, and traffic.

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3.0 Experimental Plan

In order to fulfill the objectives of this study, an experimental plan was developed as shown in Figure 3.1.1.

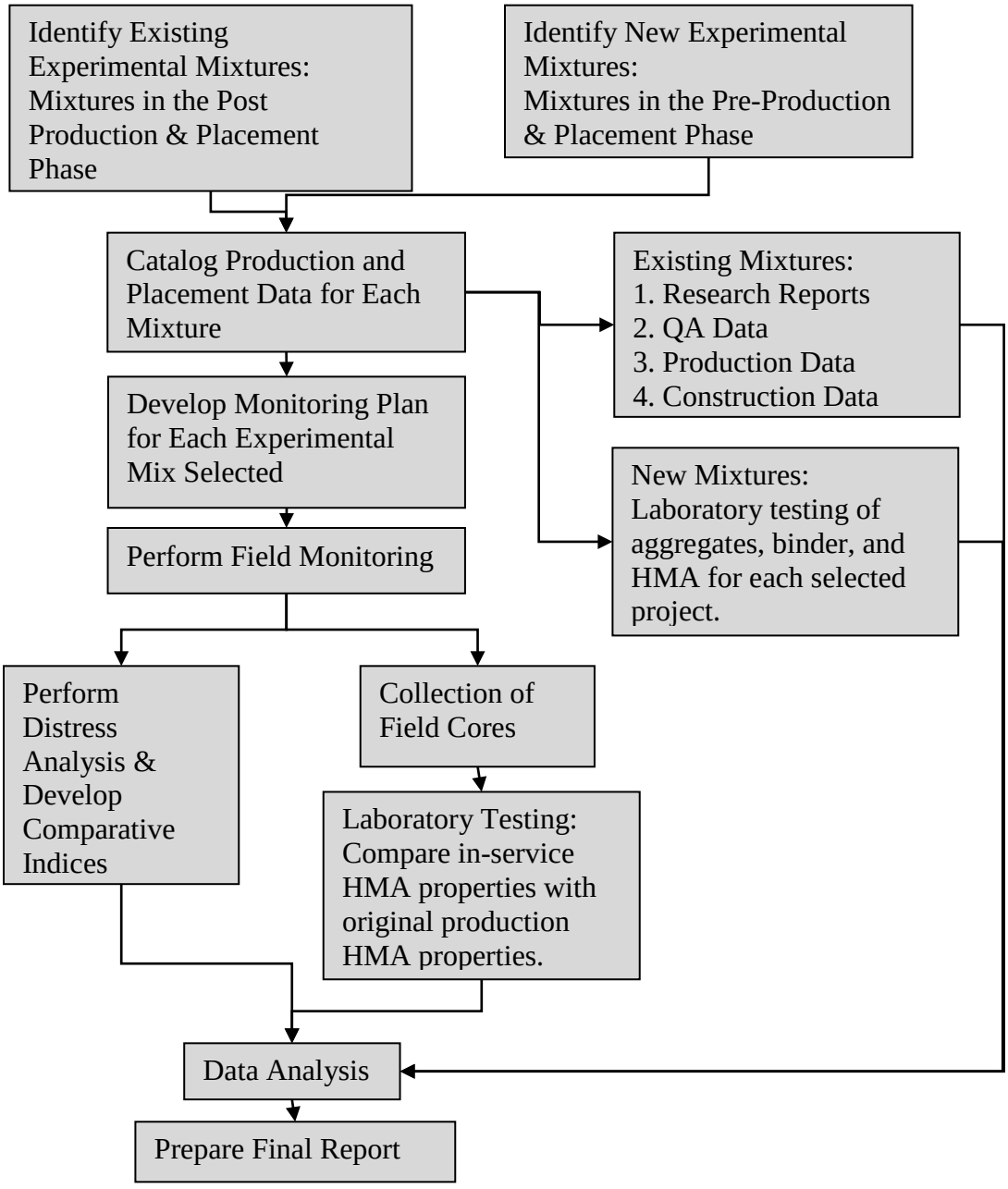

Figure 3.1.1: Experimental plan

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4.0 Project Selection and Monitoring Plan

4.1 Project Selection

At the commencement of this project, the research team solicited input from MassDOT to identify projects that were of interest for monitoring. Members of MassDOT Highway Division, including the Research and Materials and Pavement Management sections, were contacted for their input. Based on the input received, the projects shown in Table 4.1.1 were selected for inclusion in this project.

Table 4.1.1: Projects selected for monitoring by MassDOT

ID	MassDOT District	MassDOT Contract Number	MassDOT Project Number	Project Location
P1	1	57964	605211	Route 8 Lanesboro-Pittsfield
P2	2	96213	69304	I-91 Greenfield-Bernardston
P3	3	41062	603868	Route 146 Millville-Uxbridge
P4	3	62667	604991	Route 9 (Worcester Rd.) Framingham-Natick
P5	3	69939	605759	I-395 Oxford
P6	3	66933	605580	Route 20 (Washington St.) Auburn
P7	4	34700	603984	I-95 Danvers-Rowley
P8	5	32082	600885	I-495 Northbound Franklin-Mansfield
P9	5	43497	601932R	I-495 Southbound Franklin-Mansfield
P10	5	52815	604574	I-295 Attleboro-North Attleboro
P11	5	70375	605590	I-95 Canton-Norwood-Sharon-Walpole
P12	5	70962	605619	Route 28 Falmouth

For each project shown in Table 4.1.1, a significant effort was undertaken to collect all available data regarding the project from MassDOT. This included all bid/contract documents, material specifications, plant reports, construction quality assurance data, ride

quality, and distress data. Based on the available data, the primary reason for monitoring each project was identified as outlined in Table 4.1.2. Each of these projects is discussed in more detail in Section 5.0.

Table 4.1.2: Primary reason for monitoring the projects selected by MassDOT

ID	MassDOT Project Number	Project Location	Primary Reason for Monitoring
P1	605211	Route 8 Lanesboro-Pittsfield	Placement of a 1.25" thick HMA Top Course Type A – PG64-28 Latex Modified (3% SBR Latex) over a FiberMat® Type B surface treatment
P2	69304	I-91 Greenfield-Bernardston	Placement of a ¾" chemically modified crumb rubber (CMCR) elastomeric surface treatment
P3	603868	Route 146 Millville-Uxbridge	Placement of a CMCR elastomeric friction course
P4	604991	Route 9 (Worcester Rd.) Framingham-Natick	Placement of 2" of 12.5mm with 2% SBR Latex mixture Level 4 (N_{design} = 100 gyrations) over 1¼" of a 9.5mm Superpave leveling course. Pavement reinforcement system placed between the pavement layers over the concrete slab expansion joints.
P5	605759	I-395 Oxford	Placement of 1" of OGFC over 2" of Superpave Intermediate Course (SIC-12.5). Two SIC-12.5mm mixtures were placed, one with N_{design} of 80 and one with N_{design} of 100. Gyration level study.
P6	605580	Route 20 (Washington St.) Auburn	Placement of 1¾" SSC – 12.5 Polymer Modified over 1½" SIC – 12.5. A pavement reinforcement system was placed between the pavement layers over the concrete slab expansion joints.
P7	603984	I-95 Danvers-Rowley	Placement of gap graded stone matrix asphalt (GGSMA) mixture with PG64-28 and 1.5% Sasobit® WMA technology surface course incorporating 4% latex and lime.
P8	600885	I-495 Northbound Franklin-Mansfield	Placement of pavement structure over rubblized PCC slabs

Table 4.1.2: Primary reason for monitoring the projects selected by MassDOT (continued)

ID	MassDOT Project Number	Project Location	Primary Reason for Monitoring
P9	601932R	I-495 Southbound Franklin-Mansfield	Placement of 1" stress absorbing membrane interlayer (SAMI) mixture over existing concrete slabs
P10	604574	I-295 Attleboro-North Attleboro	Placement of two ultra-thin bonded overlay (UTBO) mixtures (conventional & asphalt rubber) and an asphalt rubber gap graded (ARGG) mixture with WMA
P11	605590	I-95 Canton-Norwood-Sharon-Walpole	Placement of 1" of OGFC over 1" of Superpave Surface Course (SSC-9.5). Two SSC-9.5 mixtures were placed, one with N_{design} of 80 and one with N_{design} of 100. Gyration level study.
P12	605619	Route 28 Falmouth	Placement of 2" of Superpave Surface Course (SSC-12.5). Two SSC-12.5 mixtures were placed, one with N_{design} of 80 and one with N_{design} of 100. Gyration level study.

4.2 Monitoring Plan

A significant amount of time was required to determine the best plan to monitor each project, as the primary reasons for monitoring varied significantly. Since many projects were located on active interstate roadways, field cores and photographic documentation could not be collected for all projects due to personnel safety concerns associated with a lack of traffic control. Additionally, many projects were placed prior to the commencement of this study, which did not allow for a consistent evaluation methodology throughout all phases of construction (i.e., design, production, placement, and in-service data) across all selected projects. Ultimately, it was decided that condition data (distresses, rutting, cracking, roughness, etc.) would be measured periodically throughout the duration of this project to monitor project performance *(1*). The condition data was collected using standardized techniques by the MassDOT Pavement Management Section over the life of each selected project and, more importantly, in the same manner for each project. This would allow for a more consistent and less biased evaluation of the performance evaluation of each project while also allowing for a project-to-project comparison if so desired.

The MassDOT Pavement Management Section collected condition data periodically for all the projects selected for this study using standardized methods of windshield survey or automated condition survey using a Pathway Services Inc. vehicle. Attempts were made to collect the data on an annual basis, but data for some projects were collected at different intervals due to the scheduling decided by the MassDOT Pavement Management Section. The condition data consisted of evaluation of each project in terms of distresses, including longitudinal cracking, transverse cracking, reflective cracking, and rutting (*1*). The distresses were transformed into indices on a scale from 1 to 5, with a value of 1 indicating poor condition and 5 indicating best condition. Specifically, two primary indices, a distress index (DI) and a rutting index (RI), were calculated by MassDOT. The lowest of the two indices was selected by MassDOT as the present serviceability index (PSI). Additionally, the profile of the surface was measured to evaluate the smoothness of the pavement surface. The profile measurements were used to calculate the international roughness index (IRI) for each project. Based on the available indices, the indices shown in Table 4.2.1 were utilized to monitor each project, as they cover the major distresses of interest and functional health of each project.

Table 4.2.1: Monitoring plan indices, reason for use, and thresholds

Index	Reason for Use	Thresholds
Present Serviceability Index (PSI)	Index used to trigger need for pavement rehabilitation	< 2.5 on Interstate Triggers Rehabilitation < 2.3 on Non-Interstate Triggers Rehabilitation
Distress Index (DI)	Combined index used to evaluate overall cracking (i.e., longitudinal, transverse, and reflective)	> 2.5 desired
Maximum Rut Depth	Index used to evaluate rutting	< 0.5 inch desired
International Roughness Index (IRI)	Index used to evaluate the functional performance of the road (i.e., ride quality)	Lower values indicated better functional ride quality.*

* The MassDOT 450 Specification for Hot Mix Asphalt outlines a target IRI during construction of 60 in/mile for roads with speed limits greater than or equal to 55 mph and 80 in/mile for roads with speed limits 40 to 55 mph for the pavement course below the final pavement course.

5.0 Project Monitoring Summaries

In this chapter, the results of the data collection, monitoring, and condition analysis are outlined on a project-by-project basis.

5.1 Project #1: Route 8 Lanesboro-Pittsfield

This section outlines the information and data collected for Project #1 (P1) Route 8 Lanesboro-Pittsfield.

5.1.1 Project General Information

The general information collected for this project is shown in Table 5.1.1.

Table 5.1.1: P1 general information, Route 8 Lanesboro-Pittsfield

Project ID:	P1
MassDOT District:	District 1
MassDOT Contract Number:	57964
MassDOT Project Number:	605211
Reason for Monitoring:	Placement of a 1.25" thick HMA Top Course Type A – PG64-28 Latex Modified (3% SBR Latex) over a FiberMat® Type B surface treatment
Contract Amount:	$1.4 million
Approximate Placement Date:	January 2010
Number of Years in Service:	7 years
Length of Section:	3.34 miles
Contractor:	Warner Bros., LLC, Sunderland, MA

5.1.2 Project Location

The locus map for this project is shown in Figure 5.1.1. The project stationing was as follows:

“Beginning of Project Station 63+04 (Route 8) Pittsfield along Route 8 to Station 63+04 to Station 0+00 Pittsfield/Lanesborough Town Line Station 0+00; continuing into Lanesborough from Station 0+00 and ending at Station 112+52 at the Lanesborough/Cheshire Town Line Station.”

No mile marker delineation of project start and end were supplied in the contract documents. Length of section was estimated at 3.34 miles.

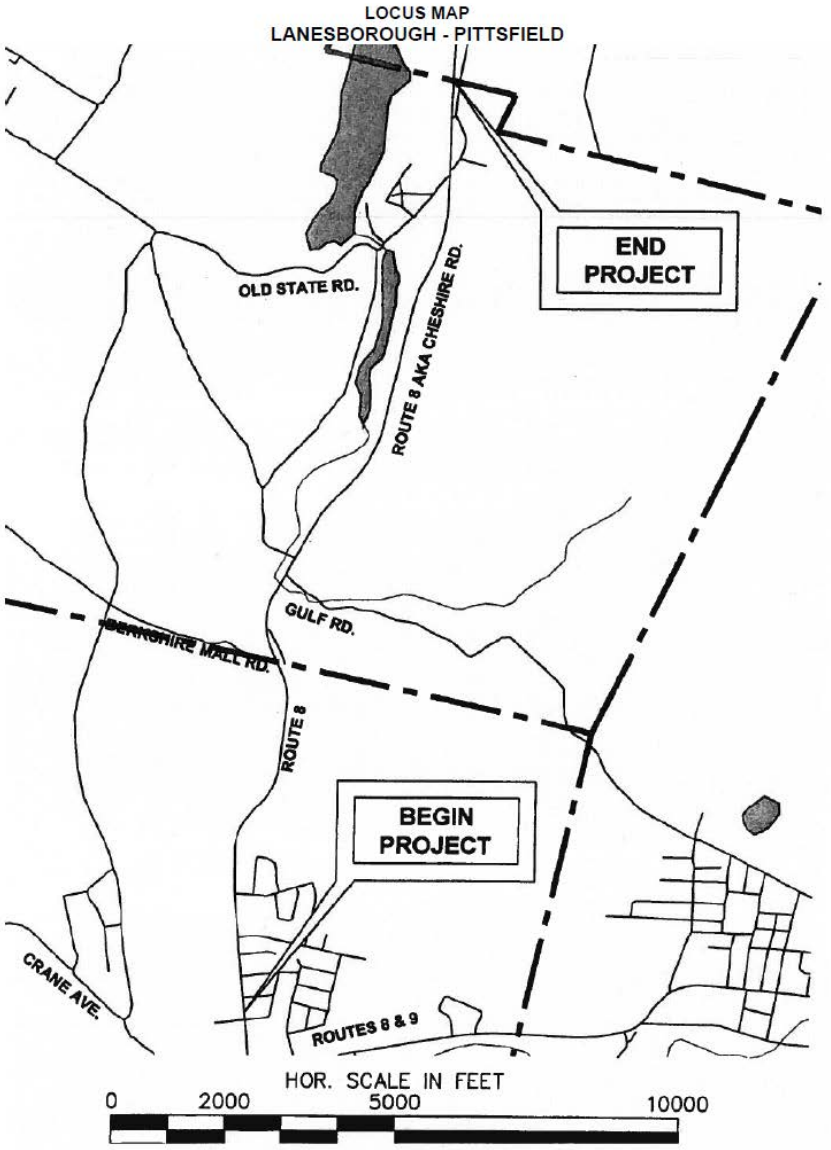

Figure 5.1.1: P1 site locus plan, Route 8 Lanesboro-Pittsfield

5.1.3 Typical Section Detail

The typical cross-section detail for the main road paving of this project is shown in Figure 5.1.2.

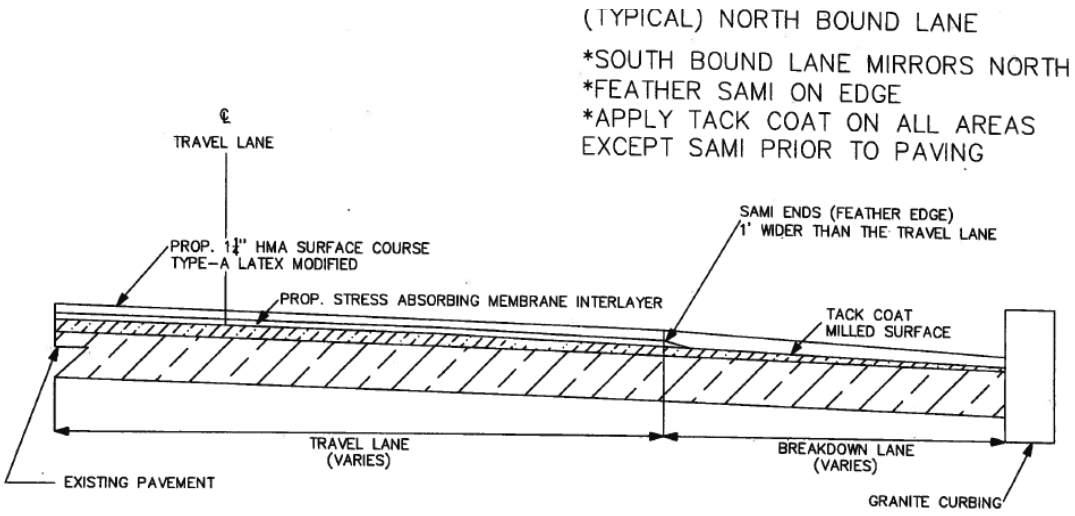

Figure 5.1.2: P1 typical section detail, Route 8 Lanesboro-Pittsfield

5.1.4 Existing Pavement Surface Preparation

A SAMI-type treatment was applied prior to the placement of the HMA surface course. This treatment was required to be a fiber-reinforced bituminous surface equivalent to a FiberMat® Type B. For this type of treatment, an asphalt emulsion was sprayed and chopped fibers were dispensed on top to provide reinforcement. This system was then covered by an aggregate layer. Ideally, this system gave the surface an improved tensile strength and improved reflective cracking resistance prior to the construction or placement of subsequent layers.

For the breakdown lane only, micromilling was conducted 12 feet from the exterior edge of the pavement.

5.1.5 Mixture Specification Requirements

The HMA Surface Course Type A – Latex Modified Top Course was required to meet the requirements of Section 460 and Section M3.11.03 of the 1995 Standard Specifications for Highways and Bridges. The requirements for the job mix formula (JMF) are shown in Table 5.1.2. A PG64-28 binder was specified for use in the mixture. This binder was then modified with the 3% latex. The latex was required to be styrene butadiene rubber (SBR) in liquid latex form, with a total rubber solids content percentage by weight of 60%–72%.

Table 5.1.2: P1 MassDOT top course specification, Route 8 Lanesboro-Pittsfield

Sieve Size	Top Course Specification Requirements	Production Tolerance
12.5 mm (1/2 inch)	95–100	± 7.0%
9.5 mm (3/8 inch)	80–100	± 7.0%
4.75 mm (No. 4)	50–76	± 7.0%
2.36 mm (No. 8)	37–54	± 4.0%
1.18 mm (No. 16)	26–40	± 4.0%
600 μm (No. 30)	17–29	± 4.0%
300 μm (No. 50)	10–21	± 4.0%
150 μm (No. 100)	5–16	± 4.0%
75 μm (No. 200)	2–7	± 2.0%
Asphalt Content	5.5–7.0%	± 0.4%

5.1.6 Mixture Production Data

No mixture production data was available.

5.1.7 Condition Data

The average condition indices (PSI, DI, maximum rut depth, and IRI) for this project with respect to in-service time (in years) are shown in Figures 5.1.3 through 5.1.6. With approximately seven years in service, the PSI remained above the 2.3 threshold for non-interstate roads, therefore indicating no need for rehabilitation at this time. The DI over time has remained above the 2.5 threshold, thereby indicating that cumulative cracking is not yet an issue. Average maximum rut depth was below the 0.5-inch threshold, indicating rutting has remained at acceptable levels. The ride quality, in terms of IRI, has increased as service life has increased. Overall, based on the indices, the use of the Fibermat® Type B overlaid with a latex modified top course has performed acceptably. This project should continue to be monitored as in-service life increases to determine the longevity of this strategy.

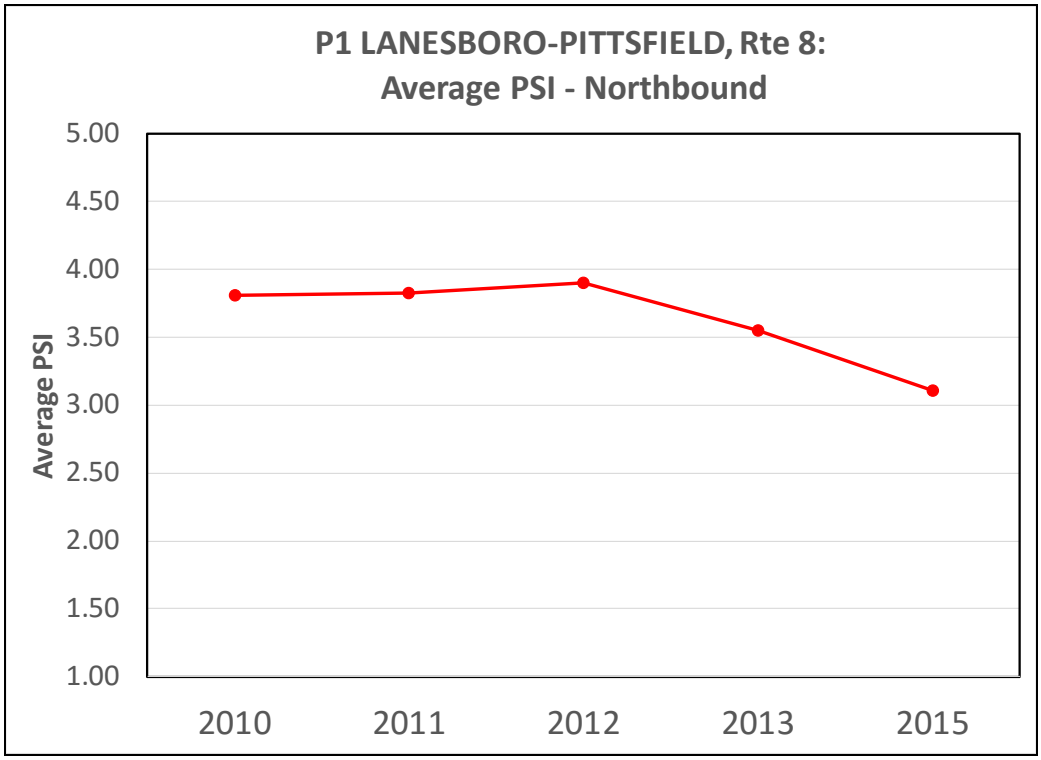

Figure 5.1.3: P1 condition data – average PSI, Route 8 Lanesboro-Pittsfield

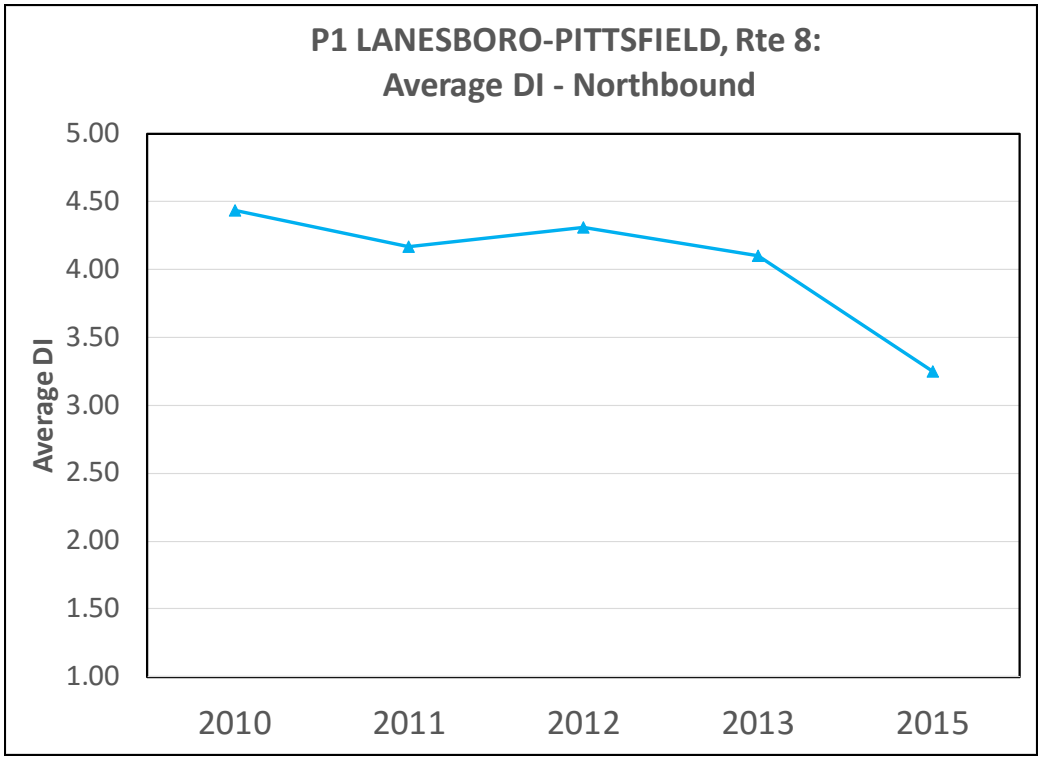

Figure 5.1.4: P1 condition data – average DI, Route 8 Lanesboro-Pittsfield

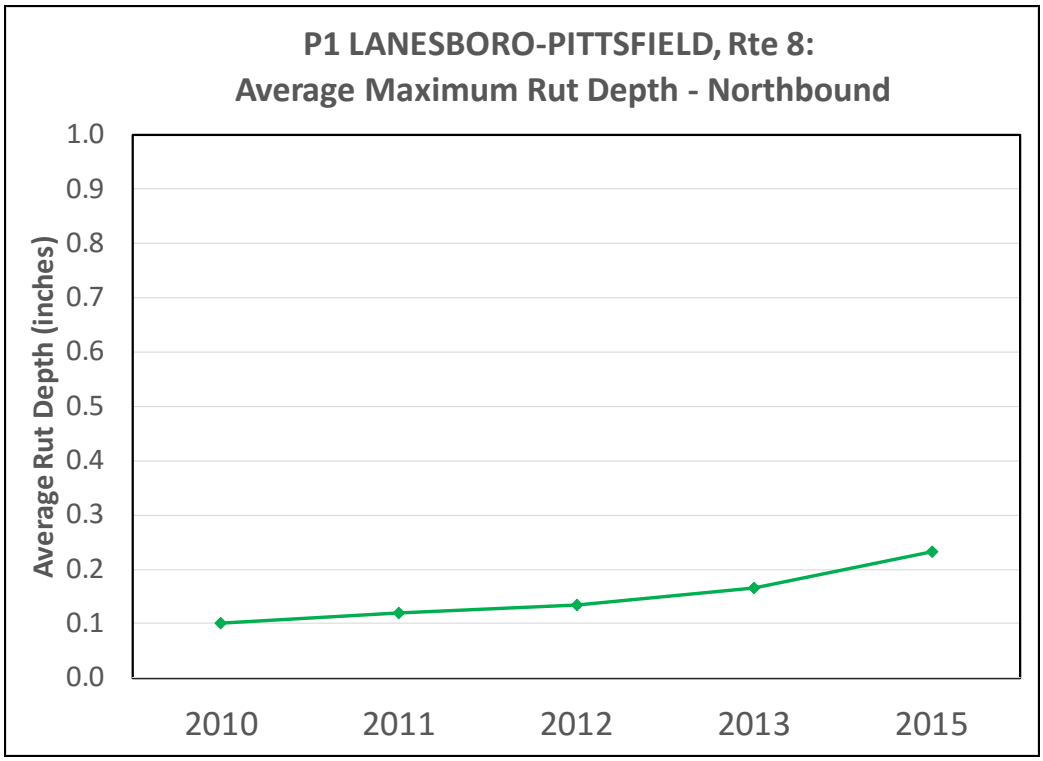

Figure 5.1.5: P1 condition data – average maximum rut depth, Route 8 Lanesboro-Pittsfield

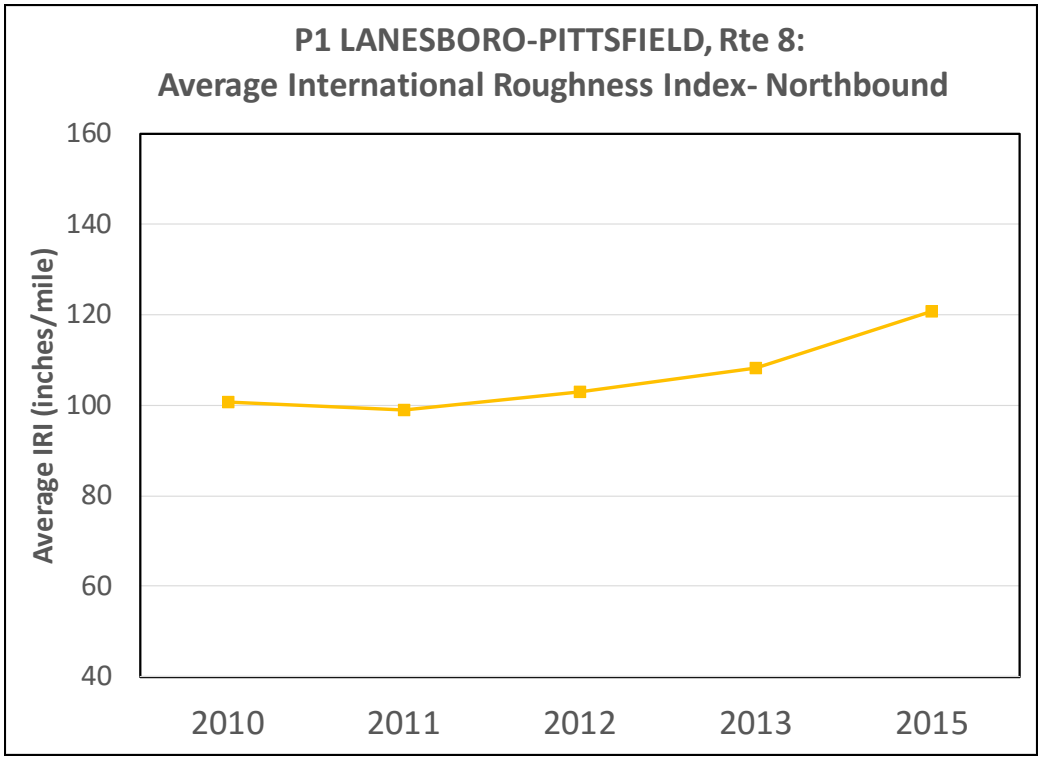

Figure 5.1.6: P1 condition data – average IRI, Route 8 Lanesboro-Pittsfield

5.2 Project #2: I-91 Greenfield-Bernardston

This section outlines the information and data collected for Project #2 (P2) I-91 Greenfield-Bernardston.

5.2.1 Project General Information

The general information collected for this project is shown in Table 5.2.1.

Table 5.2.1: P2 general information, I-91 Greenfield-Bernardston

Project ID:	P2
MassDOT District:	District 2
MassDOT Contract Number:	35010
MassDOT Project Number:	604127
Reason for Monitoring:	Placement of a ¾" chemically modified crumb rubber (CMCR) elastomeric surface treatment
Contract Amount:	$500,000 (approx.)
Approximate Placement Date:	August 2005
Number of Years in Service:	12 years
Length of Section:	1.8 miles
Contractor:	Warner Bros., LLC, Sunderland MA (Trew Corp.)

5.2.2 Project Location

No locus map for this project was available. According to available records, the project starts 6,000 feet south of the River Street overpass in Bernardston to approximately 100 feet north of the Route 10 overpass. Sections north of the Route 10 overpass were milled and overlaid in 2015.

5.2.3 Typical Section Detail

No typical cross-section detail was available. According to available records, the CMCR Elastomeric Surface Treatment was placed over a 2-inch Class 1 modified top course. The sections along the project vary in existing cross section from the modified top course down.

5.2.4 Existing Pavement Surface Preparation

No information exists on any surface preparation undertaken for this project.

5.2.5 Mixture Specification Requirements

The CMCR Asphalt Mixture was required to meet the JMF range shown in Table 5.2.2. The Contractor's JMF is also shown in Table 5.2.2. The binder utilized for mixture production was a PG76-34 with 8% CMCR (by weight of binder) supplied by Hudson Asphalt of Providence, RI. The mixing temperature range was 336°–334° F and the compaction temperature range was 325°–310° F. The mixture was required to meet volumetric criteria for air voids (4%–6%), and voids in mineral aggregate (VMA) (18% minimum).

Table 5.2.2: P2 MassDOT CMCR mixture specification & contractor JMF, I-91 Greenfield-Bernardston

Sieve Size	CMCR Asphalt Mixture Specification Requirements	Contractor's JMF	Production Tolerance
12.5 mm (1/2 inch)	100	100	± 7.0%
9.5 mm (3/8 inch)	91–95	95	± 7.0%
4.75 mm (No. 4)	40–45	45	± 7.0%
2.36 mm (No. 8)	22–26	25	± 5.0%
1.18 mm (No. 16)	–	17	± 4.0%
600 μm (No. 30)	9–12	12	± 4.0%
300 μm (No. 50)	6–8	8	± 4.0%
150 μm (No. 100)	–	6	± 4.0%
75 μm (No. 200)	3–5	4.8	± 2.0%
Asphalt Content	6.0–8.0%	8.0%	± 0.4%

5.2.6 Mixture Production Data

Production data was available for this mixture. The average gradation analysis, binder content, and volumetric properties by the Contractor and the same corresponding mixture information obtained by MassDOT during production are shown in Table 5.2.3.

Table 5.2.3: P2 production data, I-91 Greenfield-Bernardston

Sieve Size	Contractor's JMF	Production Tolerance	Contractor CMCR Mixture Average Production Data (8 Sublots)	MassDOT CMCR Mixture Average Production Data (4 Sublots)
12.5 mm (1/2 inch)	100	± 7.0%	100	100
9.5 mm (3/8 inch)	95	± 7.0%	97.9	98.1
4.75 mm (No. 4)	45	± 7.0%	49.2	49.8
2.36 mm (No. 8)	25	± 5.0%	27.4	27.3
1.18 mm (No. 16)	17	± 4.0%	16.8	16.8
600 μm (No. 30)	12	± 4.0%	11.3	11.5
300 μm (No. 50)	8	± 4.0%	7.9	8.0
150 μm (No. 100)	6	± 4.0%	5.3	5.3
75 μm (No. 200)	4.8	± 2.0%	3.4[1]	3.4
Asphalt Content	8.0%	± 0.4%	7.9%	7.7%
Air Voids	4–6%	–	5.8%[2]	5.7%[3]
VMA	18% min.	–	22.2%	22.3%

[1] Two individual sublots out of production tolerance.
[2] Three individual sublots out of production tolerance.
[3] Two individual sublots out of production tolerance.

5.2.7 Condition Data

The average condition indices (PSI, DI, maximum rut depth, and IRI) for this project with respect to in-service time (in years) are shown in Figures 5.2.1 through 5.2.4. With approximately 12 years in service, the PSI remained above the 2.5 threshold for interstate roads, therefore indicating no need for rehabilitation at this time. The DI over time has remained above the 2.5 threshold, thereby indicating that cumulative cracking is not yet an issue. Average maximum rut depth was below the 0.5-inch threshold, indicating rutting has remained at acceptable levels. The ride quality, in terms of IRI, has increased as service life has increased, but not drastically. Overall, based on the indices, the placement of a CMCR elastomeric surface treatment has performed acceptably. This project should continue to be monitored as in-service life increases to determine the longevity of this particular strategy.

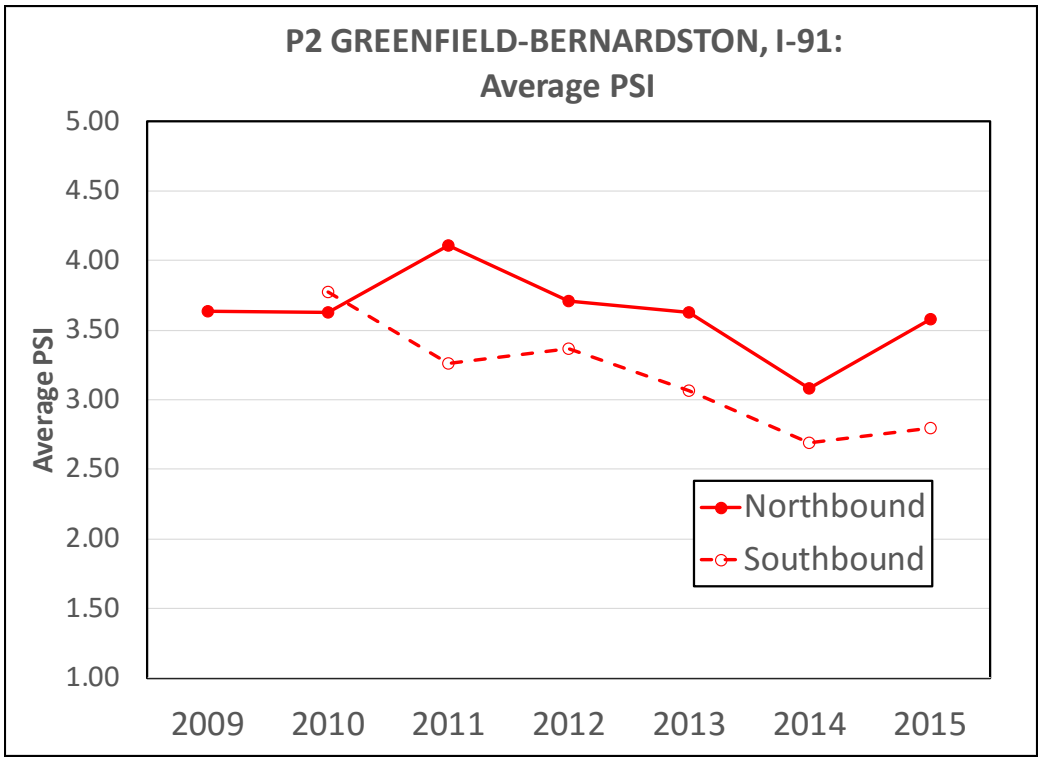

Figure 5.2.1: P2 condition data – average PSI, I-91 Greenfield-Bernardston

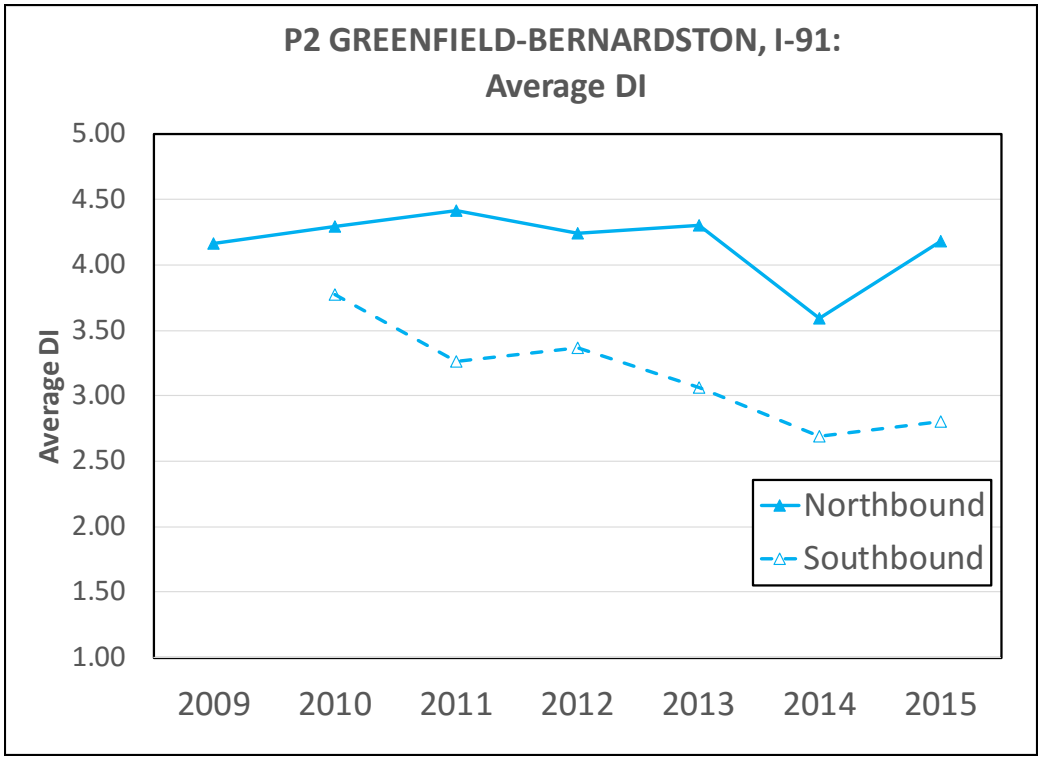

Figure 5.2.2: P2 condition data – average DI, I-91 Greenfield-Bernardston

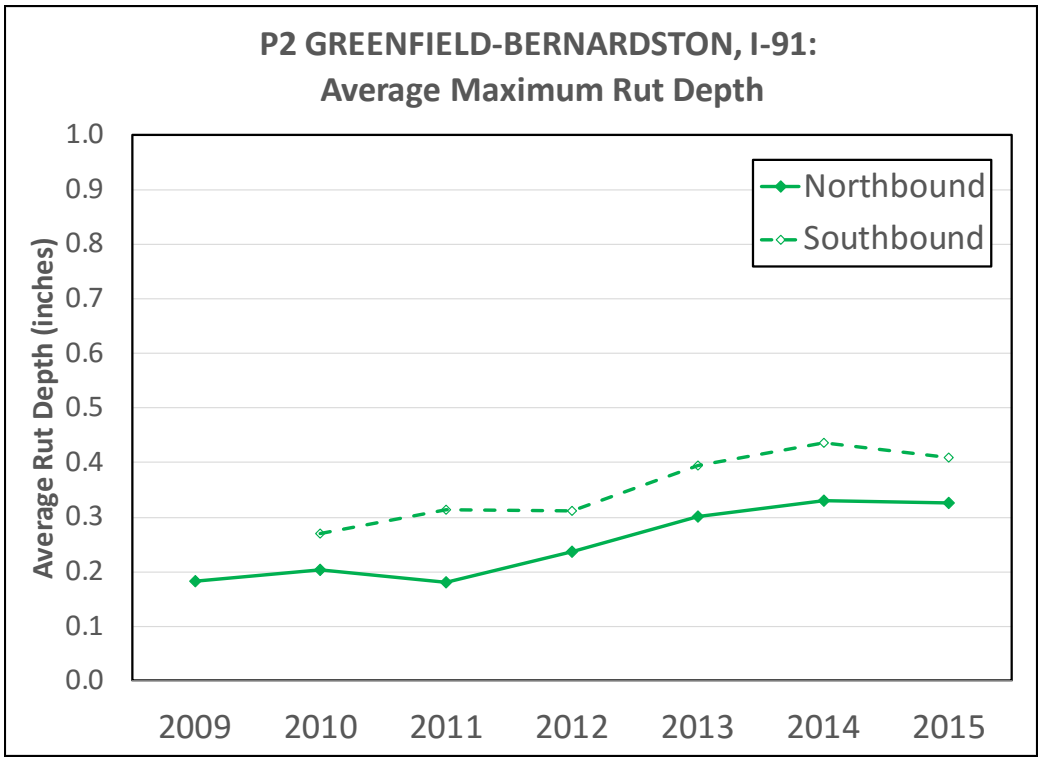

Figure 5.2.3: P2 condition data – average maximum rut depth, I-91 Greenfield-Bernardston

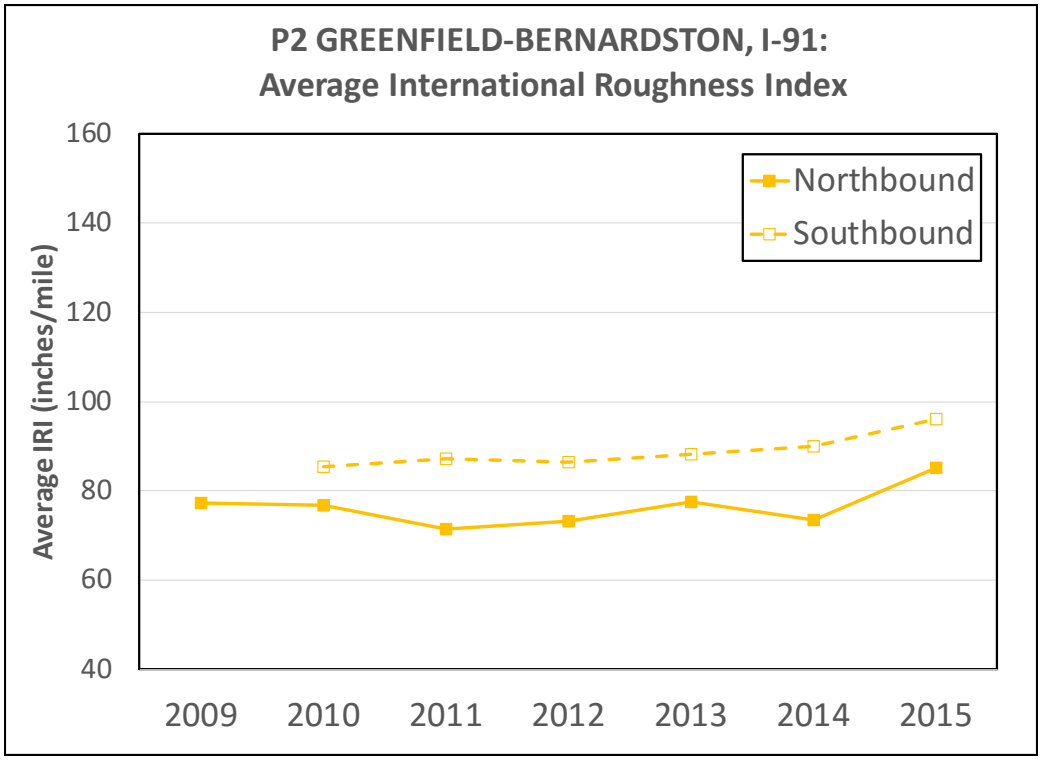

Figure 5.2.4: P2 condition data – average IRI, I-91 Greenfield-Bernardston

5.3 Project #3: Route 146 Millville-Uxbridge

This section outlines the information and data collected for Project #3 (P3) Route 146 Millville-Uxbridge.

5.3.1 Project General Information

The general information collected for this project is shown in Table 5.3.1.

Table 5.3.1: P3 general information, Route 146 Millville-Uxbridge

Project ID:	P3
MassDOT District:	District 3
MassDOT Contract Number:	41062
MassDOT Project Number:	603868
Reason for Monitoring:	Placement of a CMCR elastomeric friction course
Contract Amount:	$4,210,968
Approximate Placement Date:	8/2005–11/2005
Number of Years in Service:	11 years
Length of Section:	3.7 miles
Contractor:	J. H. Lynch and Sons

5.3.2 Project Location

No locus map was available for this project. According to available records, the project began 700 feet north of the Mill Street Bridge over Route 146 in Uxbridge and ended at the Rhode Island state line in Millville. The stationing was as follows:

Begin Project
Uxbridge
700 feet north of Mill Street overpass STA 37+80 NB STA 38+50 SB

Uxbridge/Millville Town Line STA 218+40 NB & SB

End Project
Millville
Rhode Island State Line STA 231+23 NB & SB

5.3.3 Typical Section Detail

No typical cross-section detail was available.

5.3.4 Existing Pavement Surface Preparation

The surface preparation included power sweeping the roadway and the removal of any debris, loose aggregate, soil, and dust, particularly soil that was bound to the surface prior to the placement of any mixture. The mixture was applied when the surface was dry and the surface temperature was 50° F and rising. Finally, the entire underlying surface (intermediate course) received an application of bitumen for tack coat at a rate of 0.05 gallons per square yard.

5.3.5 Mixture Specification Requirements

The CMCR Elastomeric Friction Course mixture was required to meet the MassDOT specifications shown in Table 5.3.2. The binder utilized for mixture production was a PG76-34 fabricated with a minimum of 7% CMCR (by weight of binder). The maximum mesh size of the CMCR was required to be 80 mesh. The mixture had a required compactive effort (N_{design}) of 75 gyrations. Mixture volumetric thresholds for air voids (4%–6%) and VMA (18% minimum) were specified, as well as a moisture sensitivity requirement of 80% minimum when tested in accordance with AASHTO T283.

Table 5.3.2: P3 job mix formula requirements, Route 146 Millville-Uxbridge

Sieve Size	MassDOT CMCR Elastomeric Friction Course Specification	Production Tolerance
12.5 mm (1/2 inch)	100	–
9.5 mm (3/8 inch)	91–95	± 6.0%
4.75 mm (No. 4)	40–45	± 6.0%
2.36 mm (No. 8)	22–26	± 5.0%
1.18 mm (No. 16)	–	–
600 µm (No. 30)	9–12	± 3.0%
300 µm (No. 50)	6–8	± 3.0%
150 µm (No. 100)	–	–
75 µm (No. 200)	3–5	± 1.0%
Asphalt Content	6.0–7.5%	± 0.3%

5.3.6 Mixture Production Data

No production data was available for this mixture.

5.3.7 Condition Data

The average condition indices (PSI, DI, maximum rut depth, and IRI) for this project with respect to in-service time (in years) are shown in Figures 5.3.1 through 5.3.4. Please note that no condition data was collected in 2013 for either travel direction and in 2015 for the southbound direction only. The years in service of the CMCR elastomeric friction course

(EFC) for this project is approximately 11 years. Since data collection began in 2009, the PSI remained above the 2.5 threshold for interstate roads, therefore indicating there is no need for a rehabilitation at this time. The DI over time has remained above the 2.5 threshold, thereby indicating that cumulative cracking is not yet an issue. Average maximum rut depth was below the 0.5-inch threshold, indicating rutting has remained at acceptable levels. The ride quality, in terms of IRI, has increased as service life has increased. Overall, based on the indices, the placement of a CMCR EFC has performed acceptably. This project should continue to be monitored as in-service life increases to determine the longevity of this strategy.

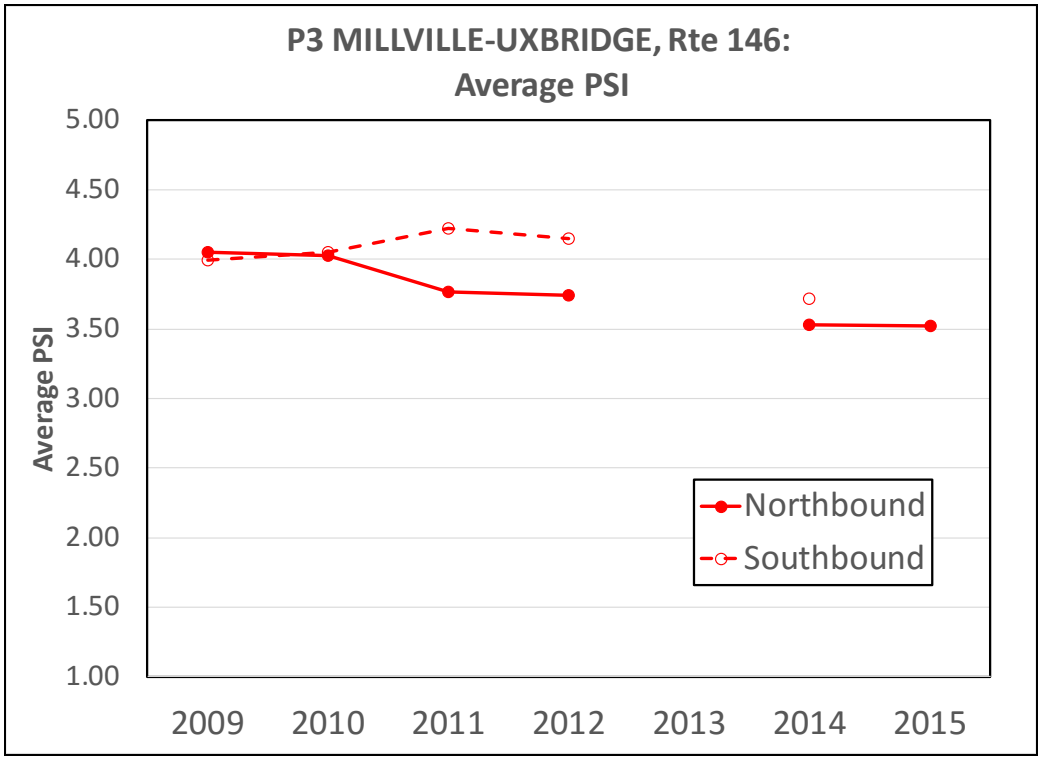

Figure 5.3.1: P3 condition data – average PSI, Route 146 Millville-Uxbridge

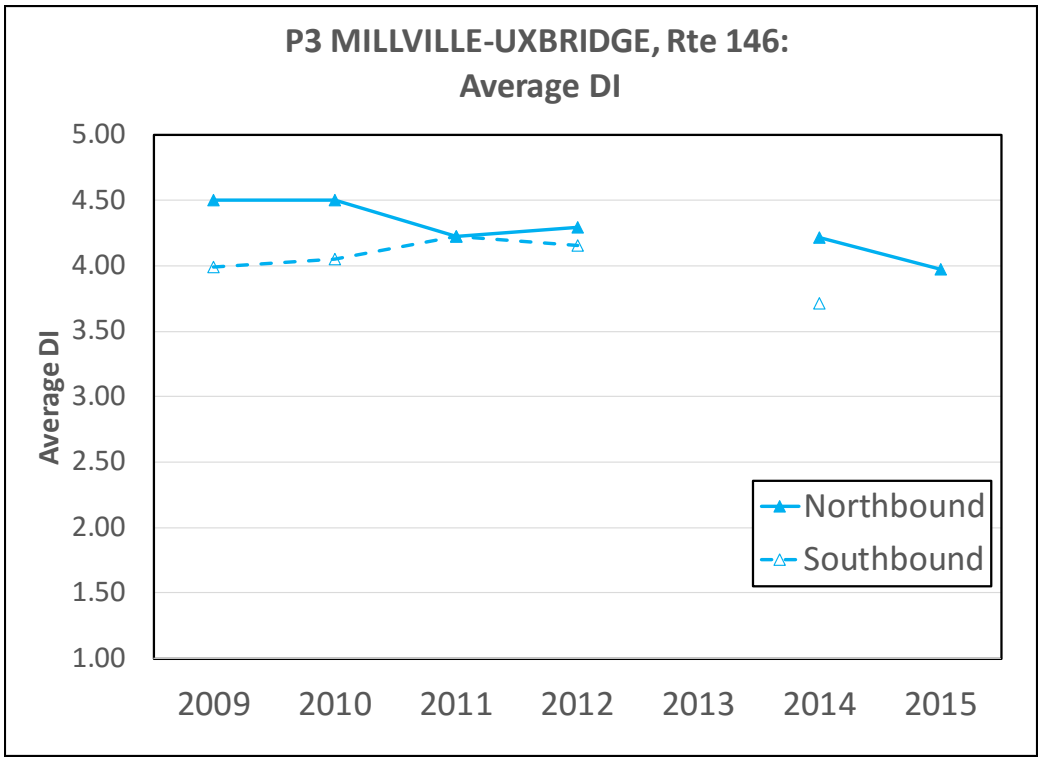

Figure 5.3.2: P3 condition data – average DI, Route 146 Millville-Uxbridge

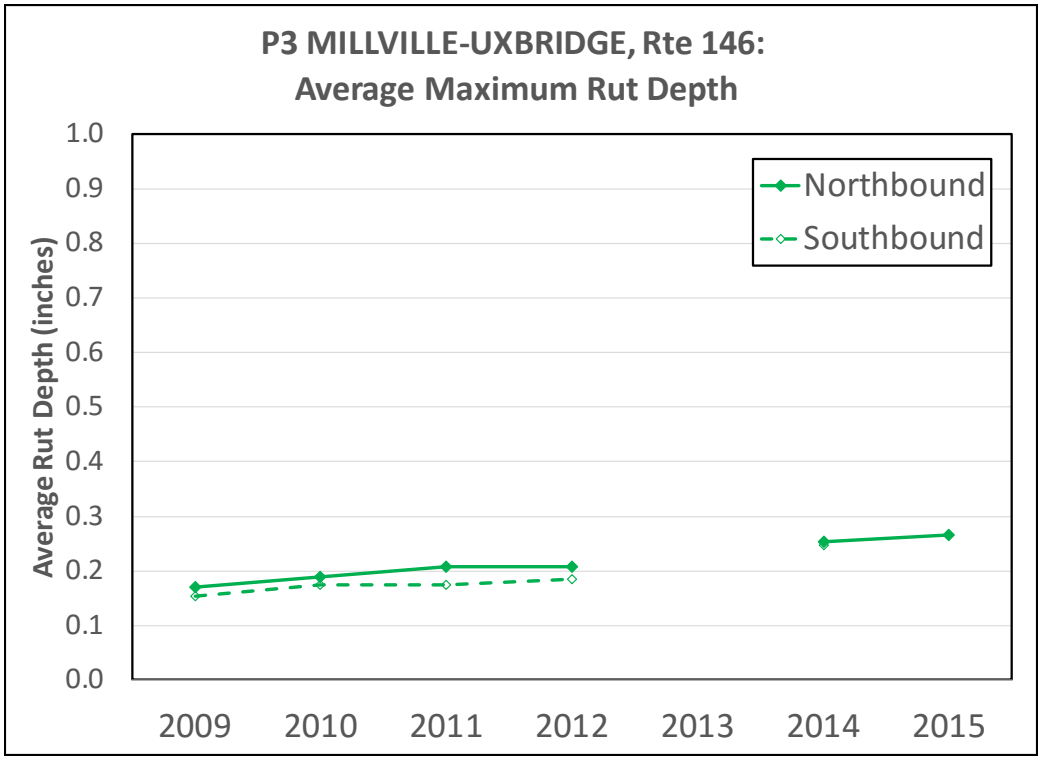

Figure 5.3.3: P3 condition data – average maximum rut depth, Route 146 Millville-Uxbridge

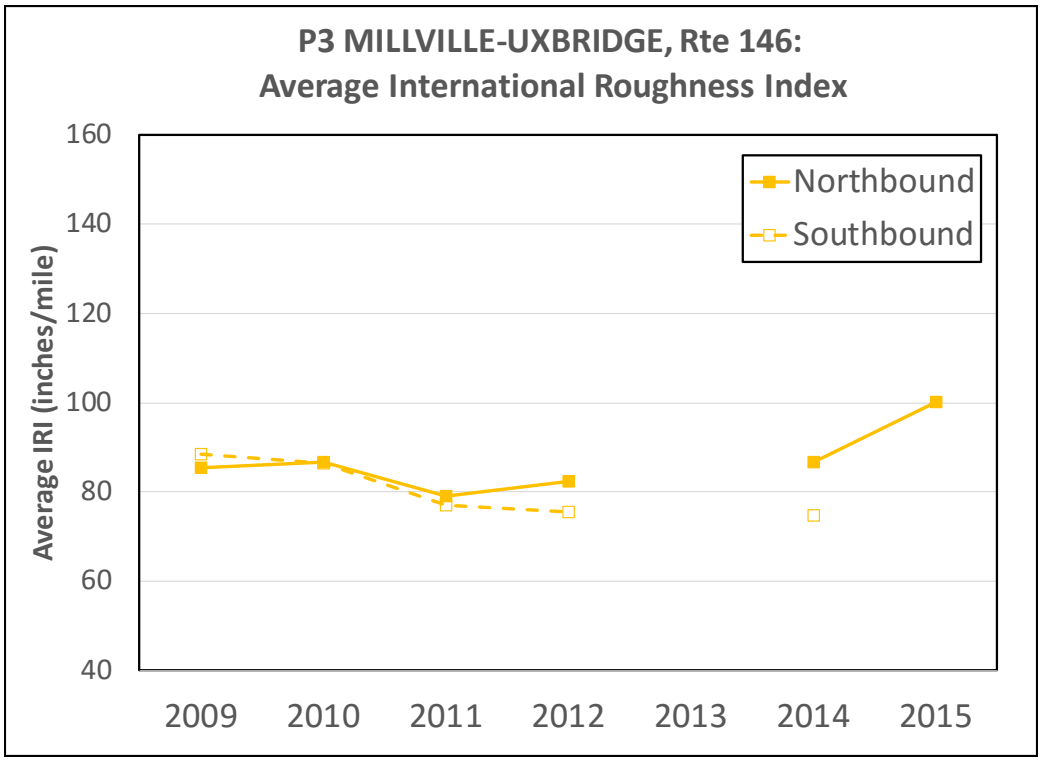

Figure 5.3.4: P3 condition data – average IRI, Route 146 Millville-Uxbridge

5.4 Project #4: Route 9 Framingham-Natick

This section outlines the information and data collected for Project #4 (P4) Route 9 Framingham-Natick.

5.4.1 Project General Information

The general information collected for this project is shown in Table 5.4.1.

Table 5.4.1: P4 general information, Route 9 Framingham-Natick

Project ID:	P4
MassDOT District:	District 3
MassDOT Contract Number:	62667
MassDOT Project Number:	604991
Reason for Monitoring:	Placement of 2" of 12.5mm with 2% SBR Latex mixture Level 4 (N_{design} = 100 gyrations) over 1-1/4" of a 9.5mm Superpave leveling course. Pavement reinforcement system placed between the pavement layers over the concrete slab expansion joints.
Contract Amount:	$10.0 million
Approximate Placement Date:	2010
Number of Years in Service:	6 years
Length of Section:	7.8 miles
Contractor:	Aggregate Industries Chelmsford /D & R General Contracting

5.4.2 Project Location

The locus maps for this project are shown in Figures 5.4.1 and 5.4.2. The project started at the Southboro/Framingham line (mile marker 113.0) and continued along Route 9 to Walnut Street in Natick. The total mileage of the project was 7.8 miles.

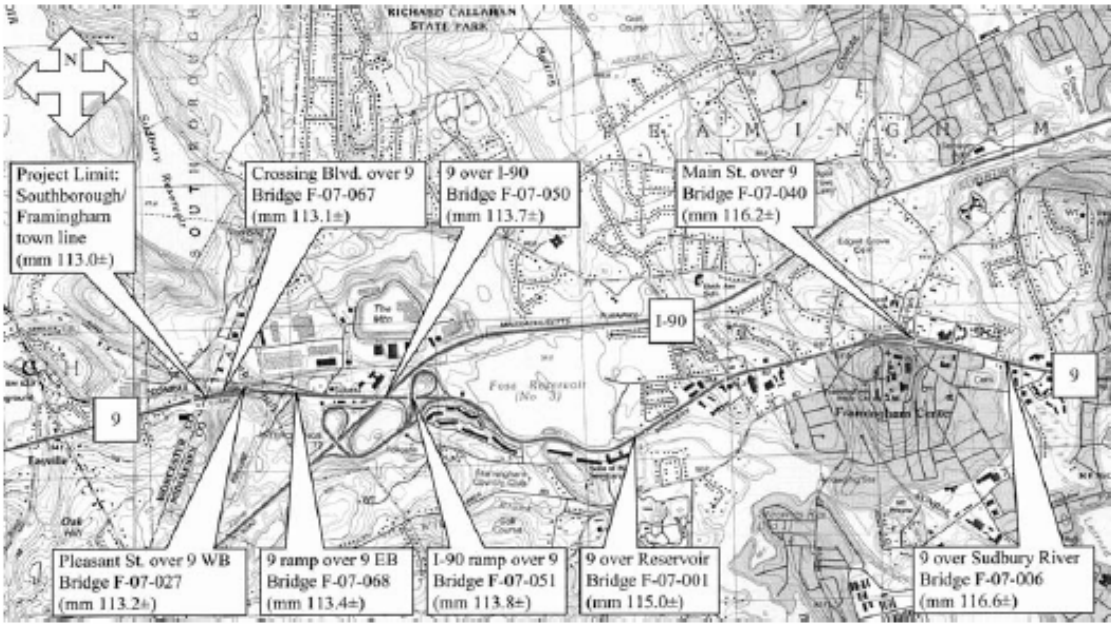

Figure 5.4.1: P4 site locus plan, part I, Route 9 Framingham-Natick

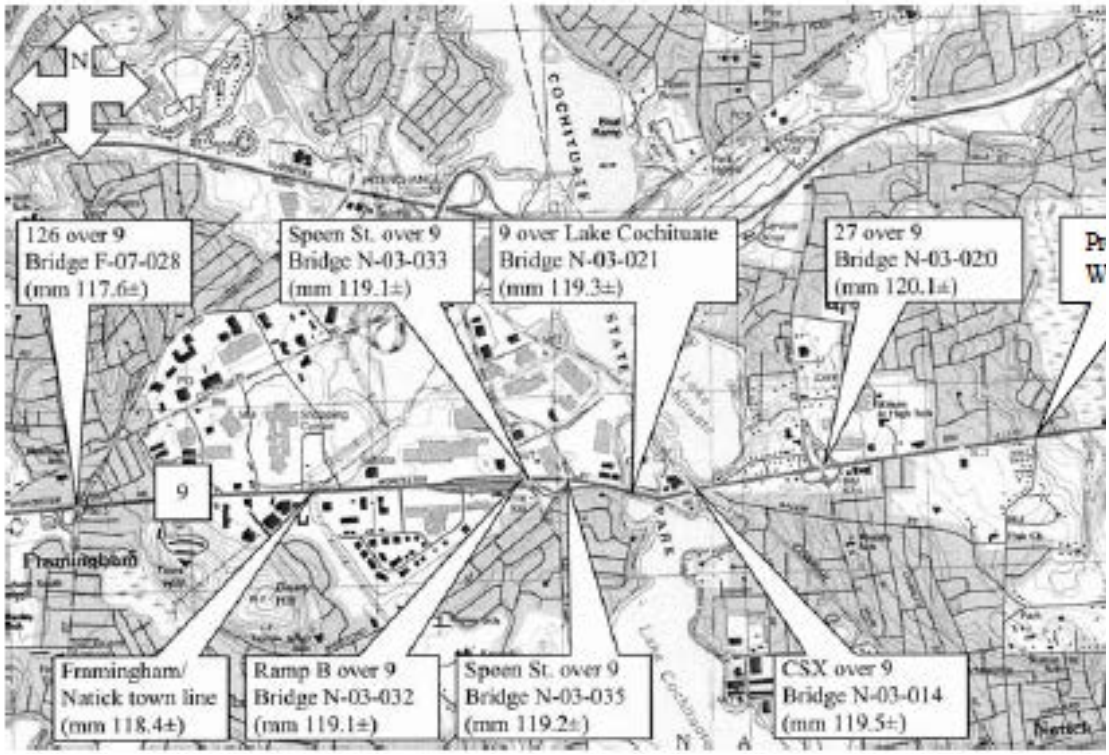

Figure 5.4.2: P4 site locus plan, part II, Route 9 Framingham-Natick

5.4.3 Typical Section Detail

The typical cross-section detail is shown in Figure 5.4.3.

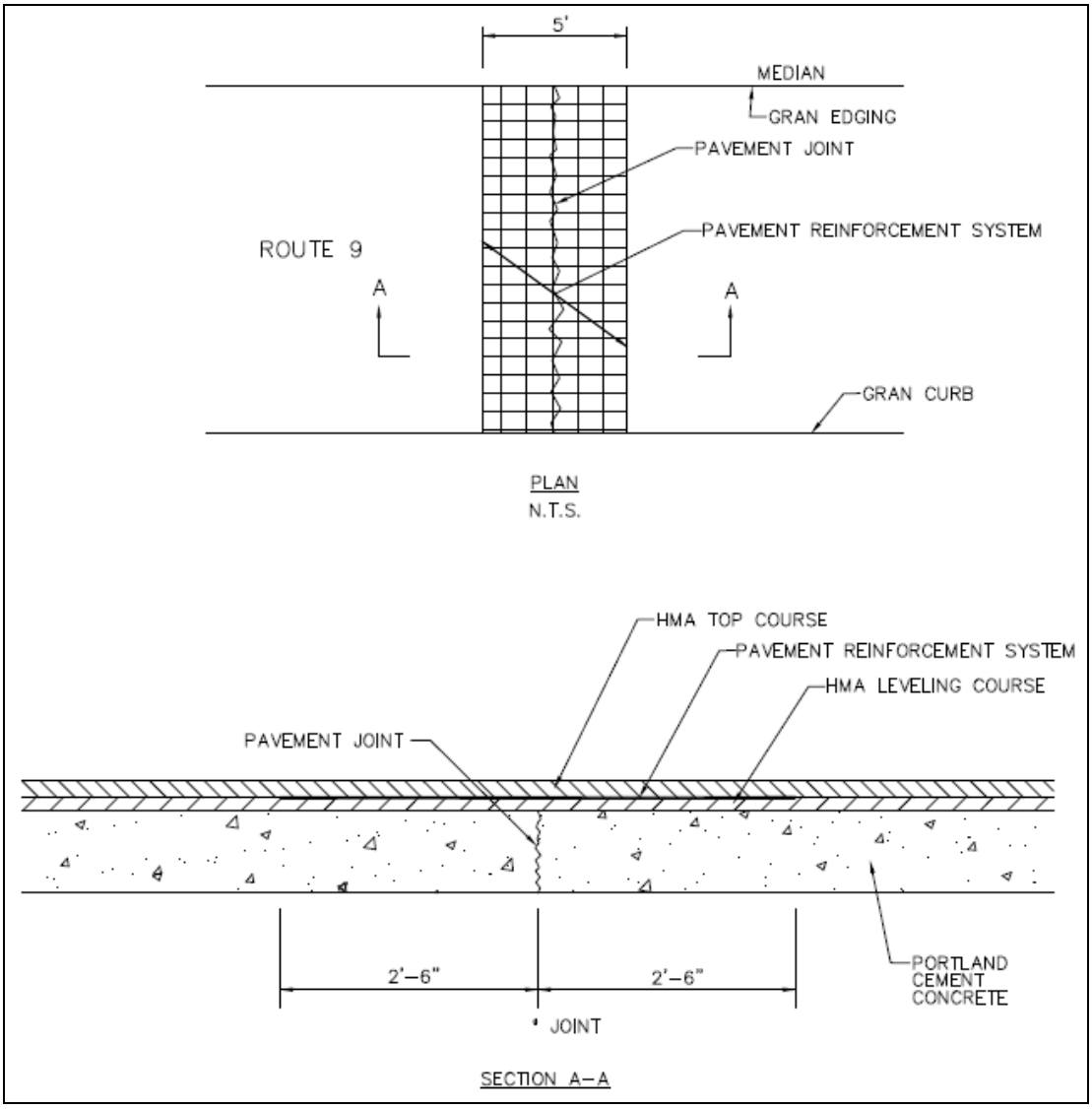

Figure 5.4.3: P4 typical section, Route 9 Framingham-Natick

5.4.4 Existing Pavement Surface Preparation

Micromilling of the existing pavement to a depth of 1.5 inches was conducted. A tack coat of asphalt emulsion, grade RS-1 was uniformly applied to existing or new pavement surfaces prior to placing pavement courses.

A pavement reinforcement system was placed between the HMA leveling and surface courses and centered over the existing underlying transverse Portland cement concrete expansion joints. The pavement reinforcement system was 60-inch wide GlasGrid 8502, as manufactured by Saint-Gobain Technical Fabrics.

5.4.5 Mixture Specification Requirements

The 12.5mm SSC latex mixture was required to meet the specification range and production tolerances shown in Table 5.4.2 in accordance with MassDOT Specification Section 455, "Superpave Hot Mix Asphalt Pavement." The MassDOT specification requirements and approved Contractor JMF are shown in Table 5.4.2.

Table 5.4.2: P4 MassDOT 12.5mm SSC specification & Contractor JMF, Route 9 Framingham-Natick

Sieve Size	MassDOT 12.5mm SSC Specification	Contractor JMF 12.5mm SSC with 2% SBR Latex Mixture	Production Tolerance
19.0 mm (3/4 inch)	100	100	–
12.5 mm (1/2 inch)	90–100	94	± 6.0%
9.5 mm (3/8 inch)	90 max	83	± 6.0%
4.75 mm (No. 4)	–	57	± 6.0%
2.36 mm (No. 8)	31–58	42	± 5.0%
1.18 mm (No. 16)	–	28	± 3.0%
600 μm (No. 30)	–	19	± 3.0%
300 μm (No. 50)	–	12	± 3.0%
150 μm (No. 100)	–	7	± 2.0%
75 μm (No. 200)	2–10	3.8	± 1.0%
Asphalt Content	–	5.4%	± 0.3%
Air Voids	4.0%	4.0%	–
Voids in Mineral Aggregate (VMA)	15.0± 1.0%	15.1%	–
Voids Filled with Asphalt (VFA)	65–75%	73.0%	–

5.4.6 Mixture Production Data

This project utilized MassDOT's Section 450 HMA Quality Assurance (QA) specifications. The average Contractor QC and MassDOT Acceptance production testing data are shown in Table 5.4.3.

Table 5.4.3: P4 production data, Route 9 Framingham-Natick

Sieve Size	Contractor JMF 12.5mm SSC with 2% SBR Latex Mixture	Production Tolerance	Contractor 12.5mm SSC with 2% SBR Latex Mixture Average Production Data (5 Sublots)	MassDOT 12.5mm SSC with 2% SBR Latex Mixture Average Production Data (3 Sublots)
19.0 mm (3/4 inch)	100	–	100	100
12.5 mm (1/2 inch)	94	± 6.0%	94.6	95.7
9.5 mm (3/8 inch)	83	± 6.0%	82	83.7
4.75 mm (No. 4)	57	± 6.0%	58.2	61.0
2.36 mm (No. 8)	42	± 5.0%	41.4	42.3
1.18 mm (No. 16)	28	± 3.0%	27.2	27.0
600 μm (No. 30)	19	± 3.0%	17.8	18.0
300 μm (No. 50)	12	± 3.0%	11.4	12.3
150 μm (No. 100)	7	± 2.0%	6.4	7.0
75 μm (No. 200)	3.8	± 1.0%	3.8	4.0
Asphalt Content	5.4	± 0.3%	5.2%	5.4%
Air Voids	4.0%	4.0%	3.5%	3.2%
VMA	15.0± 1.0%	15.1%	15.1%	15.2%
VFA	65–75%	73.0%	77.1%[1]	78.6%[1]

[1] Value out of tolerance.

5.4.7 Condition Data

The average condition indices (PSI, DI, maximum rut depth, and IRI) for this project with respect to in-service time (in years) are shown in Figures 5.4.4 through 5.4.7. Please note that no condition data was collected in 2011 and 2014 for either travel direction and in 2015 for the westbound direction only. With seven years in service, the PSI remained above the 2.3 threshold for non-interstate roads, therefore indicating no need for a rehabilitation at this time. However, it should be noted that the trend of PSI has steadily declined over the years. The DI over time has remained above the 2.5 threshold, thereby indicating that cumulative cracking is not yet an issue. Similar to PSI, DI has steadily declined over the years. Average maximum rut depth was below the 0.5-inch threshold, indicating rutting has remained at acceptable levels. The ride quality, in terms of IRI, has increased as service life has increased. The trend for both rutting and IRI have been increasing as service life increases. Overall, based on the indices, the use of the pavement reinforcing system overlaid with a latex modified 12.5mm mixture has performed acceptably. However, due to the steady decline in PSI and DI and the steady increase in maximum rut depth and IRI, it is recommended that this project should continue to be monitored annually to determine the longevity of this strategy.

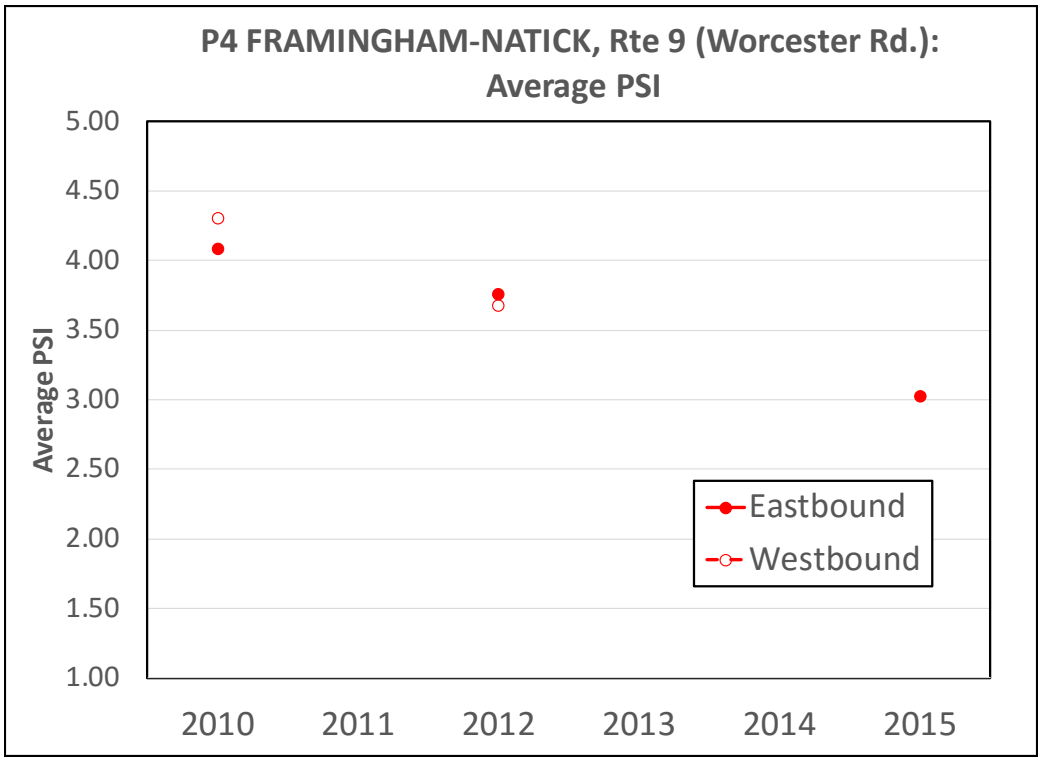

Figure 5.4.4: P4 condition data – average PSI, Route 9 Framingham-Natick

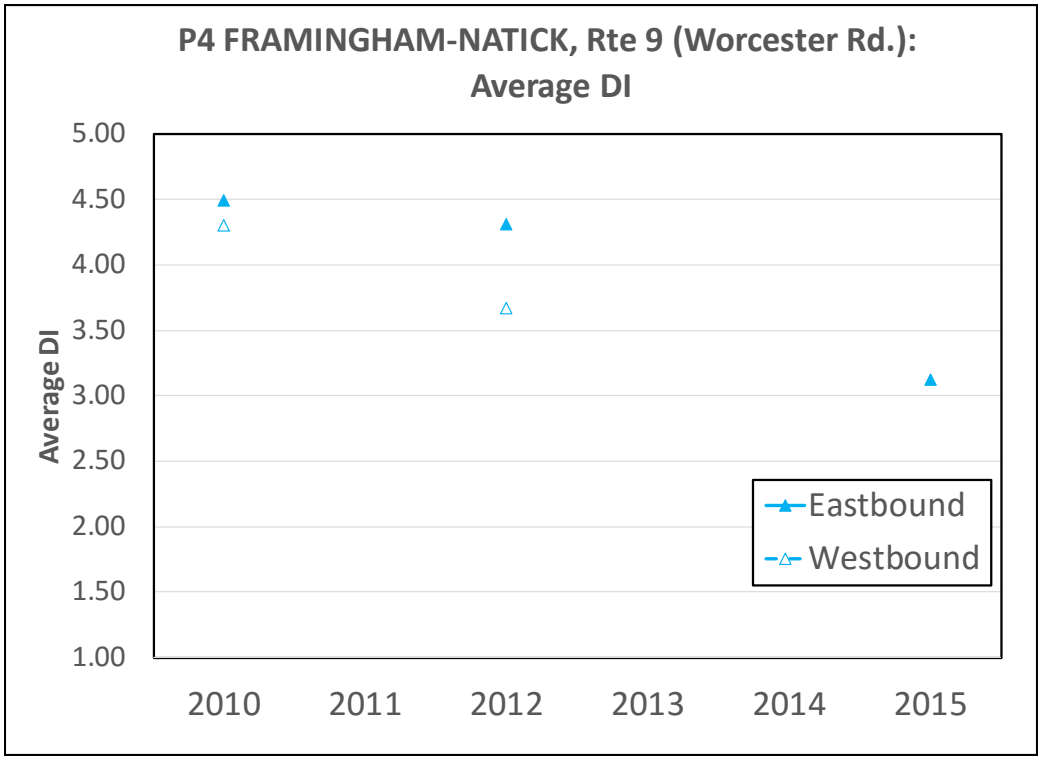

Figure 5.4.5: P4 condition data – average DI, Route 9 Framingham-Natick

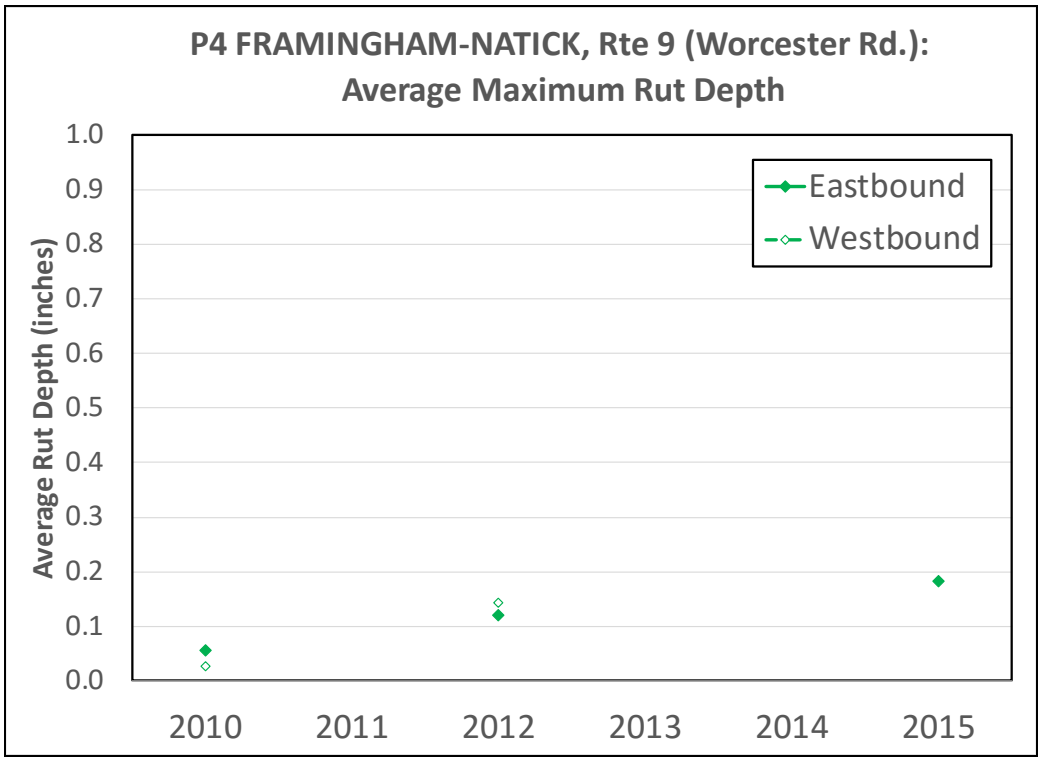

Figure 5.4.6: P4 condition data – average maximum rut depth, Route 9 Framingham-Natick

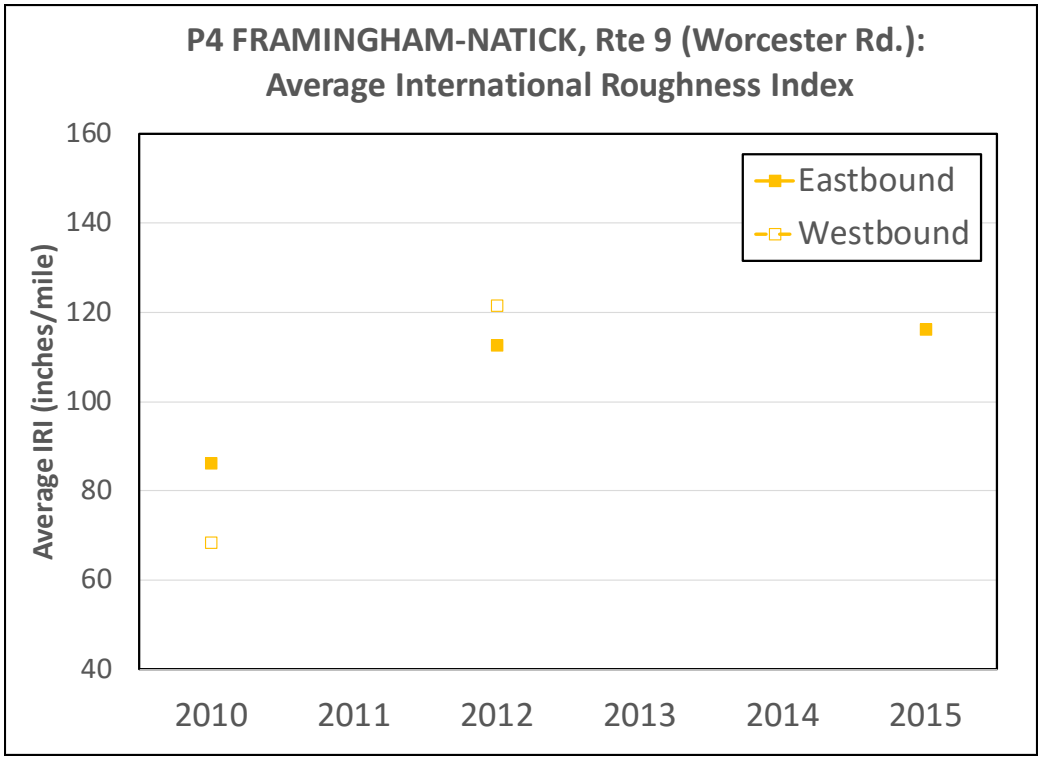

Figure 5.4.7: P4 condition data – average IRI, Route 9 Framingham-Natick

5.5 Project #5: I-395 Oxford

This section outlines the information and data collected for Project #5 (P5) I-395 Oxford.

5.5.1 Project General Information

The general information collected for this project is shown in Table 5.5.1.

Table 5.5.1: P5 general information, I-395 Oxford

Project ID:	P5
MassDOT District:	District 3
MassDOT Contract Number:	69939
MassDOT Project Number:	605759
Reason for Monitoring:	Placement of 1" of OGFC over 2" of Superpave Intermediate Course (SIC-12.5). Two SIC-12.5mm mixtures were placed, one with N_{design} of 80 and one with N_{design} of 100. Gyration level study.
Contract Amount:	$9.7 million
Approximate Placement Date:	2013
Number of Years in Service:	3 years (estimated)
Length of Section:	5.3 miles
Contractor:	J. H. Lynch & Sons

5.5.2 Project Location

The locus maps for this project are shown in Figures 5.5.1 and 5.5.2. The southern limit of the project is a pavement joint (mile marker 4.5±), which is located just north of the ramps at Cudworth Road in Oxford. The northern limit is the Oxford/Auburn Town Line (mile marker 9.8±). The total length of this project is approximately 5.3 miles.

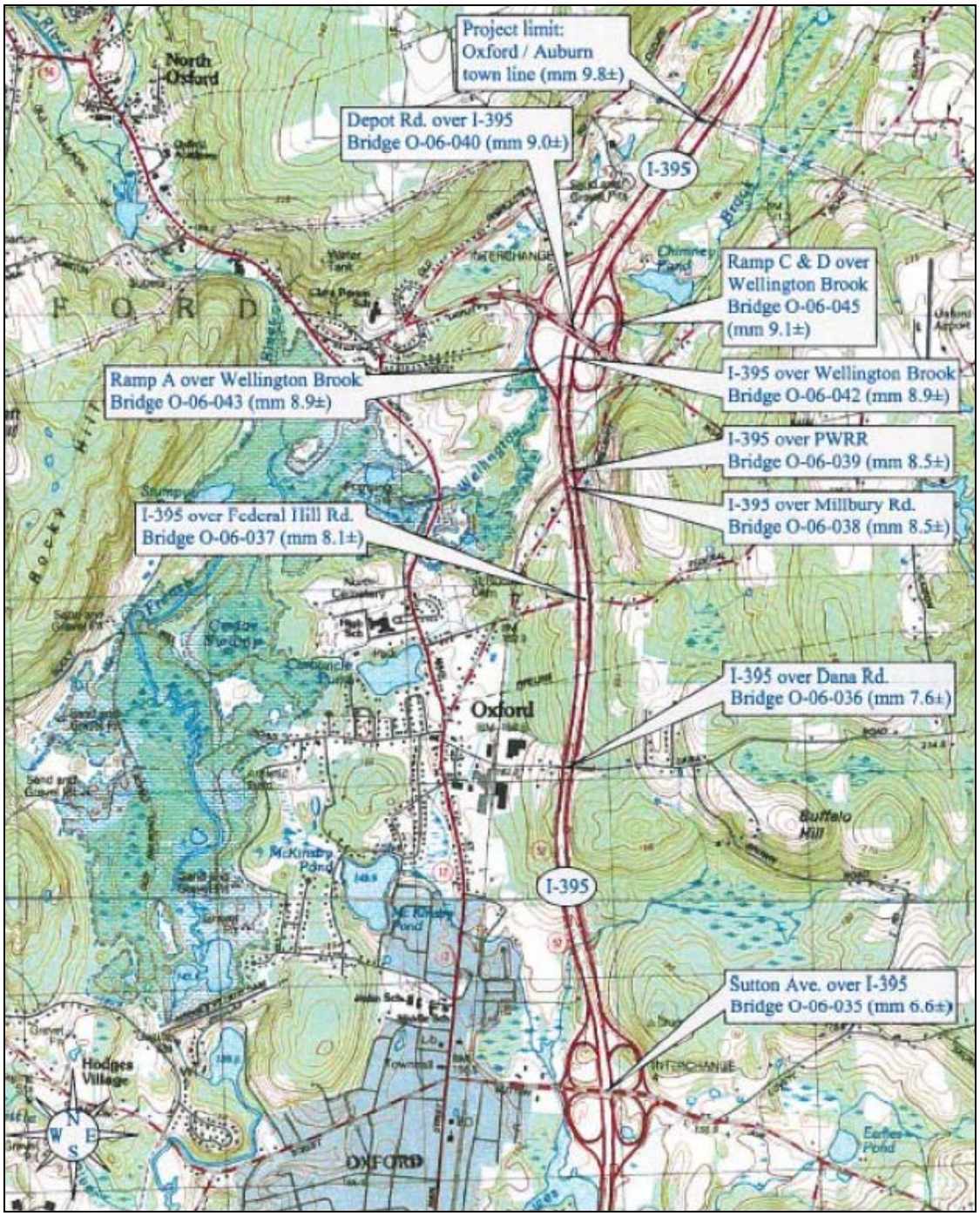

Figure 5.5.1: P5 site locus plan, part I, I-395 Oxford

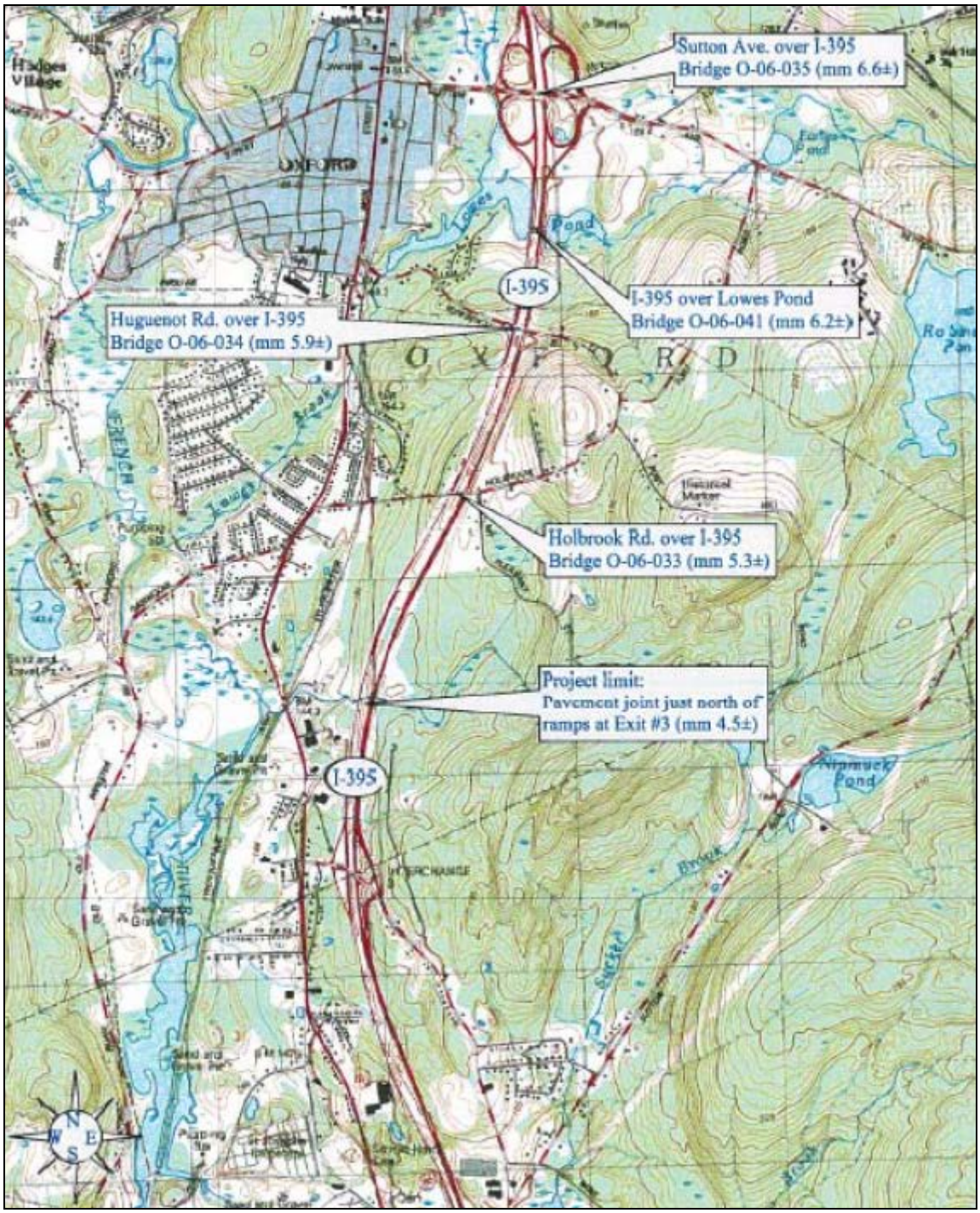

Figure 5.5.2: P5 site locus plan, part II, I-395 Oxford

5.5.3 Typical Section Detail

The typical cross-section detail is shown in Figure 5.5.3. Overall, the mainline was micromilled 1.5 inches and paved with 1 inch of open-graded friction course over 2 inches of Superpave Intermediate Course (SIC).

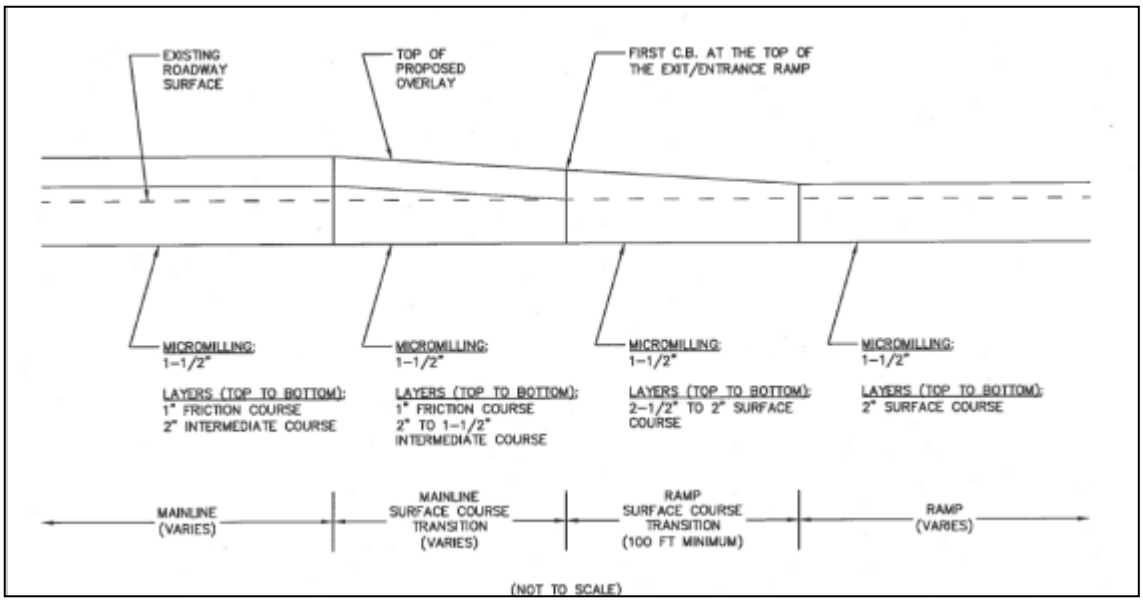

Figure 5.5.3: P5 typical section, I-395 Oxford

5.5.4 Existing Pavement Surface Preparation

Surface preparation consisted of micromilling the mainline 1.5 inches.

5.5.5 Mixture Specification Requirements

The 12.5mm SIC mixture was required to meet the specification range and production tolerances shown in Table 5.5.2 in accordance with MassDOT Specification Section 455, "Superpave Hot Mix Asphalt Pavement." Two different 12.5mm SIC mixtures were produced, one each at a design gyration level (N_{design}) of 80 and one at 100. Each mixture was designed with PG64-28 binder using the Evotherm WMA additive. WMA dosage was not specified. The approved laboratory trial mix formula (LTMF) for each mixture is shown in Table 5.5.2.

Table 5.5.2: P5 MassDOT 12.5mm SIC specification requirements and Contractor LTMF, I-395 Oxford

Sieve Size	12.5mm SIC Specification	Production Tolerance	Contractor JMF 12.5mm SIC with WMA and 20% RAP – 80 Gyration	Contractor JMF 12.5mm SIC with WMA and 20% RAP – 100 Gyration
12.5 mm (1/2 inch)	90–100	± 6.0%	98	98
9.5 mm (3/8 inch)	90 max.	± 6.0%	85	85
4.75 mm (No. 4)	–	± 6.0%	59	57
2.36 mm (No. 8)	31–58	± 5.0%	42	40
1.18 mm (No. 16)	–	± 3.0%	28	27
600 µm (No. 30)	–	± 3.0%	20	19
300 µm (No. 50)	–	± 3.0%	13	13
150 µm (No. 100)	–	± 2.0%	8	8
75 µm (No. 200)	2–10	± 1.0%	4.4	4.3
Asphalt Content	–	± 0.3%	5.3%	5.3%
Air Voids	4.0%	–	4.0%	4.0%
VMA	> 15.0%	–	15.2%	15.0%
VFA	65–75%	–	73.4%	73.1%
In-Place Density	95±2.5%	–	–	–

5.5.6 Mixture Production Data

This project utilized MassDOT's Section 450 HMA QA specifications. The data from testing of the production mixture was combined, both Contractor QC results and MassDOT Acceptance results. The average production testing results are shown in Table 5.5.3 for the 80 gyration mixture and Table 5.5.4 for the 100 gyration mixture.

Table 5.5.3: P5 12.5mm SIC 80 gyration production data, I-395 Oxford

Sieve Size	12.5mm SIC Specification	Production Tolerance	Contractor JMF 12.5mm SIC with WMA and 20% RAP – 80 Gyration	12.5mm SIC with WMA and 20% RAP – 80 Gyration Average QC & Acceptance Production Data (26 sublots)
12.5 mm (1/2 inch)	90–100	± 6.0%	98	98.7
9.5 mm (3/8 inch)	90 max.	± 6.0%	85	87.8
4.75 mm (No. 4)	–	± 6.0%	59	60.8
2.36 mm (No. 8)	31–58	± 5.0%	42	42.9
1.18 mm (No. 16)	–	± 3.0%	28	29.8
600 µm (No. 30)	–	± 3.0%	20	21.3
300 µm (No. 50)	–	± 3.0%	13	14.7
150 µm (No. 100)	–	± 2.0%	8	8.8
75 µm (No. 200)	2–10	± 1.0%	4.4	4.4
Asphalt Content	–	± 0.3%	5.3%	5.2%
Air Voids	4.0%	–	4.0%	3.5%
VMA	> 15.0%	–	15.2%	15.3%
VFA	65–75%	–	73.4%	77.1%[1]
In-Place Density	95±2.5%	–	–	94.1%

[1] Value out of tolerance.

Table 5.5.4: P5 12.5mm SIC 100 gyration production data, I-395 Oxford

Sieve Size	12.5mm SIC Specification	Production Tolerance	Contractor JMF 12.5mm SIC with WMA and 20% RAP – 100 Gyration	12.5mm SIC with WMA and 20% RAP – 100 Gyration Average QC & Acceptance Production Data (25 sublots)
12.5 mm (1/2 inch)	90–100	± 6.0%	98	98.0
9.5 mm (3/8 inch)	90 max.	± 6.0%	85	86.2
4.75 mm (No. 4)	–	± 6.0%	57	57.4
2.36 mm (No. 8)	31-58	± 5.0%	40	39.1
1.18 mm (No. 16)	–	± 3.0%	27	27.0
600 µm (No. 30)	–	± 3.0%	19	19.2
300 µm (No. 50)	–	± 3.0%	13	13.2
150 µm (No. 100)	–	± 2.0%	8	7.9
75 µm (No. 200)	2-10	± 1.0%	4.3	4.1
Asphalt Content	–	± 0.3%	5.3%	5.1%
Air Voids	4.0%	–	4.0%	3.6%
VMA	> 15.0%	–	15.0%	14.8%[1]
VFA	65–75%	–	73.1%	75.4%
In-Place Density	95±2.5%	–	–	93.8%

[1] Value out of tolerance.

5.5.7 Condition Data

The average condition indices (PSI, DI, maximum rut depth, and IRI) for this project with respect to in-service time (in years) are shown in Figures 5.5.4 through 5.5.7. Please note that no maximum rut depth or IRI indices were available for 2015. With three years in service, the PSI remained above the 2.5 threshold for interstate roads, therefore indicating no need for a rehabilitation at this time. The DI over time has remained above the 2.5 threshold, thereby indicating that cumulative cracking is not yet an issue. Average maximum rut depth was below the 0.5-inch threshold, indicating rutting has remained at acceptable levels. The ride quality, in terms of IRI, has remained nearly constant. Overall, based on the indices, each 12.5mm mixture (N_{design}= 80 or 100) overlaid with an open graded friction course (OGFC) mixture has performed acceptably. Since the project is a fairly new placement, this project should continue to be monitored to determine the longevity of these mixtures.

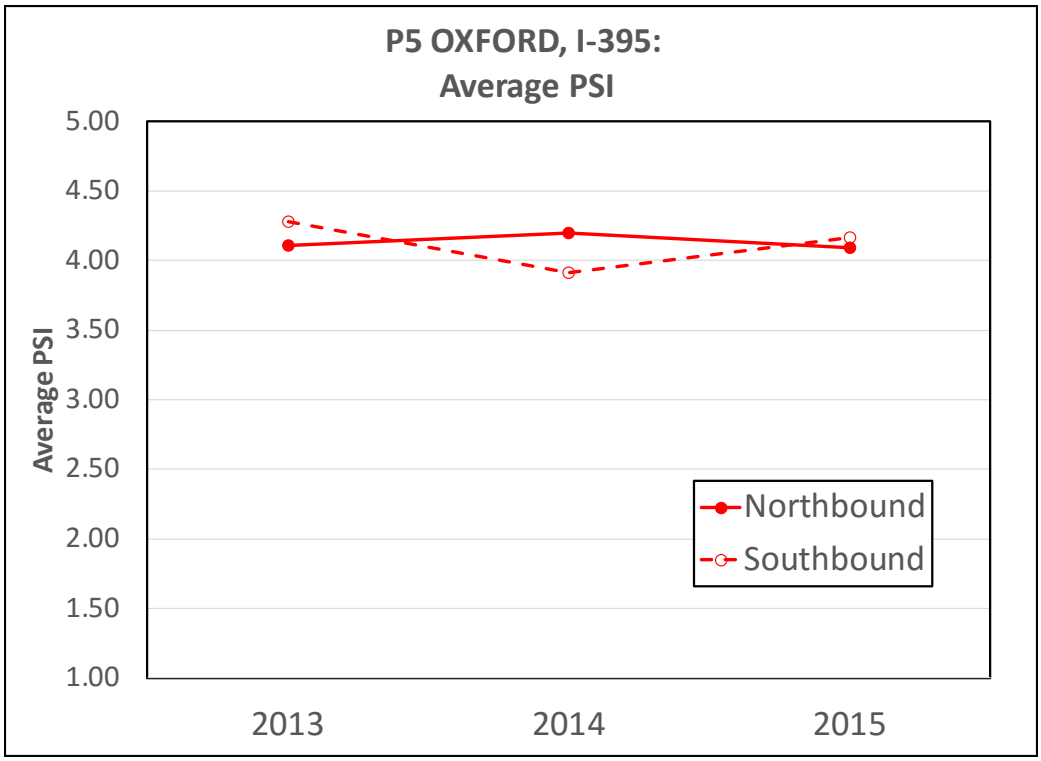

Figure 5.5.4: P5 condition data – average PSI, I-395 Oxford

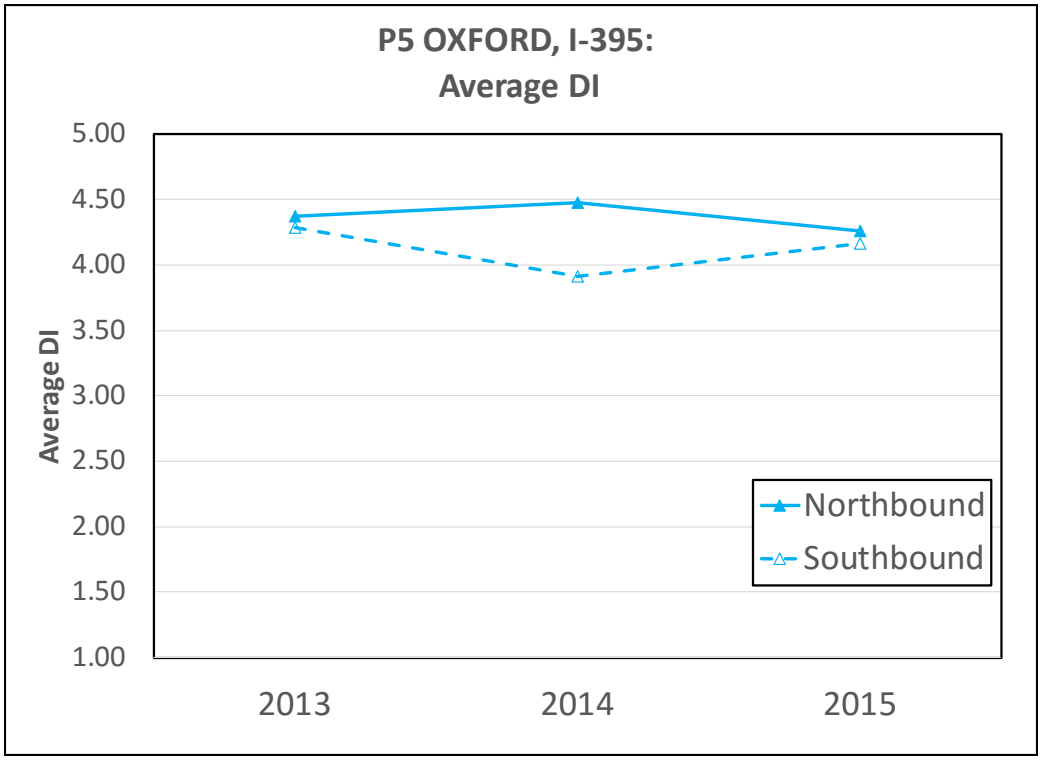

Figure 5.5.5: P5 condition data – average DI, I-395 Oxford

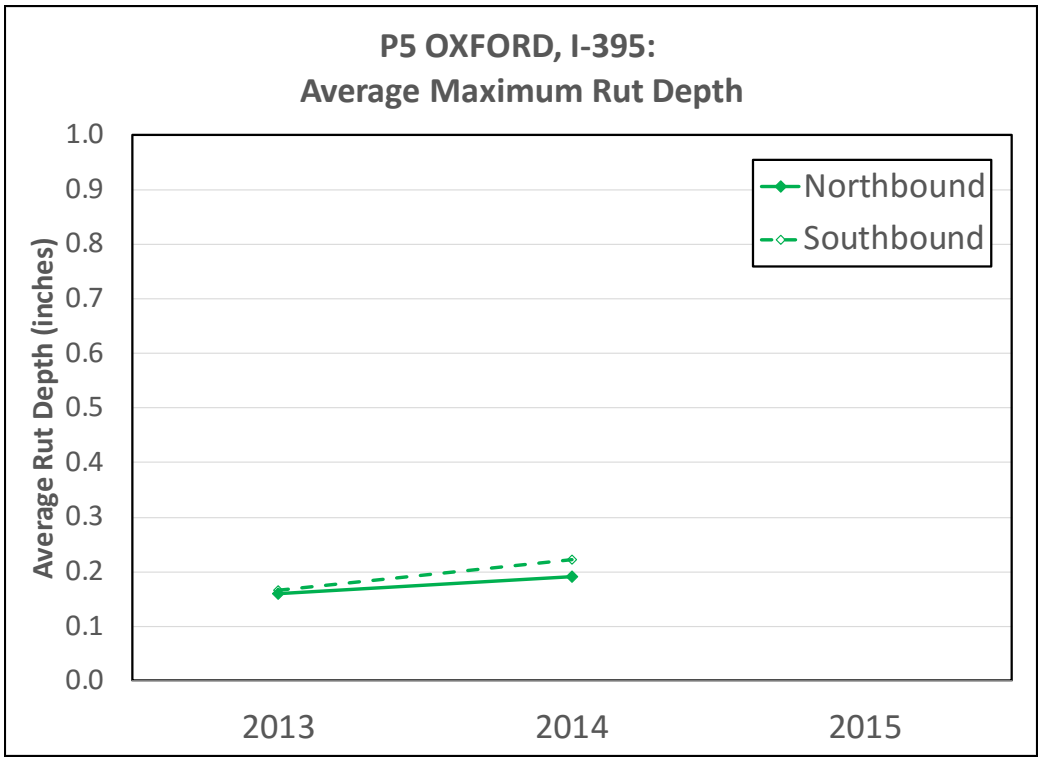

Figure 5.5.6: P5 condition data – average maximum rut depth, I-395 Oxford

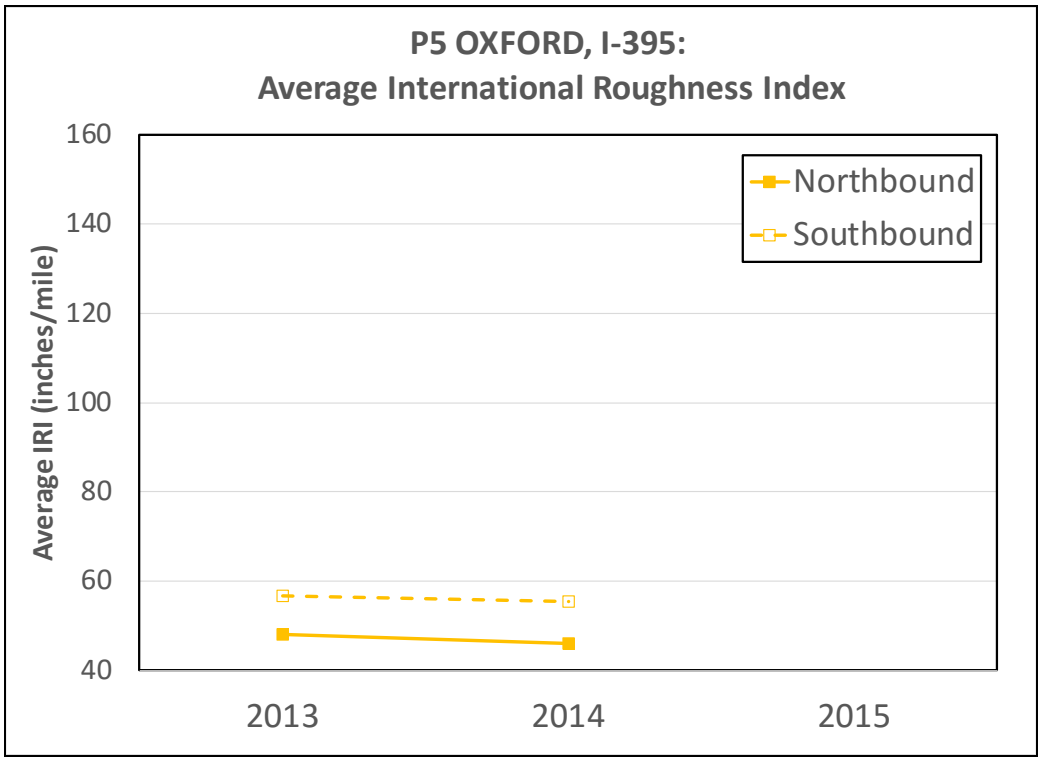

Figure 5.5.7: P5 condition data – average IRI, I-395 Oxford

5.6 Project #6: Route 20 (Washington St.) Auburn

This section outlines the information and data collected for Project #6 (P6) Route 20 (Washington St.) Auburn.

5.6.1 Project General Information

The general information collected for this project is shown in Table 5.6.1.

Table 5.6.1: P6 general information, Route 20 (Washington St.) Auburn

Project ID:	P6
MassDOT District:	District 3
MassDOT Contract Number:	66933
MassDOT Project Number:	605580
Reason for Monitoring:	Placement of 1¾" SSC – 12.5 Polymer Modified over 1½" SIC – 12.5. A pavement reinforcement system was placed between the pavement layers over the concrete slab expansion joints.
Contract Amount:	$2.6 million
Approximate Placement Date:	2011 (estimated)
Number of Years in Service:	5 years (estimated)
Length of Section:	2.5 miles
Contractor:	Aggregate Industries

5.6.2 Project Location

The locus map for this project is shown in Figure 5.6.1. The western limit of the project was at a pavement joint just west of the Coolidge St. intersection near mile marker 109.5± and ended at the Auburn-Worcester city/town line at mile marker 112.0±. The total length of this project was approximately 2.5 miles.

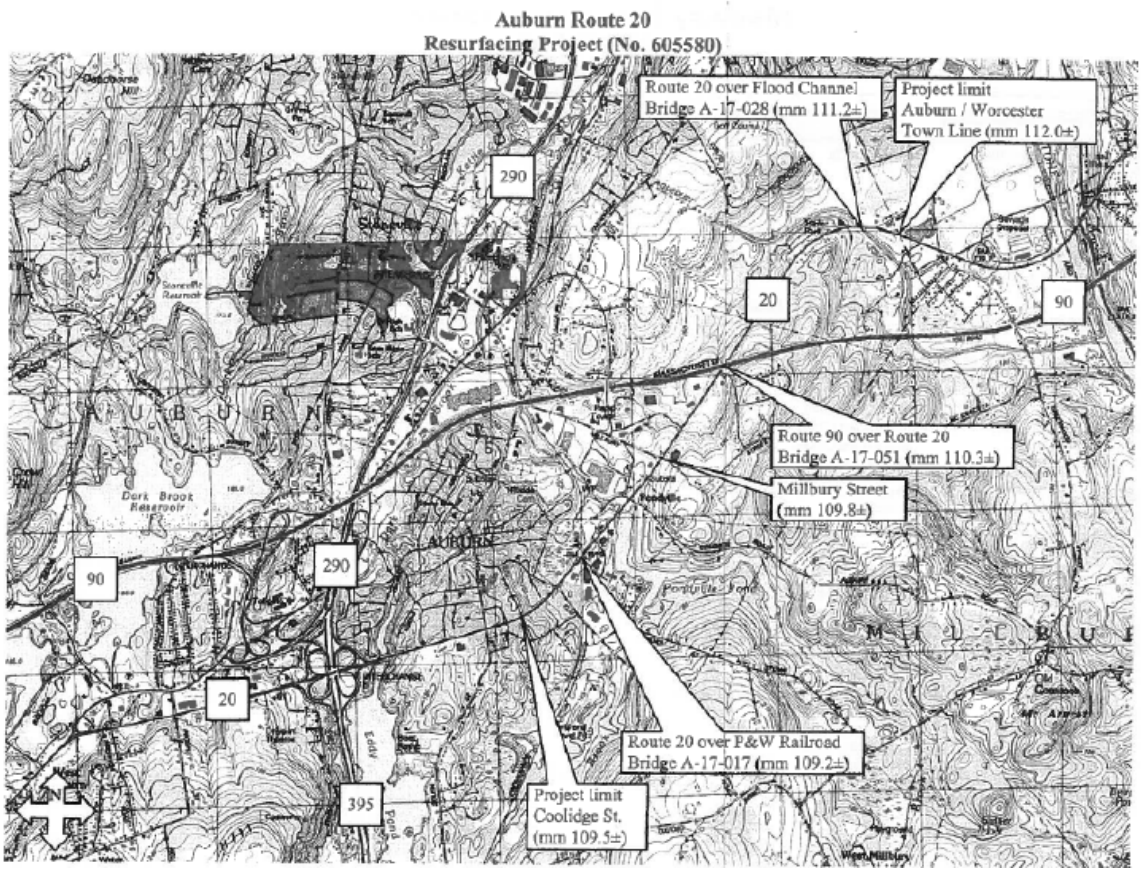

Figure 5.6.1: P6 site locus plan, Route 20 (Washington St.) Auburn

5.6.3 Typical Section Detail

The typical cross-section detail is shown in Figure 5.6.2. The typical cross section consisted of 1.75 inches Superpave Surface Course – 12.5 (SSC – 12.5) Polymer Modified over 1.5 inches Superpave Intermediate Course – 12.5 (SIC – 12.5). A pavement reinforcement system was placed between the pavement layers over the concrete slab expansion joints.

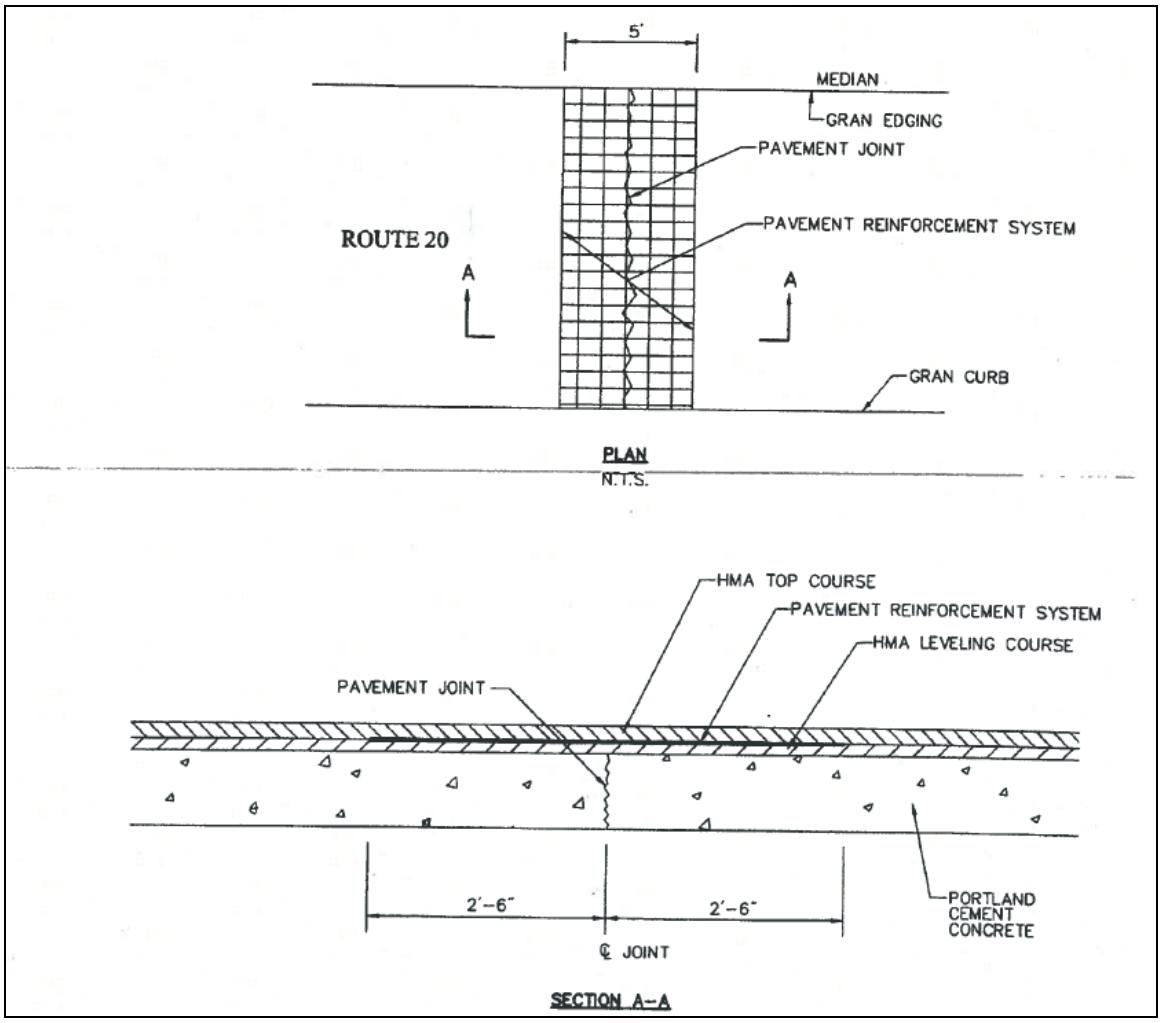

Figure 5.6.2: P6 typical section detail, Route 20 (Washington St.) Auburn

5.6.4 Existing Pavement Surface Preparation

Surface preparation consisted of micromilling 1.5 inches of the existing pavement. Tack coat, RS-1 asphalt emulsion, was uniformly applied to existing or new pavement surfaces prior to placing pavement courses at the rate of 0.05 gallons per square yard.

Additionally, an open aperture fiberglass grid pavement interlayer reinforcement system was placed between the Superpave intermediate and surface courses to help resist reflective cracking in the roadway surface course. It was centered over the existing underlying transverse Portland cement concrete expansion joints. The pavement reinforcement system was GlasGrid 8502 (Tensar International), Mirafi FG200 (TenCate), or an approved equal.

5.6.5 Mixture Specification Requirements

For this project, two 12.5mm mixtures were produced. The first mixture was a SSC-12.5mm with a polymer modified PG64-28. The polymer additive consisted of unvulcanized SBR in

liquid latex form, with a minimum quantity of rubber solids of 3% by weight of the binder of the mixture. The PG64-28 was modified to produce a performance grade asphalt binder (PGAB) grade of 70-28(+2°). The second mixture required was a SIC-12.5mm produced with a PG64-28 binder. The MassDOT mixture specification requirements and Contractor approved LTMFs are shown in Table 5.6.2.

Table 5.6.2: P6 specification requirements and approved LTMFs, Route 20 (Washington St.) Auburn.

Sieve Size	12.5mm SSC & SIC Specification	Production Tolerance	Contactor LTMF 12.5mm SSC + Polymer	Contactor LTMF 12.5mm SIC
19.0 mm (3/4 inch)	100	–	100	100
12.5 mm (1/2 inch)	90–100	–	94	94
9.5 mm (3/8 inch)	90 max.	± 6.0%	83	83
4.75 mm (No. 4)	–	± 6.0%	57	57
2.36 mm (No. 8)	31–58	± 5.0%	42	42
1.18 mm (No. 16)	–	–	28	28
600 μm (No. 30)	–	± 3.0%	19	19
300 μm (No. 50)	–	± 3.0%	12	12
150 μm (No. 100)	–	–	7	7
75 μm (No. 200)	2–10	± 1.0%	3.7	3.7
Asphalt Content	–	± 0.3%	5.2	5.2
Air Voids	4.0%	–	4.0%	4.0%
VMA	15.0% min.	–	15.6%	15.6%
VFA	65–75%	–	74.2%	74.2%

5.6.6 Mixture Production Data

No production data was available for these mixtures.

5.6.7 Condition Data

The average condition indices (PSI, DI, maximum rut depth, and IRI) for this project with respect to in-service time (in years) are shown in Figures 5.6.3 through 5.6.6. Please note that no condition data was collected in 2013 or 2015. With five years in service, the PSI remained above the 2.3 threshold for noninterstate roads, therefore indicating no need for rehabilitation at this time. The DI over time has remained above the 2.5 threshold, thereby indicating that cumulative cracking is not yet an issue. Average maximum rut depth was below the 0.5-inch threshold, indicating rutting has remained at acceptable levels. The ride quality, in terms of IRI, has remained nearly constant. Overall, based on the indices, the use of the pavement reinforcing system overlaid with a SIC-12.5mm and then a polymer modified 12.5mm mixture has performed acceptably. This project should continue to be monitored annually to determine the longevity of this particular strategy.

It should be noted that there were constructability issues observed in the areas where fabric was placed over the transverse joints. It was observed that during the overlay of the fabric mesh, transverse bumps had developed over the joints. It appeared that the tack coat utilized to secure the fabric mesh did not adhere adequately and had, in fact, slipped under the paver during the paving operation. The roadway required diamond grinding to correct the ride quality.

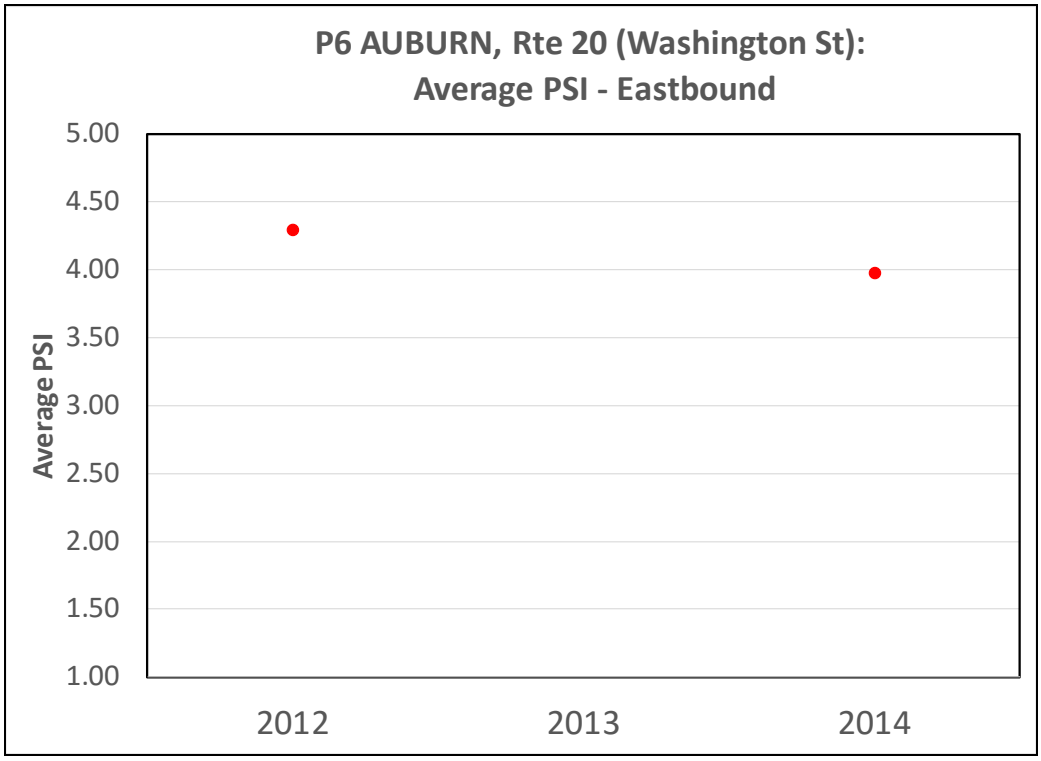

Figure 5.6.3: P6 condition data – average PSI, Route 20 (Washington St.) Auburn

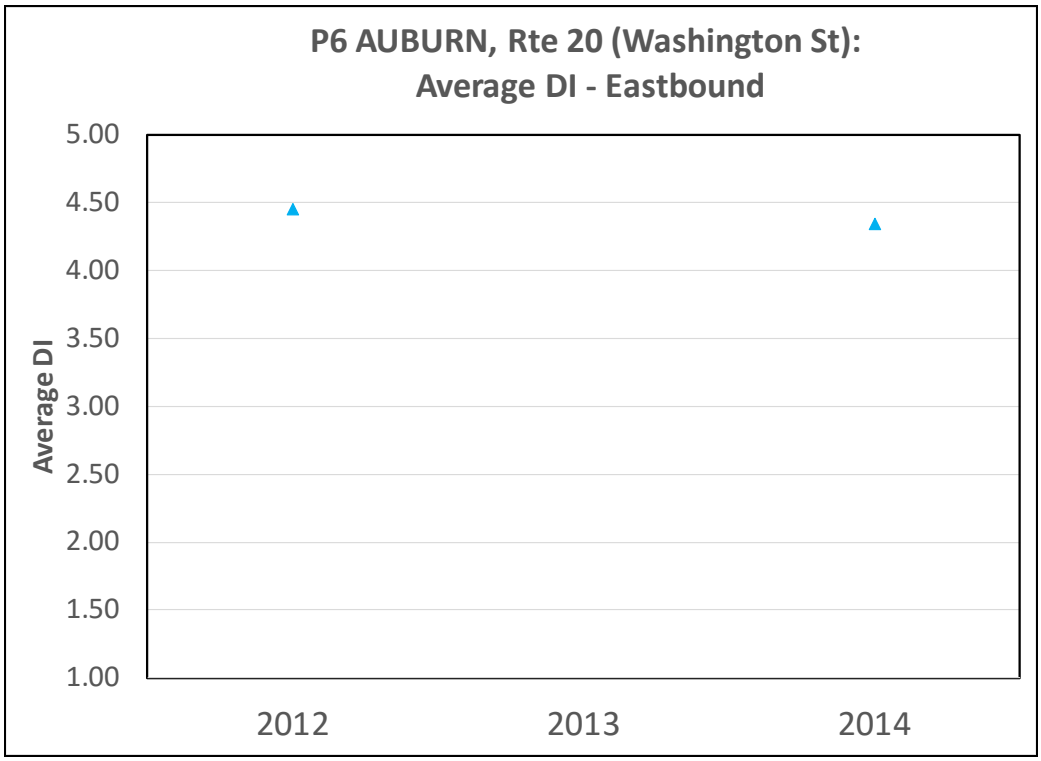

Figure 5.6.4: P6 condition data – average DI, Route 20 (Washington St.) Auburn

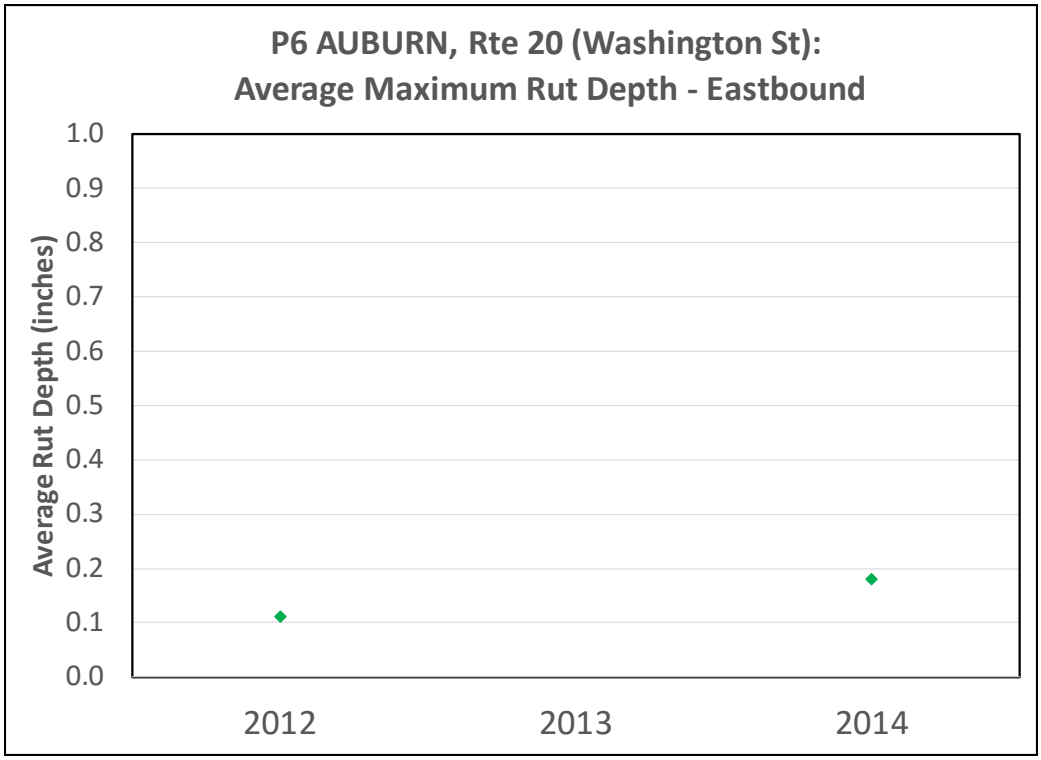

Figure 5.6.5: P6 condition data – average maximum rut depth, Route 20 (Washington St.) Auburn

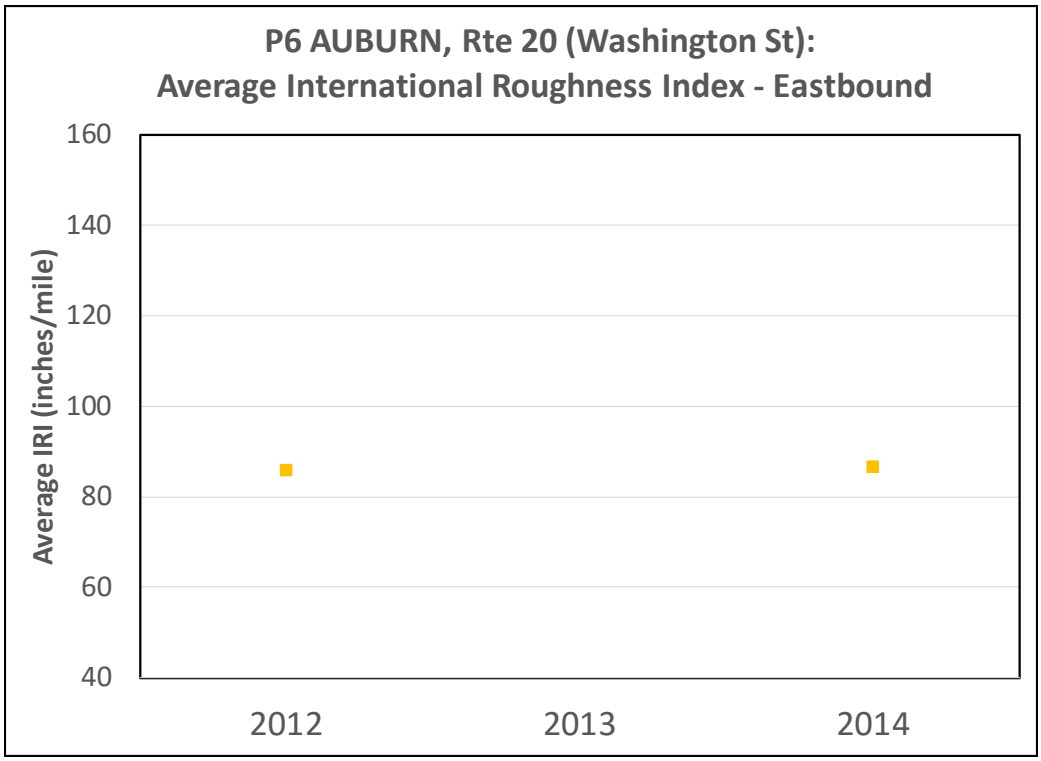

Figure 5.6.6: P6 condition data – average IRI, Route 20 (Washington St.) Auburn

5.7 Project #7: I-95 Danvers-Rowley

This section outlines the information and data collected for Project #7 (P7) I-95 Danvers-Rowley.

5.7.1 Project General Information

The general information collected for this project is shown in Table 5.7.1.

Table 5.7.1: P7 general information, I-95 Danvers-Rowley

Project ID:	P7
MassDOT District:	District 4
MassDOT Contract Number:	34700
MassDOT Project Number:	603984
Reason for Monitoring:	Placement of GGSMA mixture with PG64-28 and 1.5% Sasobit® WMA technology surface course incorporating 4% latex and lime.
Contract Amount:	–
Approximate Placement Date:	September 2005
Number of Years in Service:	11 years
Length of Section:	–
Contractor:	Aggregate Industries Saugus

5.7.2 Project Location

No locus map for this project was available. The project limit description from the bid documents is as follows:

"Beginning at the Town line between Danvers and Peabody Station 0+00 to Station 171+24.34 Danvers and Middleton Town line, from Station 0+00 proceeding northerly to Station 81+90.56 Town Line on Middleton and Topsfield, and then proceeding to Station 00+00.00 Town Line of Topsfield and Middleton, and then proceeding to Station 89+82.00 Town Line of Middleton and Boxford, and then proceeding to Station 258+67.12 Town Line of Boxford and Rowley, and then proceeding to Station 33+23.28 Town Line of Rowley and Georgetown."

Note the GGSMA mixture with WMA was placed on the southbound side of the project.

5.7.3 Typical Section Detail

No typical cross-section detail was available.

5.7.4 Existing Pavement Surface Preparation

Surface preparation included cold planing in sections the entire roadway's asphalt mix pavement surface to a depth of 1 inch to produce a uniform section for the application of the pavement overlay.

5.7.5 Mixture Specification Requirements

The mixture was required to meet the MassDOT GGSMA specification range and production tolerance shown in Table 5.7.2. The Contractor's JMF is also shown in Table 5.7.2. Please note that the GGSMA incorporated 4% latex modifier into the base PG64-28 binder.

Table 5.7.2: P7 job mix formula requirements, I-95 Danvers-Rowley

Sieve Size	MassDOT GGSMA Specification	Production Tolerance	Contractor GGSMA JMF
19.0 mm (3/4 inch)	–	–	100
12.5 mm (1/2 inch)	91–100	± 6.0%	97
9.5 mm (3/8 inch)	69–81	± 6.0%	75
4.75 mm (No. 4)	33–45	± 6.0%	39
2.36 mm (No. 8)	15–25	± 5.0%	20
1.18 mm (No. 16)	12–18	± 3.0%	15
600 μm (No. 30)	7–13	± 3.0%	10
300 μm (No. 50)	–	–	8
150 μm (No. 100)	3–7	± 2.0%	5
75 μm (No. 200)	3–5	± 1.0%	4
Asphalt Content	4.5–7.0%	–	6.4%
		–	
Air Voids	3.0–6.0%	–	–

5.7.6 Mixture Production Data

A detailed study was conducted during production to compare the GGSMA mixture with and without the WMA additive. The results of this study culminated in MassDOT Report #SPRII 03.07.10, entitled "Laboratory and Field Evaluation of Warm Mix Asphalt Technology to Determine Its Applicability for Massachusetts" (*2*). This report contains more detailed information regarding mixture production, production and placement temperatures, field density, field observations during placement, and laboratory testing of the binder and mixtures. Selected testing of production mixture is shown in Tables 5.7.3 and 5.7.4.

Table 5.7.3: P7 production data – Marshall volumetric properties (compacted at plant during production), I-95 Danvers-Rowley

Marshall Specimens	Air Voids	VMA	VFA	Bulk Specific Gravity of Specimen (G_{sb})	Maximum Theoretical Specific Gravity (G_{mm})
Sublot 1 – WMA	7.0%	21.1%	66.8%	2.379	–
Sublot 2 – WMA	6.4%	20.6%	69.1%	2.395	–
Sublot 3 – WMA	7.2%	21.3%	66.4%	2.375	–
Sublot 4 – WMA	6.8%	20.9%	67.7%	2.385	–
Sublot 5 – WMA	6.6%	20.8%	68.2%	2.389	–
Average WMA	6.8%	20.9%	67.6%	2.385	2.558*
Sublot 6 – GGSMA	5.1%	20.0%	74.7%	2.413	–
Sublot 7 – GGSMA	5.9%	20.7%	71.5%	2.392	–
Sublot 8 – GGSMA	6.4%	21.1%	69.6%	2.379	–
Sublot 9 – GGSMA	4.4%	19.4%	77.5%	2.431	–
Sublot 10 – GGSMA	5.2%	20.1%	74.2%	2.410	–
Average GGSMA	5.4%	20.3%	73.5%	2.405	2.542*

*G_{mm} values shown are from separate testing.

Table 5.7.4: P7 production data – Superpave volumetric properties (compacted at plant during production), I-95 Danvers-Rowley

SGC Specimens	Air Voids	VMA	VFA	Bulk Specific Gravity of Specimen (G_{sb})	Maximum Theoretical Specific Gravity (G_{mm})
Sublot 1 – WMA	5.5%	19.8%	72.4%	2.418	–
Sublot 2 – WMA	5.4%	19.8%	72.8%	2.420	–
Sublot 3 – WMA	4.9%	19.3%	74.9%	2.434	–
Sublot 4A – WMA*	6.0%	20.3%	70.5%	2.405	–
Sublot 4B – WMA*	5.8%	20.1%	71.0%	2.409	–
Sublot 5 – WMA	5.9%	20.2%	71.0%	2.408	–
Average WMA	5.6%	19.9%	72.1%	2.416	2.558*
Sublot 6 – GGSMA	4.8%	19.8%	75.6%	2.419	–
Sublot 7 – GGSMA	4.2%	19.2%	78.3%	2.436	–
Sublot 8 – GGSMA	5.4%	20.3%	73.4%	2.405	–
Sublot 9 – GGSMA	4.4%	19.4%	77.5%	2.431	–
Sublot 10 – GGSMA	4.2%	19.3%	78.2%	2.435	–
Average GGSMA	4.6%	19.6%	76.6%	2.425	2.542*

*G_{mm} values shown are from separate testing.

5.7.7 Condition Data

The average condition indices (PSI, DI, maximum rut depth, and IRI) for this project with respect to in-service time (in years) are shown in Figures 5.7.1 through 5.7.4. Please note that condition data collection started in 2009. With 11 years in service, the PSI remained above the 2.5 threshold for interstate roads, therefore indicating no need for rehabilitation at this time. The DI over time has remained well above the 2.5 threshold, thereby indicating that cumulative cracking is not yet an issue. Average maximum rut depth was below the 0.5-inch threshold, indicating rutting has remained at acceptable levels. The ride quality, in terms of IRI, has remained nearly constant. Overall, based on the indices, the GGSMA mixture with WMA technology has performed acceptably. This project should continue to be monitored annually to determine the longevity of this particular strategy.

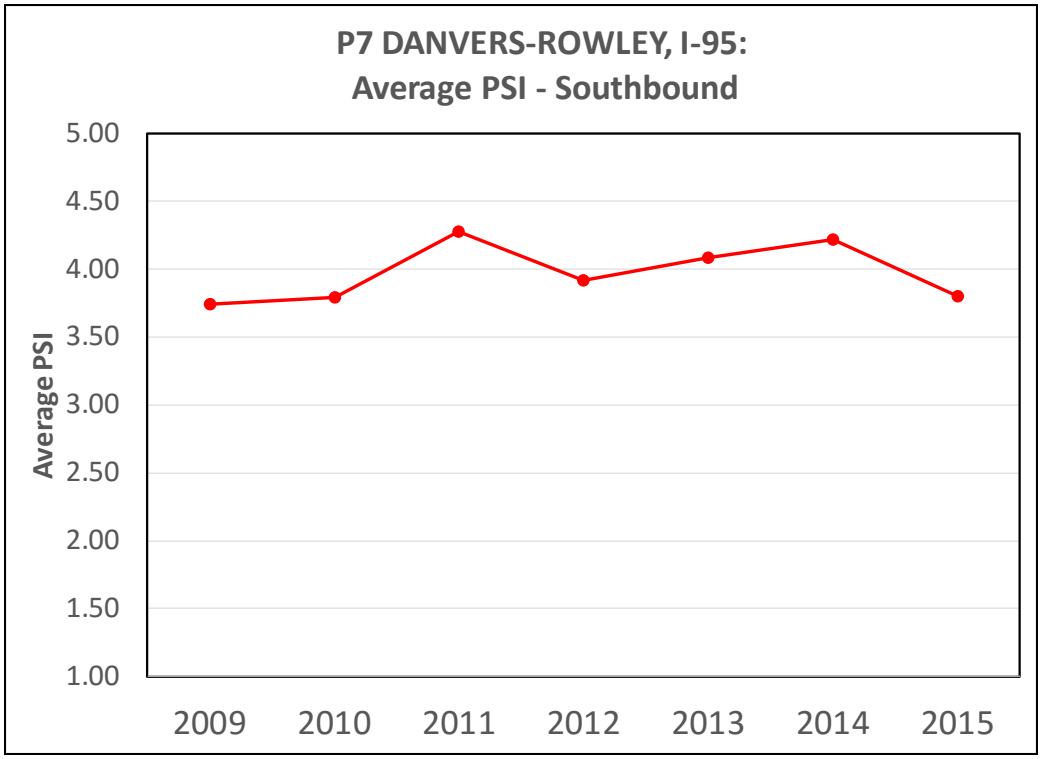

Figure 5.7.1: P7 condition data – average PSI, I-95 Danvers-Rowley

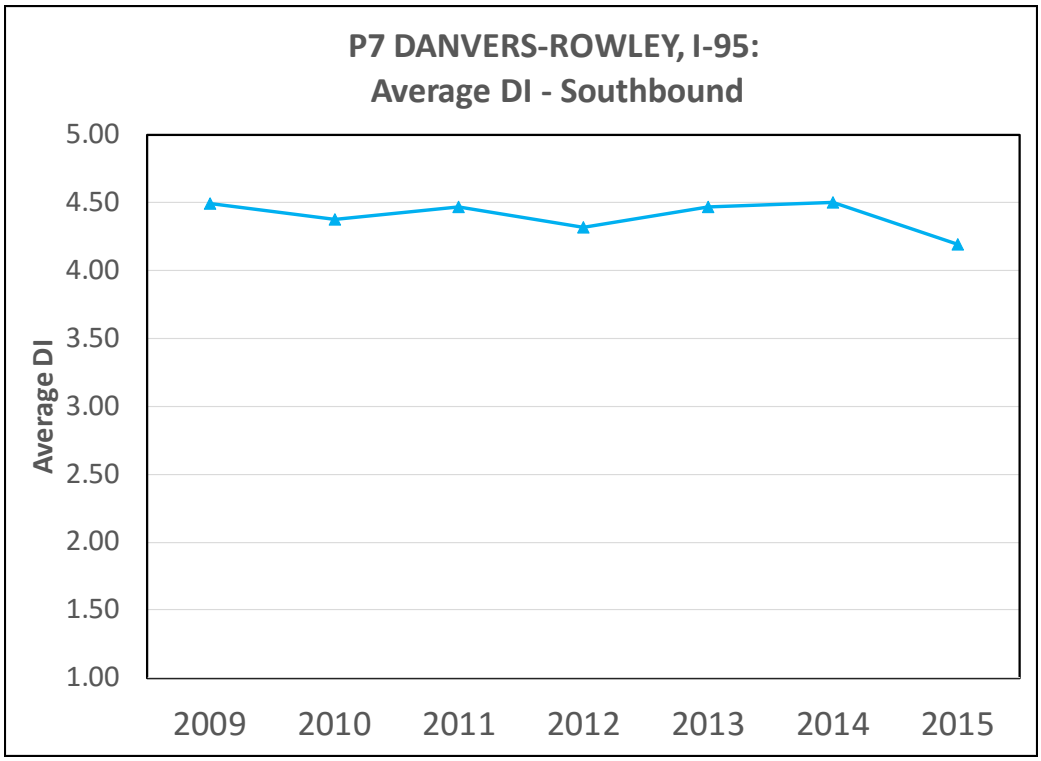

Figure 5.7.2: P7 condition data – average DI, I-95 Danvers-Rowley

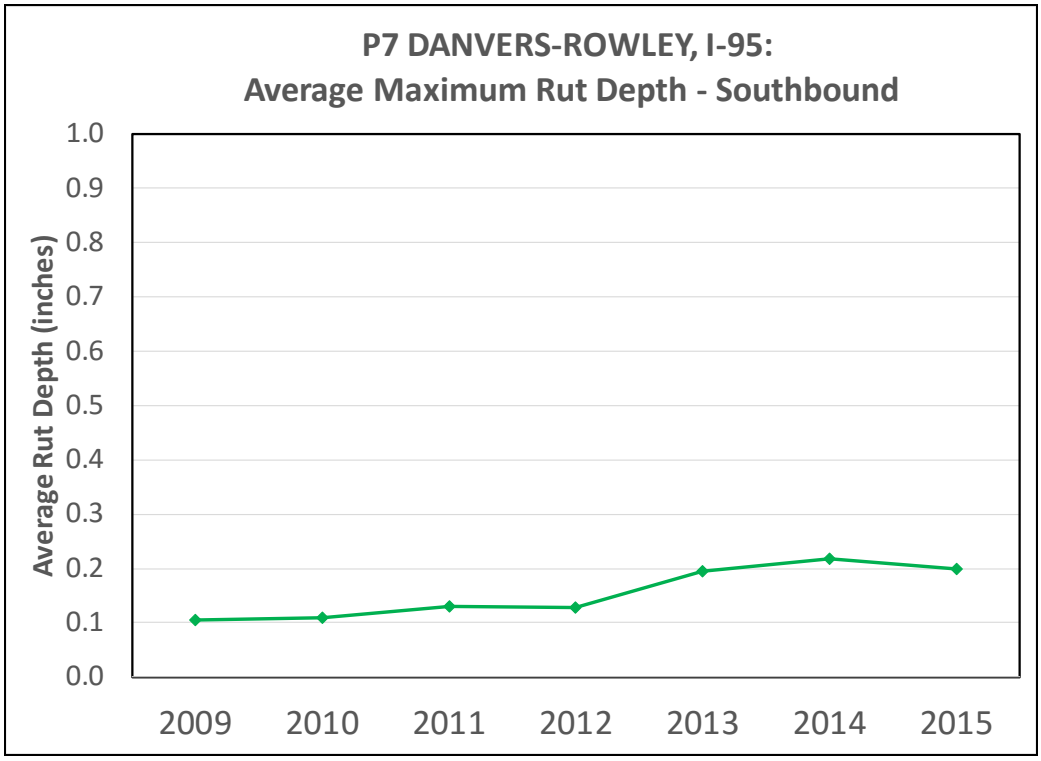

Figure 5.7.3: P7 condition data – average maximum rut depth, I-95 Danvers-Rowley

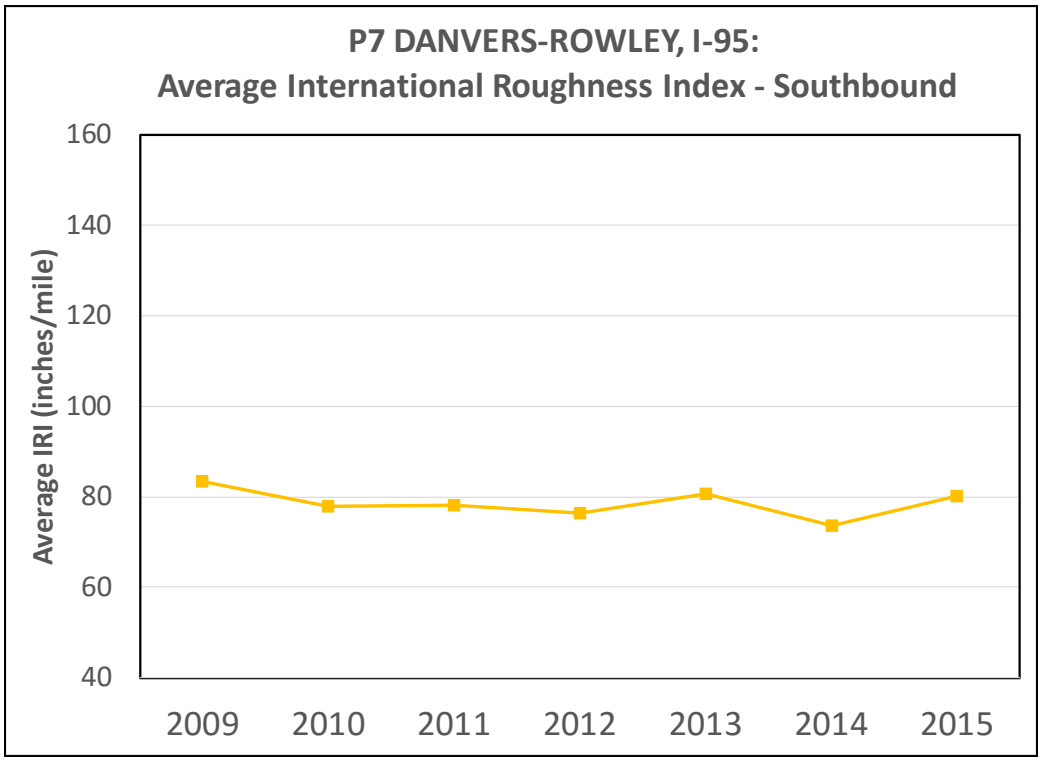

Figure 5.7.4: P7 condition data – average IRI, I-95 Danvers-Rowley

5.8 Project #8: I-495 Northbound Franklin-Mansfield

This section outlines the information and data collected for Project #8 (P8) I-495 Northbound Franklin-Mansfield.

5.8.1 Project General Information

The general information collected for this project is shown in Table 5.8.1.

Table 5.8.1: P8 general information, I-495 Northbound Franklin-Mansfield

Project ID:	P8
MassDOT District:	District 5
MassDOT Contract Number:	32082
MassDOT Project Number:	600885
Reason for Monitoring:	Placement of pavement structure over rubblized PCC slabs
Contract Amount:	–
Approximate Placement Date:	July 2005
Number of Years in Service:	11 years
Length of Section:	–
Contractor:	Roads Corporation

5.8.2 Project Location

No locus map for this project was available.

5.8.3 Typical Section Detail

No typical cross-section detail was available.

5.8.4 Existing Pavement Surface Preparation

No data on existing surface preparation was available.

5.8.5 Mixture Specification Requirements

No specification requirement was available.

5.8.6 Mixture Production Data

No production data was available for this mixture.

5.8.7 Condition Data

The average condition indices (PSI, DI, maximum rut depth, and IRI) for this project with respect to in-service time (in years) are shown in Figures 5.8.1 through 5.8.4. Please note that condition data collection started in 2009. With 11 years in service, the PSI remained above the 2.5 threshold for interstate roads, therefore indicating no need for rehabilitation at this time. The DI over time has remained above the 2.5 threshold, thereby indicating that cumulative cracking is not yet an issue. Average maximum rut depth was below the 0.5-inch threshold, indicating rutting has remained at acceptable levels. The ride quality, in terms of IRI, has remained nearly constant. Overall, based on the indices, the placement of the pavement structure over rubblized PCC slabs has performed acceptably. Since trends in PSI

and DI are starting to decline, this project should continue to be monitored annually to determine the longevity of this strategy.

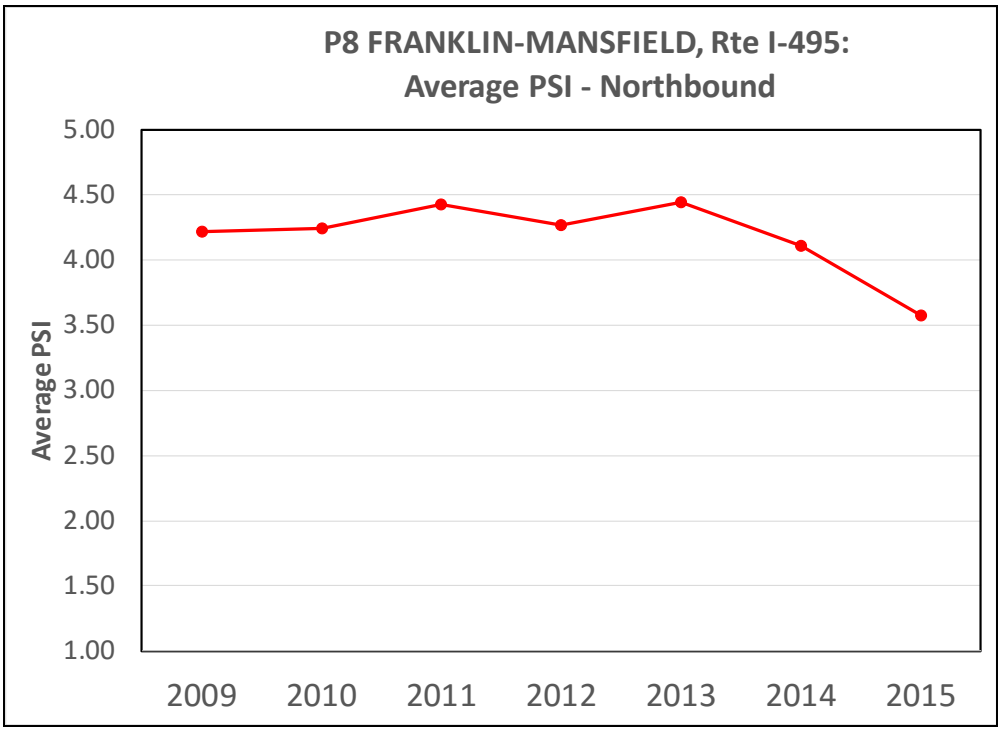

Figure 5.8.1: P8 condition data – average PSI, I-495 Northbound Franklin-Mansfield

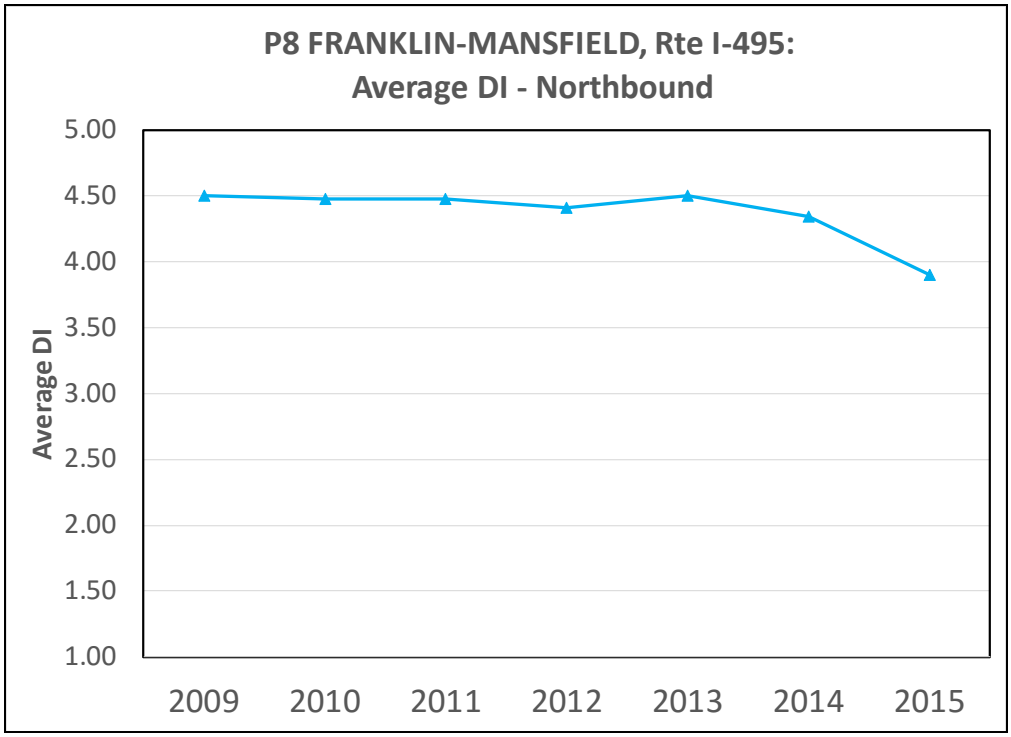

Figure 5.8.2: P8 condition data – average DI, I-495 Northbound Franklin-Mansfield

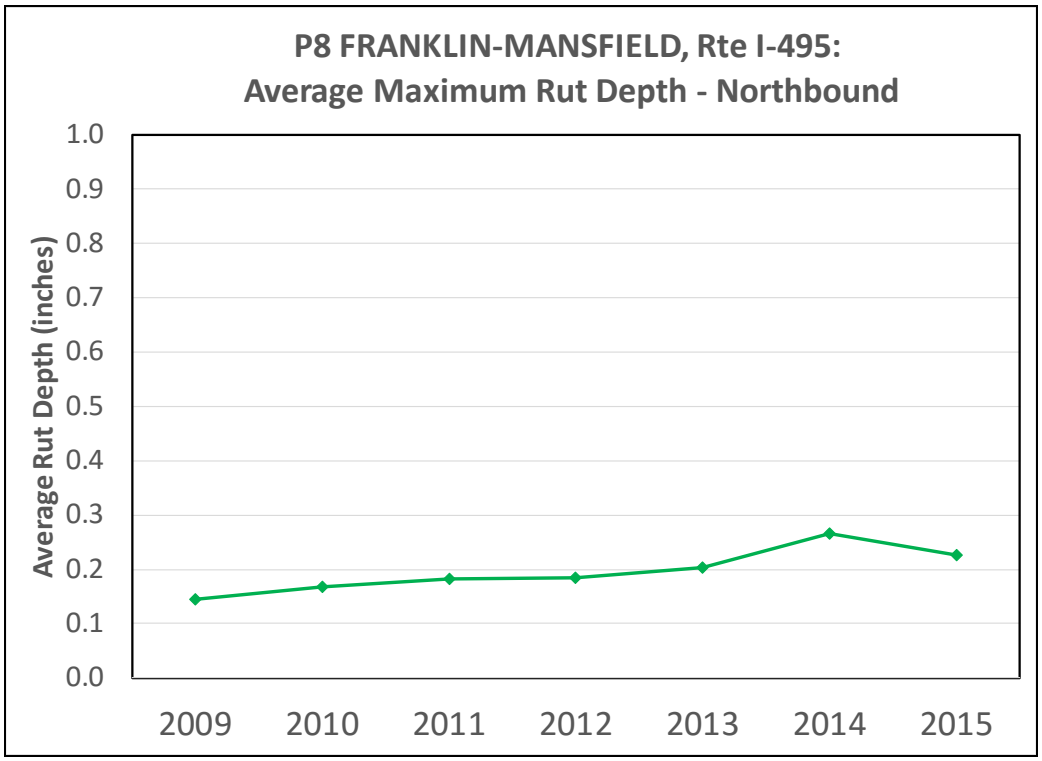

Figure 5.8.3: P8 condition data – average maximum rut depth, I-495 Northbound Franklin-Mansfield

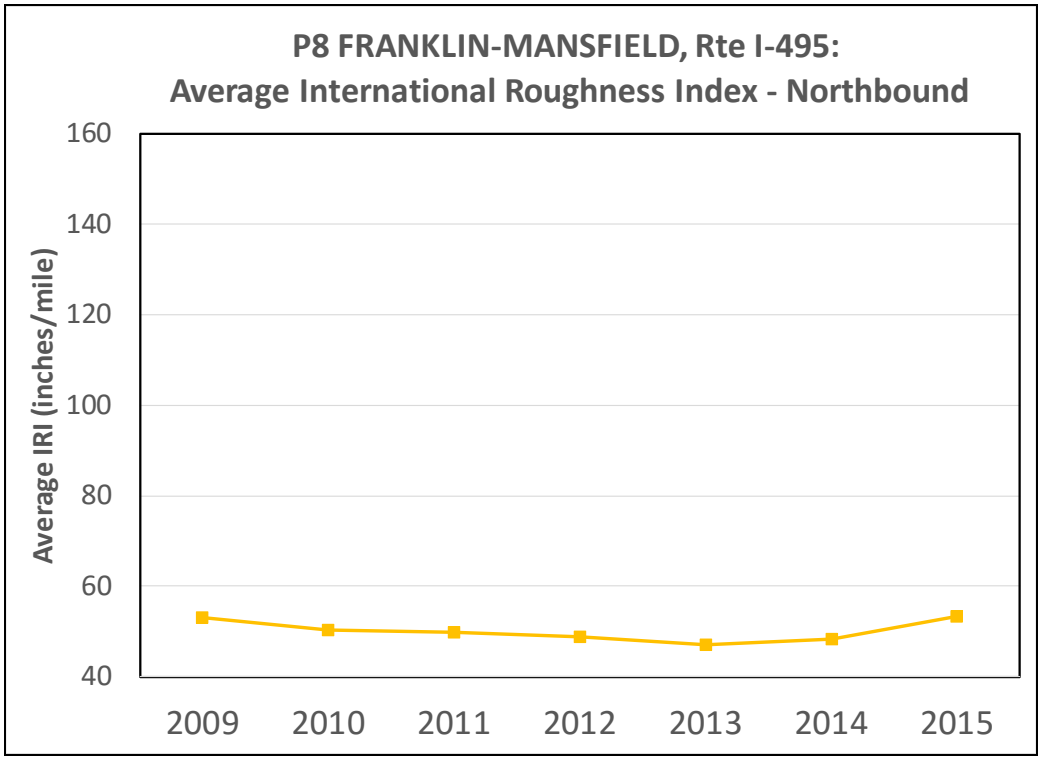

Figure 5.8.4: P8 condition data – average IRI, I-495 Northbound Franklin-Mansfield

5.9 Project #9: I-495 Southbound Franklin-Mansfield

This section outlines the information and data collected for Project #9 (P9) I-495 Southbound Franklin-Mansfield.

5.9.1 Project General Information

The general information collected for this project is shown in Table 5.9.1.

Table 5.9.1: P9 general information, I-495 Southbound Franklin-Mansfield

Project ID:	P9
MassDOT District:	District 5
MassDOT Contract Number:	43497
MassDOT Project Number:	601932R
Reason for Monitoring:	Placement of 1" SAMI mixture over existing concrete slabs
Contract Amount:	$23 million
Approximate Placement Date:	October 2008
Number of Years in Service:	8 years
Length of Section:	9.77 miles
Contractor:	Middlesex Corporation (Aggregate Industries Wrentham)

5.9.2 Project Location

No locus map for this project was available. According to the bid documents, the project description is as follows:

"The project began in Franklin at Station 110+00, 1.5 miles south of the Route I-495/King Street interchange, and proceeds southerly along Route I-495 through the Franklin-Wrentham line Station 259+49 Franklin = Station 0-7.34 Wrentham; through the Wrentham-Plainville line Station 190+55.51 Wrentham = Station 0+00.00 Plainville; through the Plainville-Foxborough line Station 74+33.08 Plainville = Station 0+00.00 Foxborough; through the Foxborough-Mansfield line Station 90+68.30 Foxborough = Station 0+00.00 Mansfield; ending in Mansfield at Station 11+00, 1100 feet north of the Route I-495/Route I-95 interchange. The total length of the project was 9.77 miles."

5.9.3 Typical Section Detail

The project consisted of overlaying the existing cement concrete roadway with an HMA SAMI and hot asphalt pavement layers. The first overlay layer placed was the 1-inch SAMI layer. This SAMI layer was covered with 2 inches of binder course material.

5.9.4 Existing Pavement Surface Preparation

Prior to the placement of the HMA overlay, the existing concrete slab was prepared as follows. HMA patches or sections of the HMA patches within the concrete roadway that had a tolerance greater that 0.5 inches above the adjacent concrete surface were individually cold planed flush with the surrounding surface. Depressions were filled and potholes repaired on the roadway to create a level surface. Gaps in the longitudinal and transverse joints in concrete pavement were cleaned, dried using high-pressure air, and sealed with joint filler (asphalt rubber compound of the hot poured type conforming to Subsection M3.05.4 and ASTM D 3405, with a minimum 15% ground reclaimed tire rubber). Deteriorated concrete joints were reconstructed prior to the overlay. Immediately prior to applying the HMA-SAMI, the surface was thoroughly cleaned of all vegetation, loose materials, dirt, mud, visible moisture, and other objectionable materials. Tack coat was applied over the PCC at a rate of 0.02 gallons per square yard.

5.9.5 Mixture Specification Requirements

The SAMI mixture was required to meet the MassDOT specification shown in Table 5.9.2. The mixture was developed using a PG70-XX or higher PGAB and a design gyration level (N_{design}) of 50. Additionally, the Contractor was required to submit performance testing results from the asphalt pavement analyzer (APA) and flexural beam fatigue for its JMF prior to mixture approval.

Table 5.9.2: P9 MassDOT SAMI specification requirements, I-495 Southbound Franklin-Mansfield

Sieve Size	MassDOT SAMI Specification	Production Tolerance	Contractor SAMI JMF
12.5 mm (1/2 inch)	–	–	–
9.5 mm (3/8 inch)	100	–	100
4.75 mm (No. 4)	80–100	–	91
2.36 mm (No. 8)	60–85	± 4.0%	73
1.18 mm (No. 16)	40–70	–	53
600 μm (No. 30)	25–55	–	36
300 μm (No. 50)	15–35	–	21
150 μm (No. 100)	8–20	–	13
75 μm (No. 200)	6–14	± 1.0%	7.0
Asphalt Content	7.0% min.	± 0.3%	8.3
Air Voids	0.5–2.5%	± 0.5%	–
VMA	16.0% min.	- 1.0%	–
APA rut depth at 8,000 cycles at 60° C, mm	< 12 mm	–	–
Flexural beam fatigue N_f at 15° C & 2,000 με	>100,000	–	–

5.9.6 Mixture Production Data

A significant number of specimens (over 19) were tested during the production of the SAMI mixture from June 2007 to June 2008. The average production data over that time is shown in Table 5.9.3.

Table 5.9.3: P9 production data, I-495 Southbound Franklin-Mansfield

Sieve Size	Contractor SAMI JMF	Production Tolerance	Average Production Data (16 sublots)
9.5 mm (3/8 inch)	100	–	100
4.75 mm (No. 4)	91	–	92.2
2.36 mm (No. 8)	73	± 4.0%	74.2
1.18 mm (No. 16)	53	–	53.2
600 µm (No. 30)	36	–	35.7
300 µm (No. 50)	21	–	22.2
150 µm (No. 100)	13	–	11.5
75 µm (No. 200)	7.0	± 1.0%	6.5
Asphalt Content	8.3	± 0.3%	8.4%
Air Voids	0.5–2.5%	± 0.5%	1.0%
VMA	16.0% min.	- 1.0%	19.2%

Additionally, field density measurements were collected by MassDOT for the SAMI mixture as outlined in Table 5.9.4.

Table 5.9.4: P9 MassDOT SAMI field density measurements, I-495 Southbound Franklin-Mansfield

Date	Lot	Density	Air Voids (0.5–2.5%) ±0.5%
6/3/2008	Sublot 7	96.8%	3.2%
6/19/2008	Sublot 6	96.7%	3.3%
6/19/2008	Sublot 9	96.9%	3.1%
6/20/2008	Lot 1 – Sublot 1	97.4%	2.6%
6/20/2008	Lot 1 – Sublot 2	96.9%	3.1%
6/20/2008	Lot 1 – Sublot 3	97.3%	2.7%

5.9.7 Condition Data

The average condition indices (PSI, DI, maximum rut depth, and IRI) for this project with respect to in-service time (in years) are shown in Figures 5.9.1 through 5.9.4. Please note that condition data collection started in 2009. With eight years in service, the PSI remained above the 2.5 threshold for interstate roads, therefore indicating no need for rehabilitation at this time. The DI over time has remained above the 2.5 threshold, thereby indicating that cumulative cracking is not yet an issue. Average maximum rut depth was below the 0.5-inch threshold, indicating rutting has remained at acceptable levels. The ride quality, in terms of IRI, has remained nearly constant. Overall, based on the indices, the placement of the SAMI

mixture over PCC slabs has performed acceptably. This project should continue to be monitored annually to determine the longevity of this strategy.

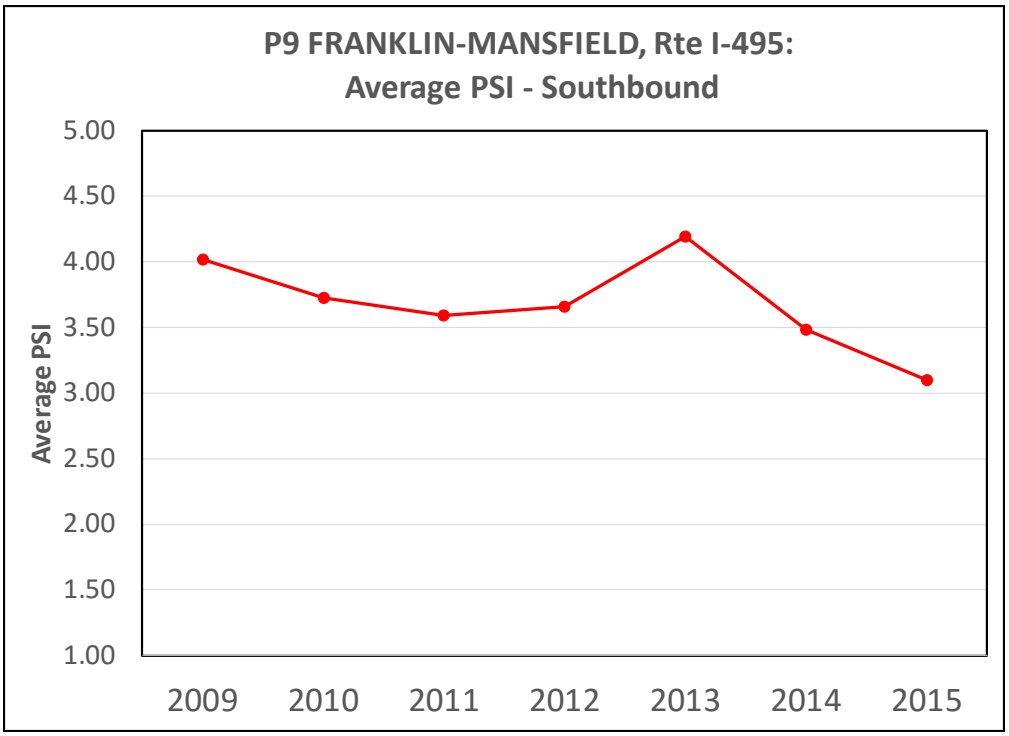

Figure 5.9.1: P9 condition data – average PSI, I-495 Southbound Franklin-Mansfield

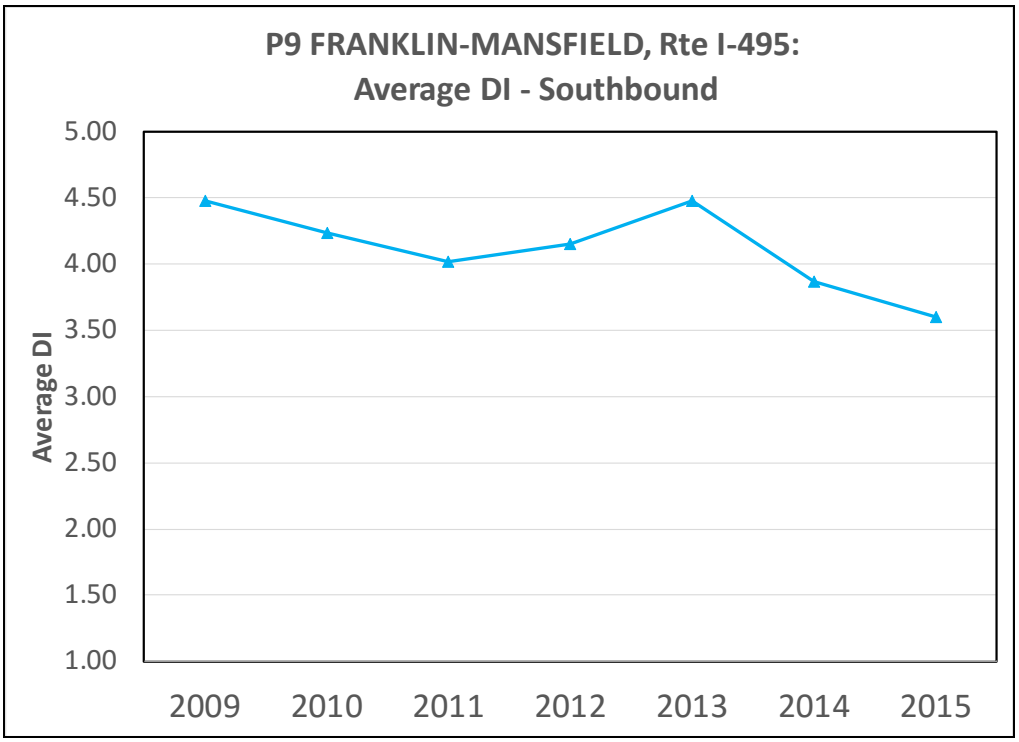

Figure 5.9.2: P9 condition data – average DI, I-495 Southbound Franklin-Mansfield

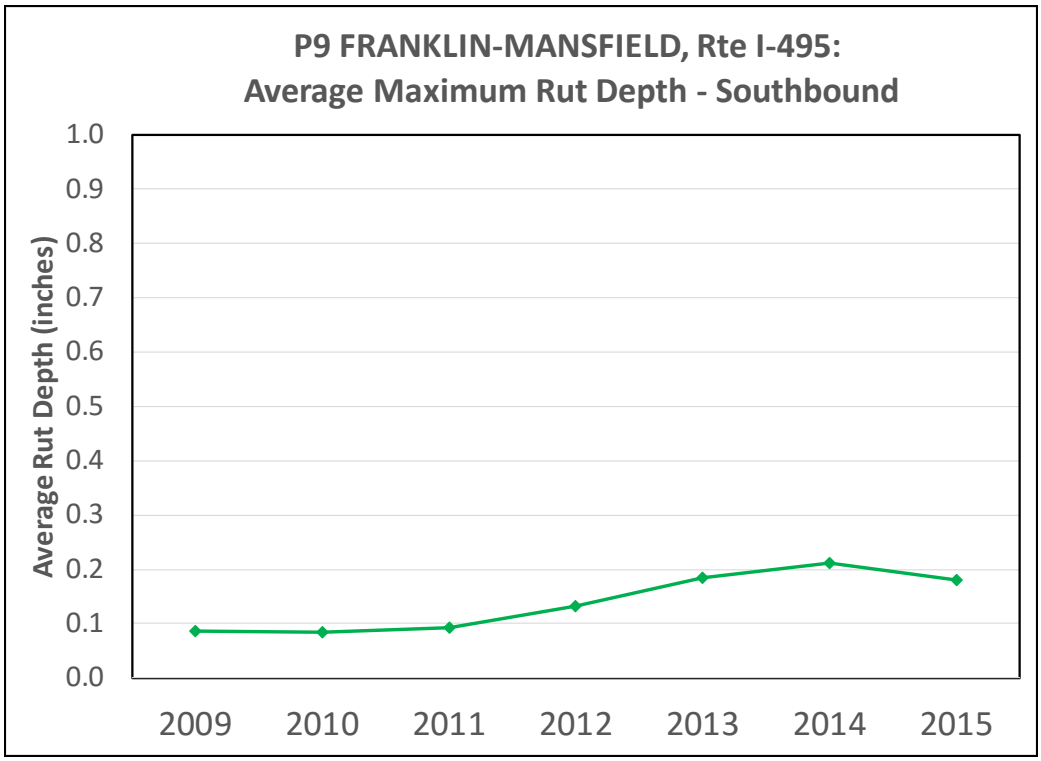

Figure 5.9.3: P9 condition data – average maximum rut depth, I-495 Southbound Franklin-Mansfield

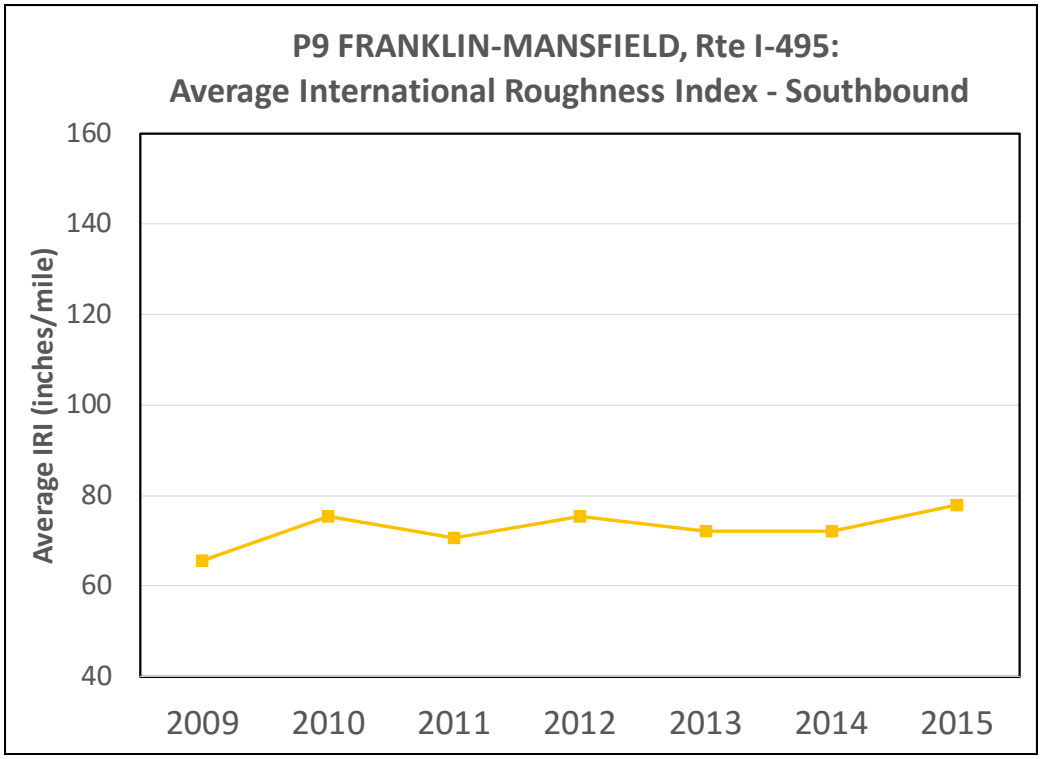

Figure 5.9.4: P9 condition data – average IRI, I-495 Southbound Franklin-Mansfield

5.10 Project #10: I-295 Attleboro-North Attleboro

This section outlines the information and data collected for Project #10 (P10) I-295 Attleboro-North Attleboro.

5.10.1 Project General Information

The general information collected for this project is shown in Table 5.10.1.

Table 5.10.1: P10 general information, I-295 Attleboro-North Attleboro

Project ID:	P10
MassDOT District:	District 5
MassDOT Contract Number:	52815
MassDOT Project Number:	604574
Reason for Monitoring:	Placement of two UTBO mixtures (conventional & asphalt rubber) and an ARGG mixture with WMA
Contract Amount:	–
Approximate Placement Date:	October 2008
Number of Years in Service:	8 years
Length of Section:	4.17 miles
Contractor:	J. H. Lynch & Sons

5.10.2 Project Location

No locus map for this project was available. The project description from the bid documents is as follows:

"Beginning on Route I-295 at the Cumberland R.I.-North Attleborough Town Line at Sta. 0+00 (MM 0.0), thence northerly through the North Attleborough-Attleborough Line at station 177+34.30 North Attleborough = Sta. 500+00 Attleboro, and ending just east of the interchange with Route I-95 in Attleboro at Sta. 543+00± (MM 4.1), a length of 22,034 feet or 4.17 miles."

5.10.3 Typical Section Detail

No typical cross-section detail was available. The project consisted of separate placement of different overlay mixtures. Each mixture had a thickness of 1 inch or less. A UTBO mixture (conventional and asphalt rubber) was placed on the southbound side over an HMA Type I Leveling Course (1 inch maximum depth). An ARGG mixture with WMA additive (Advera®) was placed on the northbound side over an HMA Type I Leveling Course (1 inch maximum depth).

5.10.4 Existing Pavement Surface Preparation

The mainline of I-295 was cold planed to a depth of 1.75 inches prior to placement of any of the mixtures.

For UTBO mixtures, crack sealing was conducted to prevent emulsion from entering open cracks. Cracks and joints greater than 0.25 inch wide were cleaned and flush filled with rubberized asphalt crack sealant meeting the requirements of ASTM 3405. Equipment used for blowing cleaning, drying, and heating sidewalls of cracks and joints was a hot compressed air (H.C.A.) lance capable of producing a flame-retarded air stream at a minimum temperature of 2,500° F. All surface irregularities greater than 1 inch deep were filled. A warm polymer modified asphalt emulsion tack coat was spray applied immediately prior to the application of the UTBO mixture at a temperature of 140º to 160º F at a rate of 0.15 to 0.25 gallons per square yard. The tack coat was required to be grade CRS-2 asphalt emulsion modified with latex, natural or synthetic, and meeting the requirements of ASTM D2397, except as modified in Table 5.10.2. It was required that the latex be co-milled at the bulk emulsion facility to ensure complete and balanced blending. Immediately after applying the tack coat, the UTBO mixture was applied across the full width of the tack coat at a temperature of 300º to 325º F.

Table 5.10.2: P10 UTBO tack coat requirements, I-295 Attleboro-North Attleboro

Property	Method	Minimum	Maximum
Latex Content, % Mass of Total Residue	–	3.0	–
Viscosity at 25° C, Seconds	AASHTO T59	20	100
Residue by Distillation, %	AASHTO T59	63	–
Demulsibility, % by weight of Residue	AASHTO T59	60	–

The ARGG with WMA mixture was required to be applied only when the surface was dry and the surface temperature was 50° F and rising. The cold planed surface received a coating of bitumen for tack coat at an application rate of 0.05 gallons per square yard.

5.10.5 Mixture Specification Requirements

The UTBO mixtures were required to meet the specifications shown in Table 5.10.3. The asphalt binder for the conventional UTBO was required to be a PG64-28. For the asphalt rubber UTBO, the base asphalt was required to be a PG58-28, which was then mechanically blended with rubber to conform to ASTM D 6114 type II specifications.

Table 5.10.3: P10 UTBO specification requirements, I-295 Attleboro-North Attleboro

Sieve Size	MassDOT UTBO Specification	Contractor UTBO JMF
19.0 mm (3/4 inch)	100	100
12.5 mm (1/2 inch)	85–100	99
9.5 mm (3/8 inch)	45–85	61
6.35 mm (1/4 inch)	30–50	38
4.75 mm (No. 4)	24–41	36
2.36 mm (No. 8)	21–33	26
1.18 mm (No. 16)	15–26	18
600 μm (No. 30)	11–20	13
300 μm (No. 50)	8–16	11
150 μm (No. 100)	5–10	8
75 μm (No. 200)	4–7	5.5
Asphalt Content (Conventional PG64-28)	4.8–5.2%	5.0%
Asphalt Content (PG58-28 Asphalt Rubber Modified)	5.8–6.4%	6.0%

The ARGG with WMA mixture was required to meet the MassDOT specification requirements shown in Table 5.10.4. The base asphalt was required to be a PG58-28, which was then mechanically blended with rubber to conform to ASTM D 6114 type II specifications.

Table 5.10.4: P10 ARGG mixture with WMA specification requirements, I-295 Attleboro-North Attleboro

Sieve Size	MassDOT ARGG Specification	Production Tolerance	Contractor ARGG with WMA JMF
19.0 mm (3/4 inch)	100	–	100
12.5 mm (1/2 inch)	100	± 6.0%	98
9.5 mm (3/8 inch)	83–87	± 6.0%	85
4.75 mm (No. 4)	33–37	± 6.0%	40
2.36 mm (No. 8)	18–22	± 4.0%	22
1.18 mm (No. 16)	8–12	± 3.0%	17
600 μm (No. 30)	–	–	–
300 μm (No. 50)	–	–	–
150 μm (No. 100)	–	–	–
75 μm (No. 200)	2–7	± 1.0%	4.1
Binder Content	6.5% min.	–	7.5%
Air Voids	3–6%	–	4.5%
VMA	18–23% min.	–	–
Draindown	0.3% max.	–	–

5.10.6 Mixture Production Data

The data from testing of the production mixture was combined, both Contractor QC results and MassDOT Acceptance results. The average production testing results are shown in Table 5.10.5 for the conventional UTBO mixture, Table 5.10.6 for the asphalt rubber UTBO mixture, and Table 5.10.7 for the ARGG mixture with WMA.

Table 5.10.5: P10 conventional UTBO production data, I-295 Attleboro-North Attleboro

Sieve Size	MassDOT UTBO Specification	Contractor UTBO JMF	Average QC & Acceptance Production Data (5 Sublots)
19.0 mm (3/4 inch)	100	100	100
12.5 mm (1/2 inch)	85–100	99	96.0
9.5 mm (3/8 inch)	45–85	61	58.9
6.35 mm (1/4 inch)	30–50	38	–
4.75 mm (No. 4)	24–41	36	37.4
2.36 mm (No. 8)	21–33	26	28.6
1.18 mm (No. 16)	15–26	18	18.7
600 µm (No. 30)	11–20	13	12.6
300 µm (No. 50)	8–16	11	9.6
150 µm (No. 100)	5–10	8	7.2
75 µm (No. 200)	4–7	5.5	5.0
Asphalt Content (Conventional PG64-28)	4.8–5.2%	5.0%	5.2%

Table 5.10.6: P10 asphalt rubber UTBO production data, I-295 Attleboro-North Attleboro

Sieve Size	MassDOT UTBO Specification	Contractor UTBO JMF	Average QC & Acceptance Production Data (4 Sublots)
19.0 mm (3/4 inch)	100	100	100.0
12.5 mm (1/2 inch)	85–100	99	95.2
9.5 mm (3/8 inch)	45–85	61	57.2
6.35 mm (1/4 inch)	30–50	38	–
4.75 mm (No. 4)	24–41	36	35.8
2.36 mm (No. 8)	21–33	26	27.1
1.18 mm (No. 16)	15–26	18	18.7
600 µm (No. 30)	11–20	13	13.2
300 µm (No. 50)	8–16	11	10.0
150 µm (No. 100)	5–10	8	7.5
75 µm (No. 200)	4–7	5.5	5.2
Asphalt Content (PG58-28 Asphalt Rubber Modified)	5.8–6.4%	6.0%	5.9%
Air Voids	–	–	4.1%

Table 5.10.7: P10 ARGG mixture with WMA production data, I-295 Attleboro-North Attleboro

Sieve Size	MassDOT ARGG Specification	Production Tolerance	Contractor ARGG + WMA JMF	ARGG + WMA Average QC & Acceptance Production Data (6 Sublots)
19.0 mm (3/4 inch)	100	–	100	100
12.5 mm (1/2 inch)	100	± 6.0%	98	98.2
9.5 mm (3/8 inch)	83–87	± 6.0%	85	85.9
4.75 mm (No. 4)	33–37	± 6.0%	40	42.0
2.36 mm (No. 8)	18–22	± 4.0%	22	22.3
1.18 mm (No. 16)	8–12	± 3.0%	17	16.9
600 μm (No. 30)	–	–	–	–
300 μm (No. 50)	–	–	–	–
150 μm (No. 100)	–	–	–	–
75 μm (No. 200)	2–7	± 1.0%	4.1	2.4
Binder Content	6.5% min.	–	7.5%	7.5%
		–		
Air Voids	3–6%	–	4.5%	7.0%
VMA	18–23% min.	–	–	–
Draindown	0.3% max.	–	–	–

5.10.7 Condition Data

The average condition indices (PSI, DI, maximum rut depth, and IRI) for this project with respect to in-service time (in years) are shown in Figures 5.10.1 through 5.10.4. Please note that condition data collection started in 2009. UTBO mixtures were placed on the southbound side, with the UTBO control placed north of Boston Road and the UTBO asphalt rubber placed south of Boston Road. The ARGG mixture with WMA was placed on the northbound side. With eight years in service, the PSI for the entire project remained above the 2.5 threshold for interstate roads, therefore indicating no need for rehabilitation at this time. The DI over time has remained above the 2.5 threshold, thereby indicating that cumulative cracking is not yet an issue. Average maximum rut depth was below the 0.5-inch threshold, indicating rutting has remained at acceptable levels. The ride quality, in terms of IRI, has remained nearly constant. Overall, based on the indices, the mixtures placed have performed acceptably. This project should continue to be monitored annually to determine the longevity of these strategies.

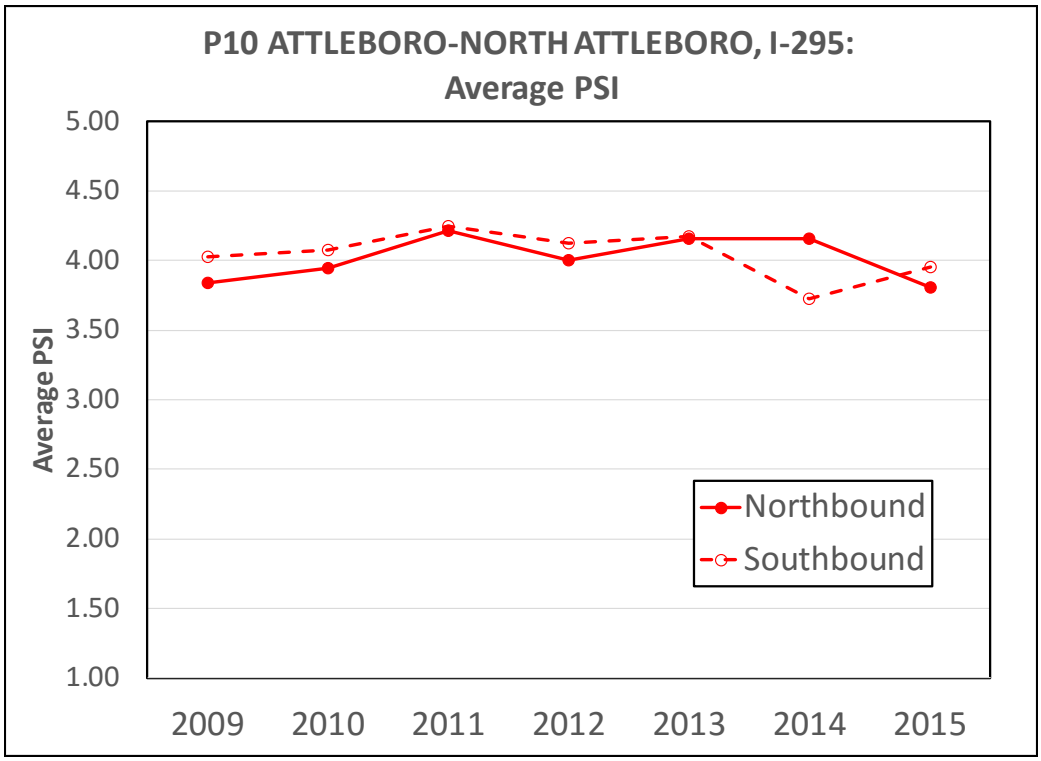

Figure 5.10.1: P10 condition data – average PSI, I-295 Attleboro-North Attleboro

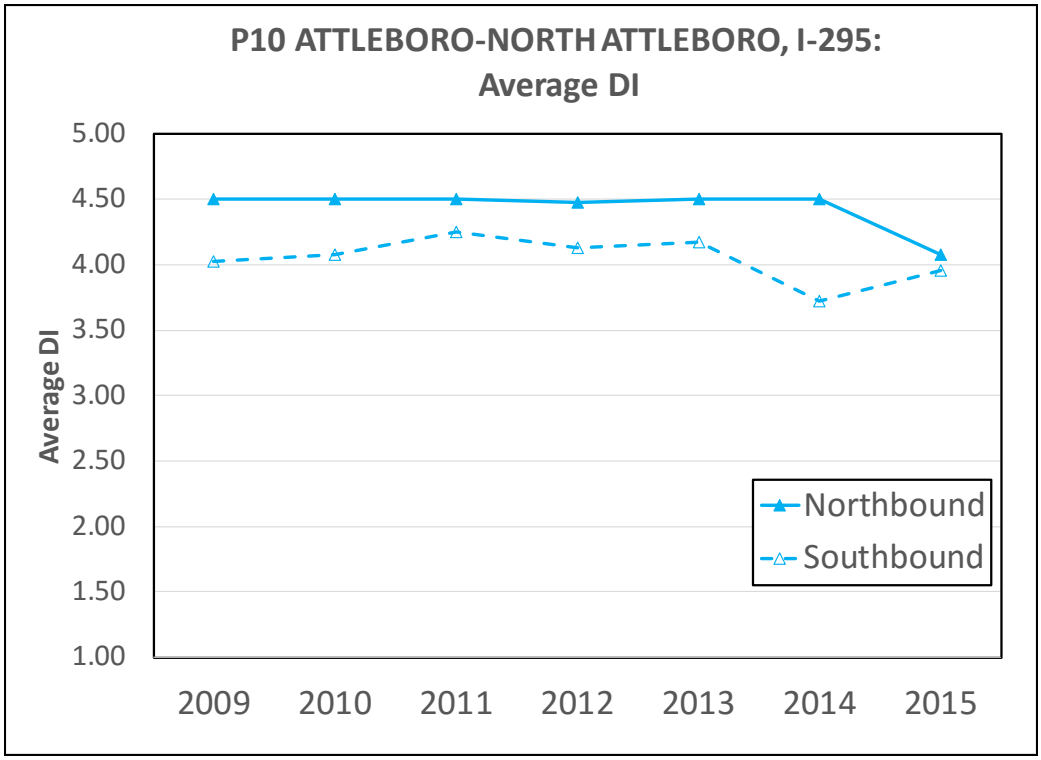

Figure 5.10.2: P10 condition data – average DI, I-295 Attleboro-North Attleboro

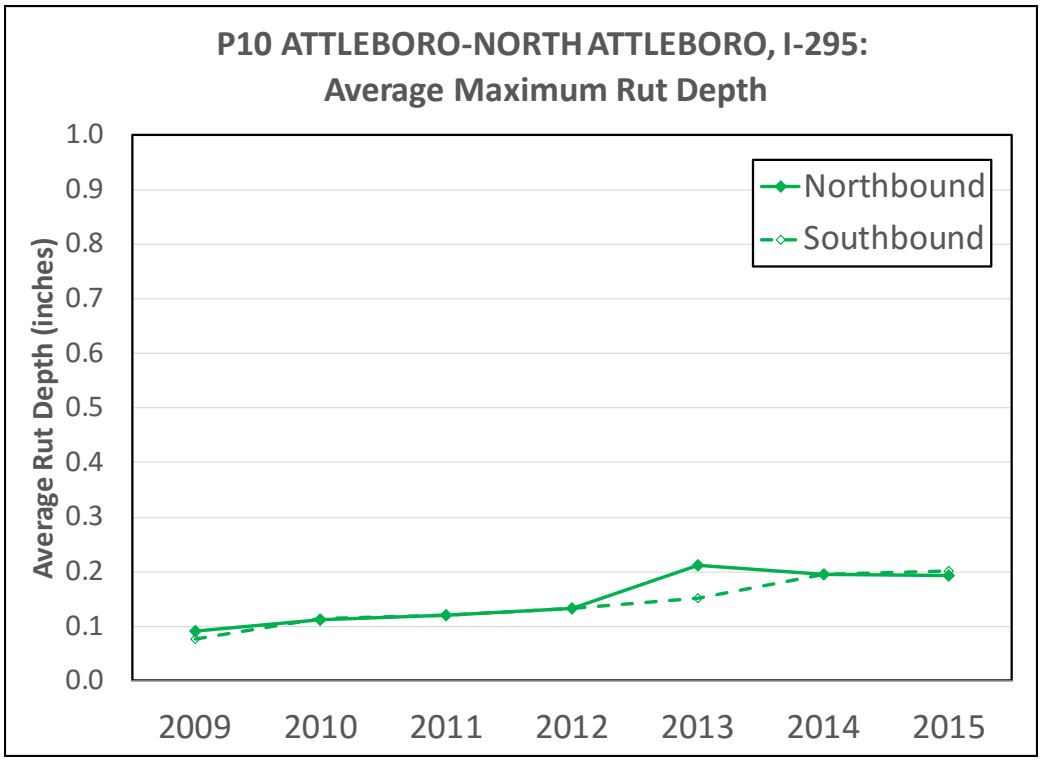

Figure 5.10.3: P10 condition data – average maximum rut depth, I-295 Attleboro-North Attleboro

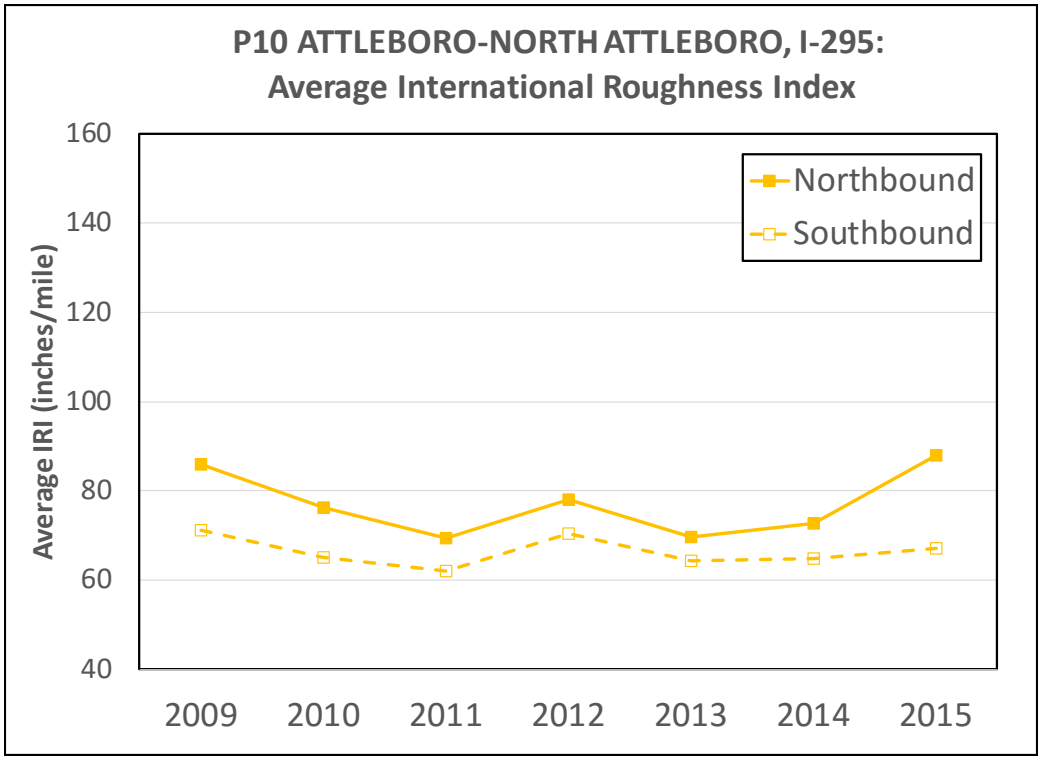

Figure 5.10.4: P10 condition data – average IRI, I-295 Attleboro-North Attleboro

5.11 Project #11: I-95 Canton-Norwood-Sharon-Walpole

This section outlines the information and data collected for Project #11 (P11) I-95 Canton-Norwood-Sharon-Walpole.

5.11.1 Project General Information

The general information collected for this project is shown in Table 5.11.1.

Table 5.11.1: P11 general information, I-95 Canton-Norwood-Sharon-Walpole

Project ID:	P11
MassDOT District:	District 5
MassDOT Contract Number:	70375
MassDOT Project Number:	605590
Reason for Monitoring:	Placement of 1" of OGFC over 1" of Superpave Surface Course (SSC-9.5). Two SSC-9.5 mixtures were placed, one with N_{design} of 80 and one with N_{design} of 100. Gyration level study.
Contract Amount:	$9.3 million
Approximate Placement Date:	2013
Number of Years in Service:	3 years
Length of Section:	5.74 miles
Contractor:	D & R General Contracting (Aggregate Industries Wrentham)

5.11.2 Project Location

The locus map for this project is shown in Figure 5.11.1.

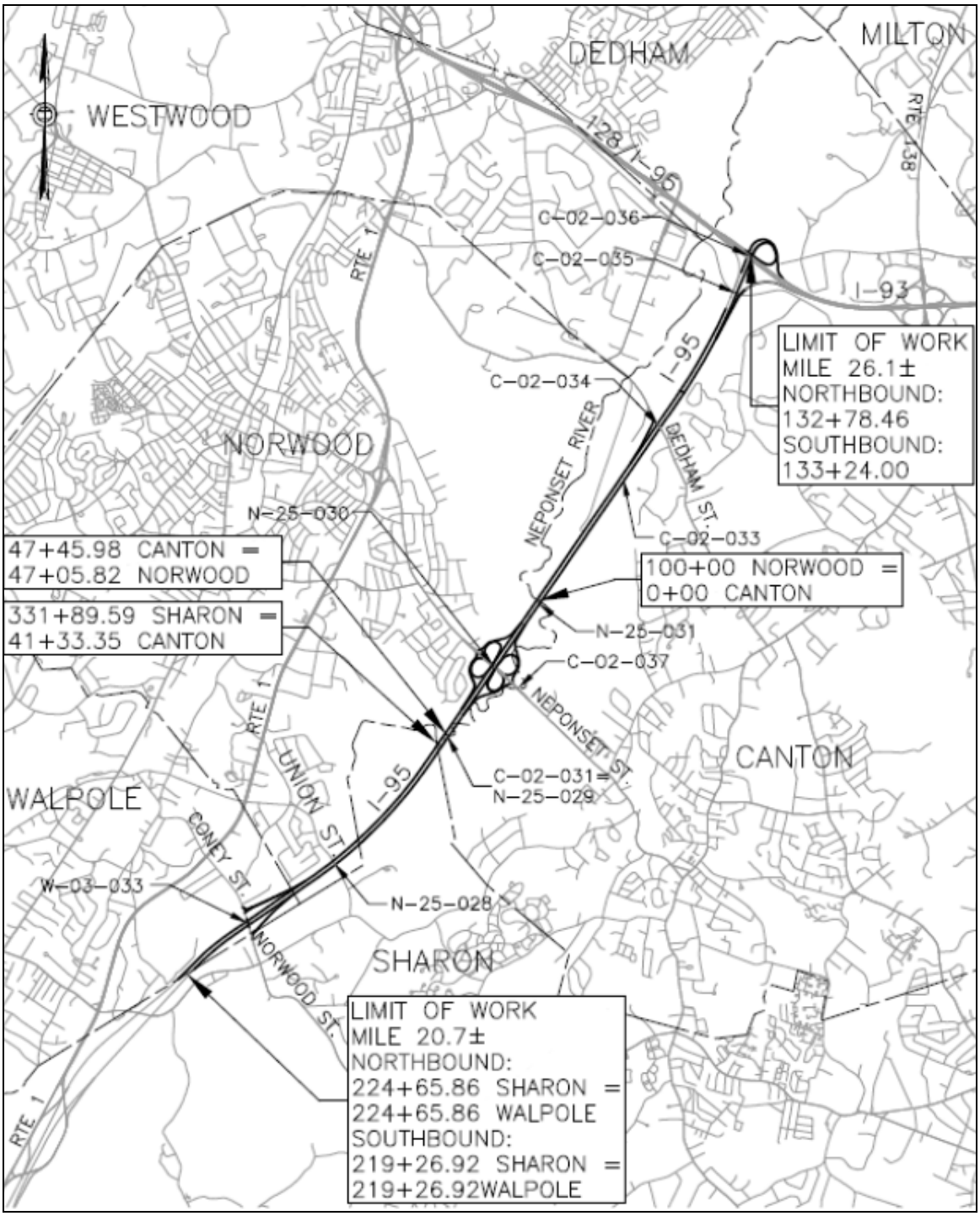

Figure 5.11.1: P11 site locus plan, I-95 Canton-Norwood-Sharon-Walpole

The project description from the bid documents is as follows:

“Beginning at the Sharon - Walpole Town Line at Northbound Station 224+65.86 and Southbound Station 219+26.92 (Mile Marker 20.7), thence continuing northerly through the Walpole - Norwood Town Line at Station 265+39.23 Walpole = Station 265+39.23 Norwood

(Mile Marker 21.4), thence continuing northerly through the Norwood - Sharon Town Line at Station 292+28.02 Norwood = Station 292+28.02 Sharon (Mile Marker 21.8), thence continuing northerly through the Sharon - Canton Town Line at Station 331+89.59 Sharon = Station 41+33.35 Canton (Mile Marker 22.7), thence continuing northerly through the Canton - Norwood Town Line at Station 47+45.98 Canton = Station 47+05.82 Norwood (Mile Marker 22.8), thence continuing northerly through the Norwood – Canton Town Line at Station 100+00 Norwood = Station 0+00 Canton (Mile Marker 23.6), thence continuing northerly to Northbound Station 132+78.46 and Southbound Station 133+24.00 (Mile Marker 26.1), omitting Southbound Station 113+00.11 to 125+91.08, a length of 30,309 feet or 5.74 miles."

5.11.3 Typical Section Detail

The typical cross-section detail is shown in Figure 5.11.2. The project entailed resurfacing of the I-95 mainline with 1 inch of HMA Open Graded Friction Course – Polymer Modified (OGFC-P) over 1 inch of HMA Superpave Surface Course – 9.5 (SSC-9.5).

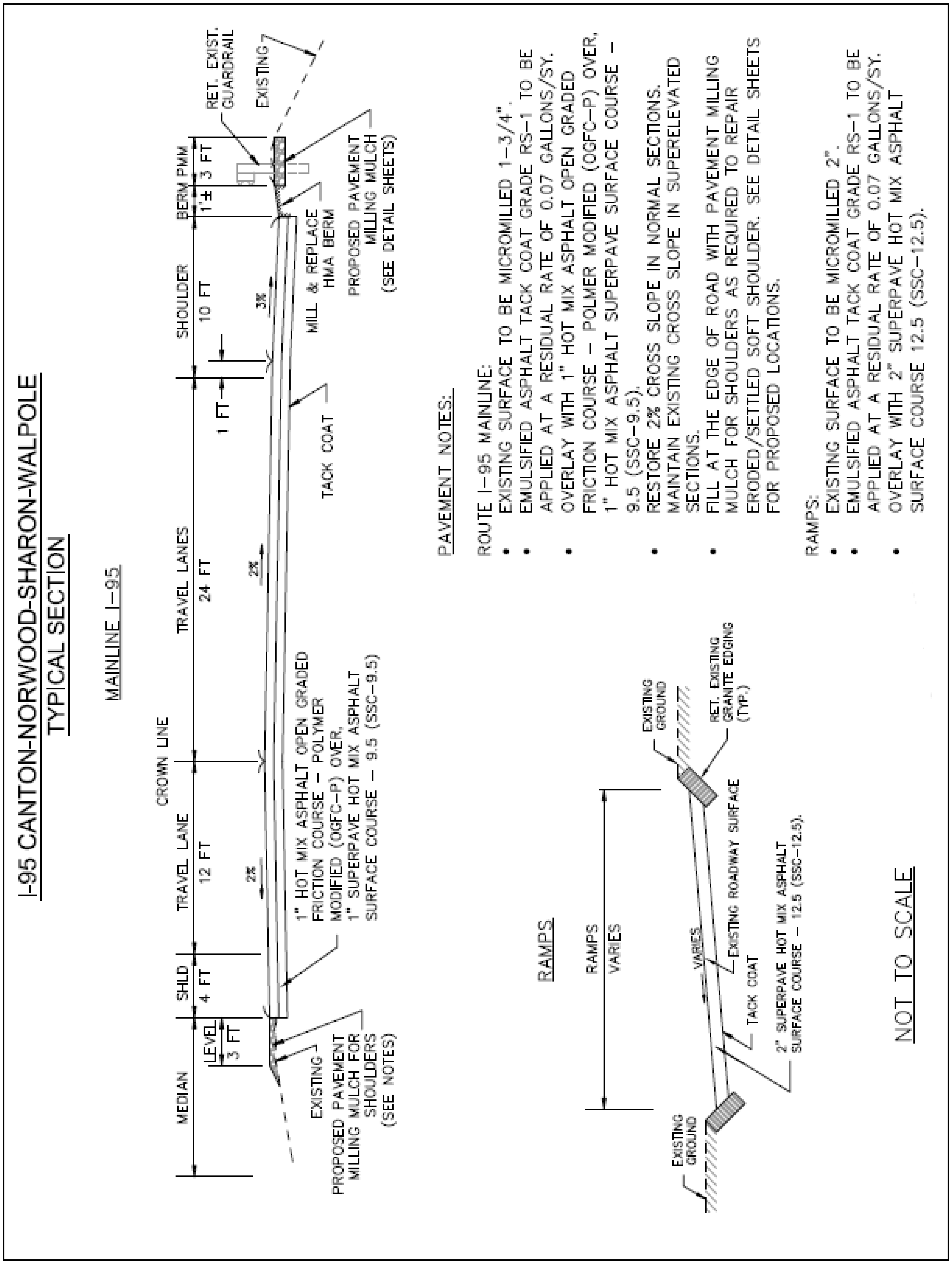

Figure 5.11.2: P11 typical section, I-95 Canton-Norwood-Sharon-Walpole

5.11.4 Existing Pavement Surface Preparation

The mainline of the I-95 was micromilled to a depth of 1.75 inches. Tack coat (emulsified asphalt grade RS-1) was applied to the milled surface at an application rate of 0.07 gallons per square yard. A tack coat application rate of 0.05 gallons per square yard was used over the Superpave surface course prior to overlaying with the OGFC.

5.11.5 Mixture Specification Requirements

Two SSC-9.5 mixtures were developed for this project, each with varying design compactive effort levels (N_{design}). One mixture was developed with N_{design} = 80 and another with N_{design} = 100. These mixtures were then overlaid with an OGFC mixture. The two SSC-9.5 mixtures were produced using a PG64-28 asphalt binder. Each mixture was required to meet the MassDOT specification shown in Table 5.11.2. The approved Contractor JMF with corresponding volumetric properties is also shown in Table 5.11.2. Note that a WMA additive was utilized in the production of both mixtures, but the exact WMA used could not be determined.

Table 5.11.2: P11 MassDOT SSC-9.5 specification requirements and Contractor JMF, I-95 Canton-Norwood-Sharon-Walpole

Sieve Size	MassDOT SSC-9.5 Specification N_{design} of 80 or 100	Production Tolerance	Contractor SSC-9.5 JMF
12.5 mm (1/2 inch)	100	± 6.0%	100
9.5 mm (3/8 inch)	90–100	± 6.0%	94
4.75 mm (No. 4)	90 max.	± 6.0%	65
2.36 mm (No. 8)	35–67	± 5.0%	42
1.18 mm (No. 16)	–	± 3.0%	30
600 µm (No. 30)	–	± 3.0%	20
300 µm (No. 50)	–	± 3.0%	13
150 µm (No. 100)	–	± 2.0%	8
75 µm (No. 200)	2–10	± 1.0%	4.6
Asphalt Content	–	± 0.3%	6.0% (80 Gyration) 5.9% (100 Gyration)
Air Voids	4.0%	–	4.0%
VMA	16.0% min.	–	16.8%
VFA	73–76%	–	75.7%

5.11.6 Mixture Production Data

The data from testing of the production mixture was combined, both Contractor QC results and MassDOT Acceptance results. The averages of these production testing results for the sublots tested are shown in Table 5.11.3 for the 80 gyration mixture and Table 5.11.4 for the 100 gyration mixture.

Table 5.11.3: P11 MassDOT SSC-9.5 80 gyration production data, I-95 Canton-Norwood-Sharon-Walpole

Sieve Size	MassDOT SSC-9.5 Specification N_{design} of 80 or 100	Production Tolerance	Contractor SSC-9.5 JMF	SSC-9.5 WMA 80 Gyration Average Production Data (19 Sublots)
12.5 mm (1/2 inch)	100	± 6.0%	100	99.8
9.5 mm (3/8 inch)	90–100	± 6.0%	94	94.4
4.75 mm (No. 4)	90 max.	± 6.0%	65	64.4
2.36 mm (No. 8)	35–67	± 5.0%	42	43.7
1.18 mm (No. 16)	–	± 3.0%	30	29.1
600 µm (No. 30)	–	± 3.0%	20	19.2
300 µm (No. 50)	–	± 3.0%	13	12.1
150 µm (No. 100)	–	± 2.0%	8	7.0
75 µm (No. 200)	2–10	± 1.0%	4.6	3.9
Asphalt Content	–	–	6.0%	6.0%
Air Voids	4.0%	–	4.0%	3.73%
VMA	16.0% min.	–	16.8%	17.1%
VFA	73–76%	–	75.7%	78.2%[1]

[1] Value outside of specification.

Table 5.11.4: P11 MassDOT SSC-9.5 100 gyration production data, I-95 Canton-Norwood-Sharon-Walpole

Sieve Size	MassDOT SSC-9.5 Specification N_{design} of 80 or 100	Production Tolerance	Contractor SSC-9.5 JMF	SSC-9.5 WMA 100 Gyration Average Production Data (17 Sublots)
12.5 mm (1/2 inch)	100	± 6.0%	100	99.7
9.5 mm (3/8 inch)	90–100	± 6.0%	94	95.0
4.75 mm (No. 4)	90 max.	± 6.0%	65	64.7
2.36 mm (No. 8)	35–67	± 5.0%	42	43.5
1.18 mm (No. 16)	–	± 3.0%	30	29.1
600 µm (No. 30)	–	± 3.0%	20	19.3
300 µm (No. 50)	–	± 3.0%	13	12.1
150 µm (No. 100)	–	± 2.0%	8	6.9
75 µm (No. 200)	2–10	± 1.0%	4.6	3.9
Asphalt Content	–	–	5.9%	5.93%
Air Voids	4.0%	–	4.0%	3.67%
VMA	16.0% min.	–	16.8%	16.7%
VFA	73–76%	–	75.7%	78.0%[1]

[1] Value outside of specification.

5.11.7 Condition Data

The average condition indices (PSI, DI, maximum rut depth, and IRI) for this project with respect to in-service time (in years) are shown in Figures 5.11.3 through 5.11.6. With three years in service, the PSI for the project remained above the 2.5 threshold for interstate roads, therefore indicating no need for a rehabilitation at this time. The DI over time has remained above the 2.5 threshold, thereby indicating that cumulative cracking is not yet an issue. Average maximum rut depth was below the 0.5-inch threshold, indicating rutting has remained at acceptable levels. The ride quality, in terms of IRI, has remained nearly constant. Overall, based on the indices, the two SSC-9.5 mixtures with N_{design} of 80 and 100 overlaid with OGFC have performed acceptably. Since this project was placed fairly recently, it should continue to be monitored annually to determine the longevity of these mixtures.

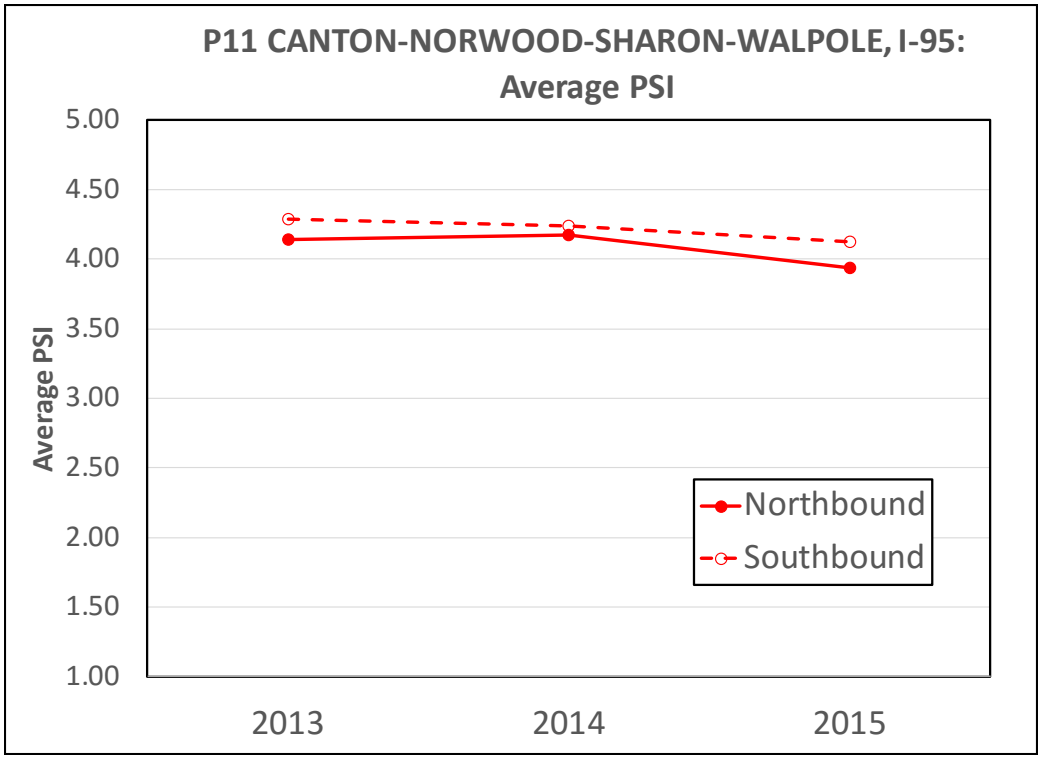

Figure 5.11.3: P11 condition data – average PSI, I-95 Canton-Norwood-Sharon-Walpole

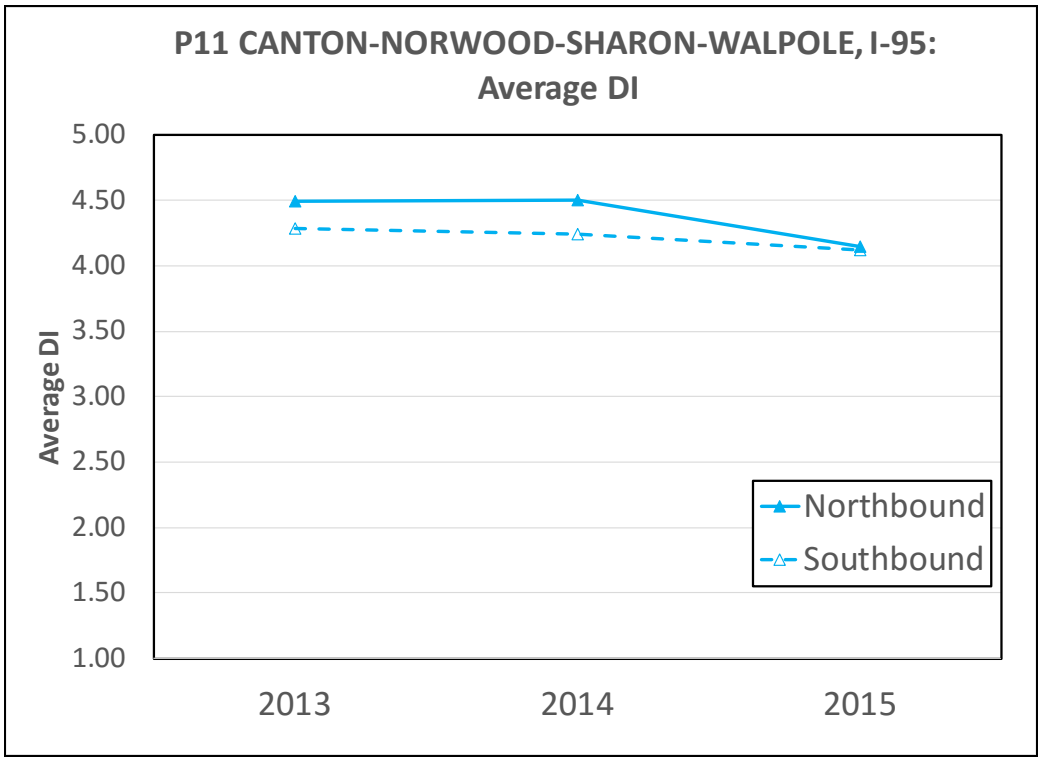

Figure 5.11.4: P11 condition data – average DI, I-95 Canton-Norwood-Sharon-Walpole

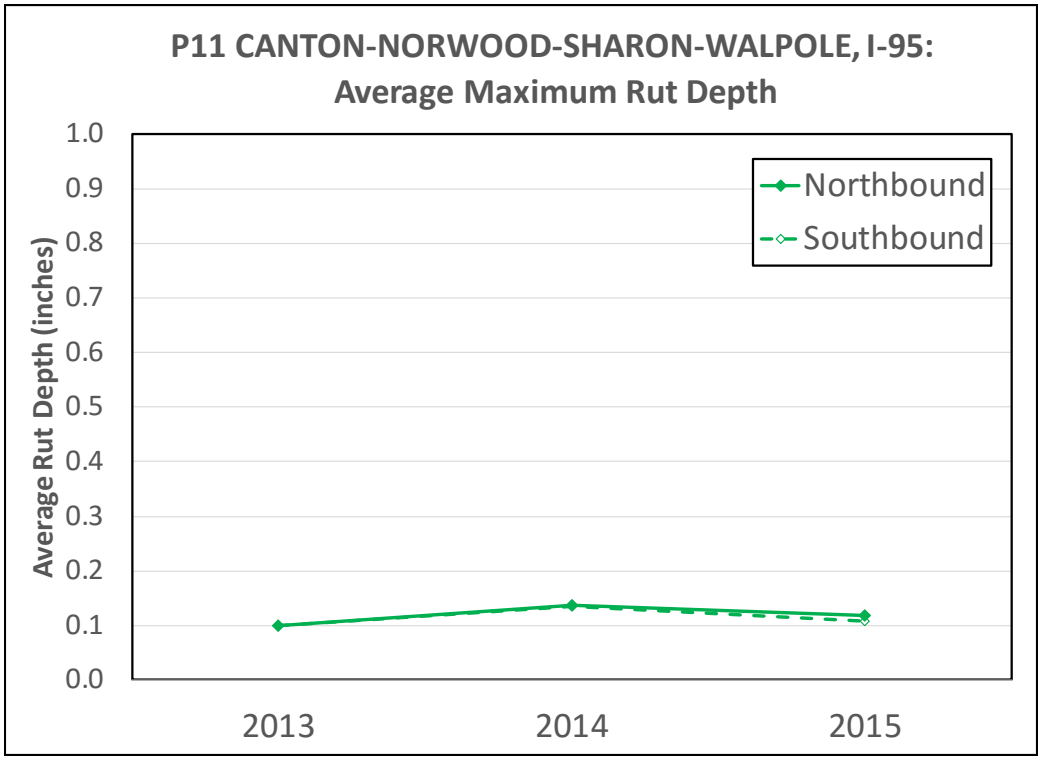

Figure 5.11.5: P11 condition data – average maximum rut depth, I-95 Canton-Norwood-Sharon-Walpole

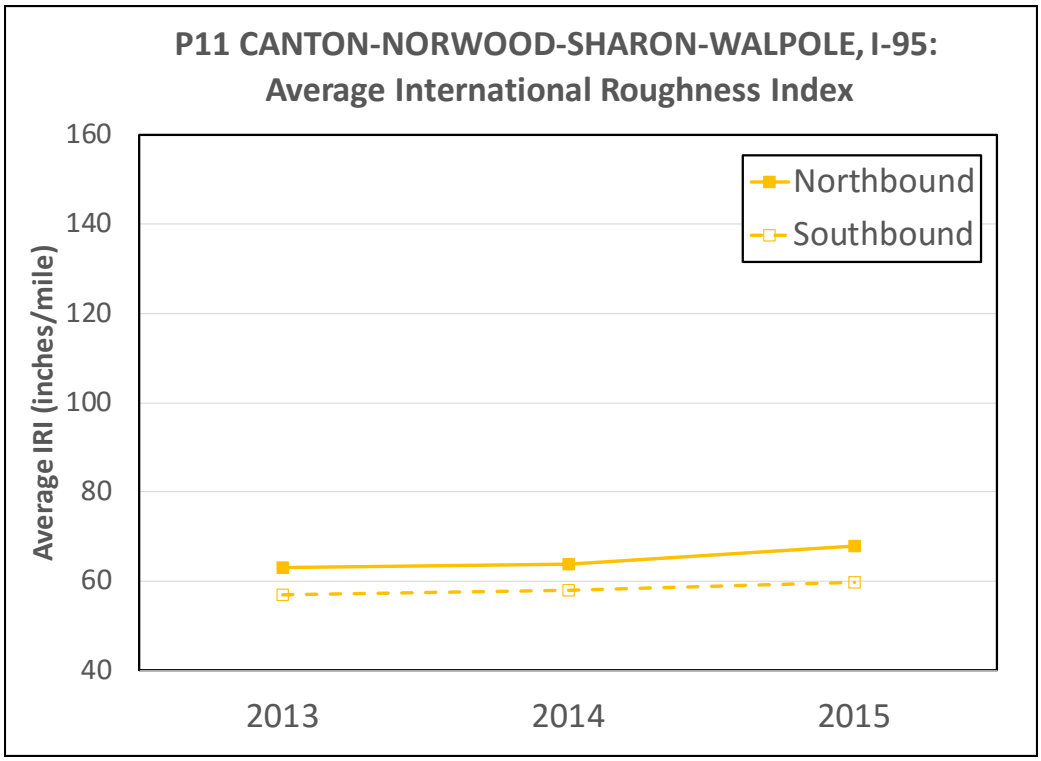

Figure 5.11.6: P11 condition data – average IRI, I-95 Canton-Norwood-Sharon-Walpole

5.12 Project #12: Route 28 Falmouth

This section outlines the information and data collected for Project #12 (P12) Route 28 Falmouth.

5.12.1 Project General Information

The general information collected for this project is shown in Table 5.12.1.

Table 5.12.1: P12 general information, Route 28 Falmouth

Project ID:	P12
MassDOT District:	District 5
MassDOT Contract Number:	70962
MassDOT Project Number:	605619
Reason for Monitoring:	Placement of 2" of Superpave Surface Course (SSC-12.5). Two SSC-12.5 mixtures were placed, one with N_{design} of 80 and one with N_{design} of 100. Gyration level study.
Contract Amount:	$4.4 million
Approximate Placement Date:	December 2012
Number of Years in Service:	4 years
Length of Section:	5.5 miles
Contractor:	Lawrence Lynch

5.12.2 Project Location

The locus map for this project is shown in Figure 5.12.1. The project description from the bid documents is as follows:

"Beginning at the Bourne and Falmouth town line at Sta. 426+54.86 Bourne = Sta. 3+96.42 Falmouth (M.M. 56.4), thence continuing southerly and ending at Sta. 314+50± (M.M. 50.8±) at the end of the divided highway, a length of 29,095 feet or 5.5 miles."

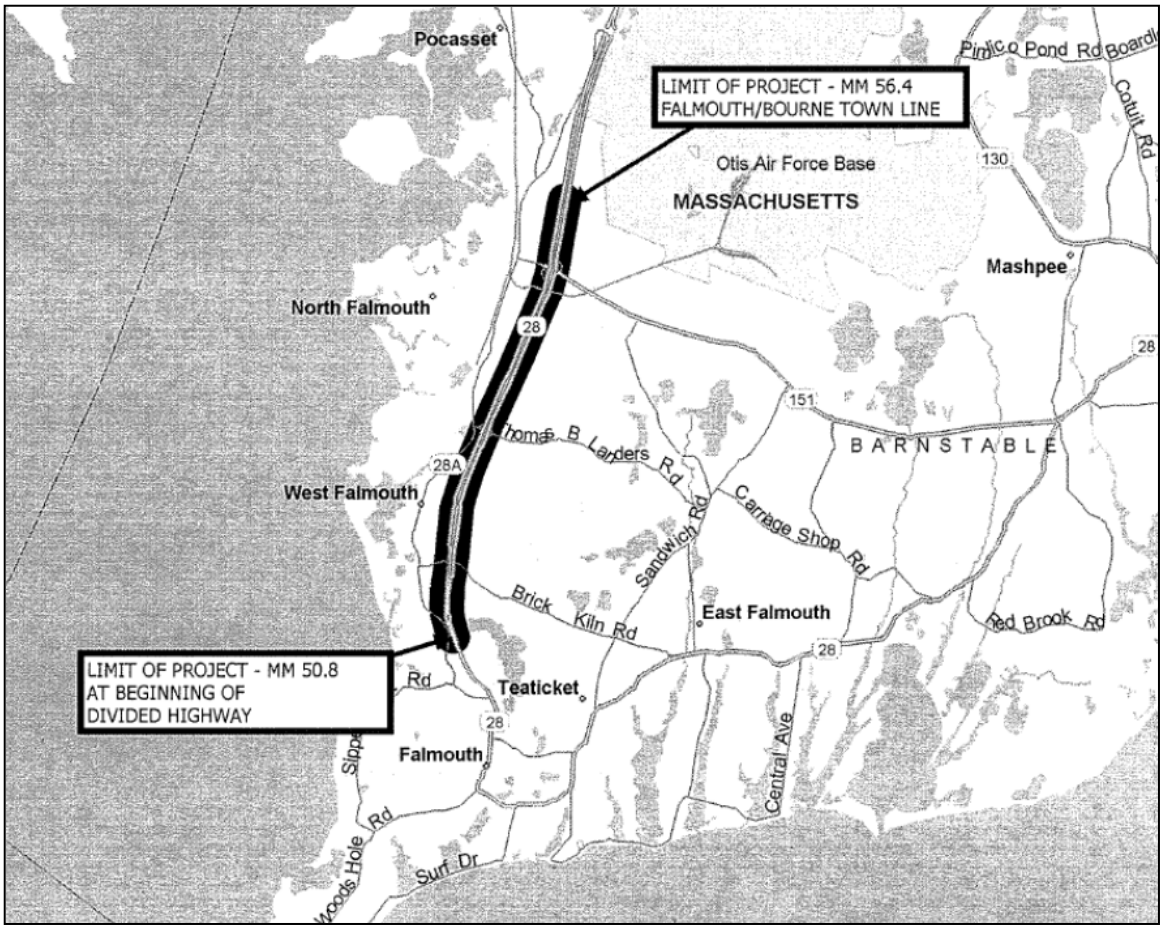

Figure 5.12.1: P12 site locus plan, Route 28 Falmouth

5.12.3 Typical Section Detail

The typical cross-section detail is shown in Figure 5.12.2. Work included micromilling 2 inches of existing road and overlay of the existing pavement structure of the Route 28 mainline with a depth of 2 inches Superpave surface course 12.5 (SSC-12.5).

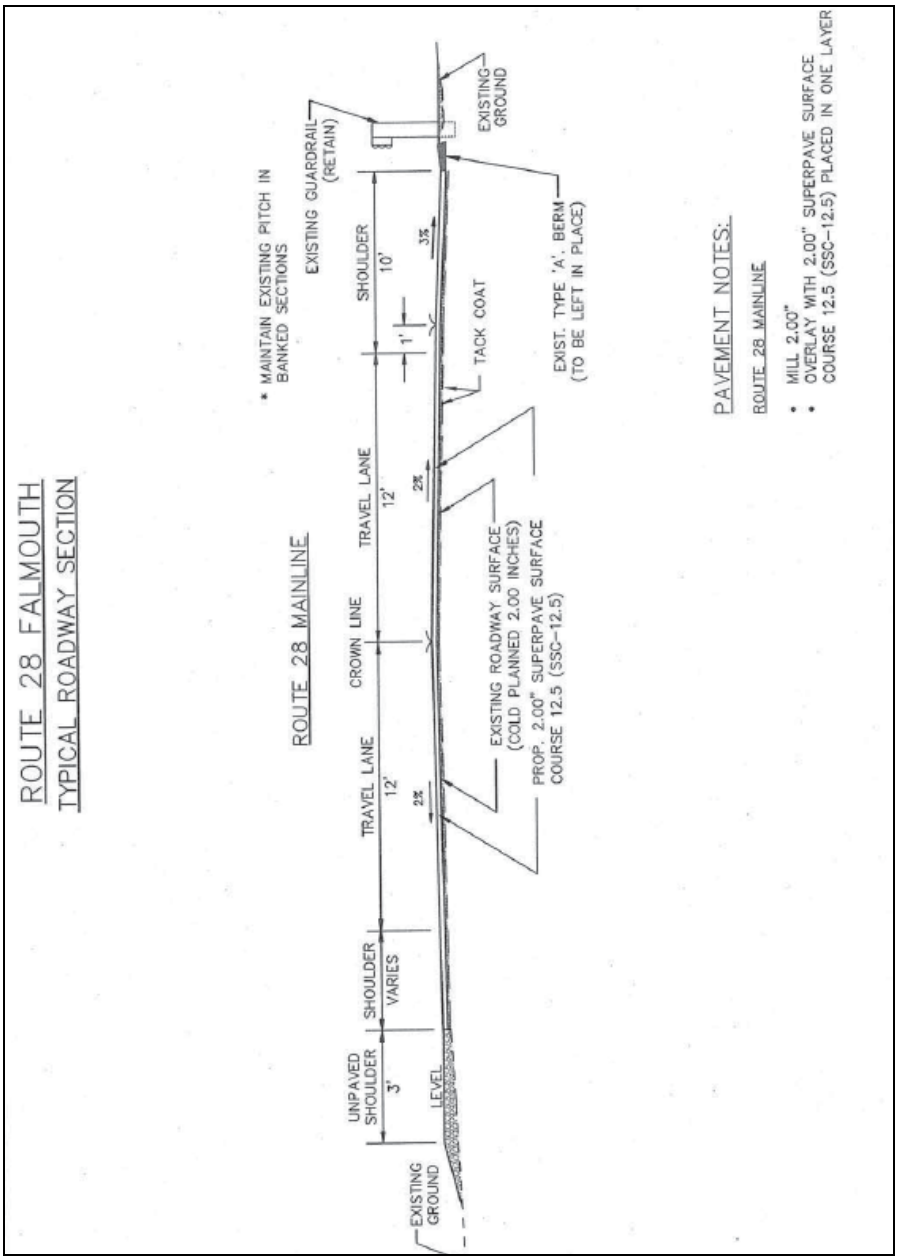

Figure 5.12.2: P12 typical section detail, Route 28 Falmouth

5.12.4 Existing Pavement Surface Preparation

The mainline of the Route 28 was micromilled to a depth of 2 inches. Tack coat (emulsified asphalt grade RS-1) was applied to the milled surface at an application rate of 0.07 gallons per square yard.

5.12.5 Mixture Specification Requirements

Two SSC-12.5 mixtures were developed for this project, each with varying design compactive effort levels (N_{design}). One mixture was developed with N_{design} = 80 and another

with N_{design} = 100. The two SSC-12.5 mixtures were produced using a PG64-28 asphalt binder. Each mixture was required to meet the MassDOT specification shown in Table 5.12.2. The approved Contractor JMFs with corresponding volumetric properties are shown for each mixture in Table 5.12.2. Note that a WMA additive (Evotherm) was utilized in the production of both mixtures, but the exact dosage is not known.

Table 5.12.2: P12 MassDOT SSC-12.5 specification requirements and Contractor JMF, Route 28 Falmouth

Sieve Size	MassDOT SSC-12.5 Specification N_{design} of 80 or 100	Production Tolerance	Contractor SSC-12.5 JMF 80 Gyration	Contractor SSC-12.5 JMF 100 Gyration
19.0 mm (3/4 inch)	100	± 6.0%	100	100
12.5 mm (1/2 inch)	90–100	± 6.0%	98	98
9.5 mm (3/8 inch)	90 max.	± 6.0%	79	79
4.75 mm (No. 4)	–	± 6.0%	57	57
2.36 mm (No. 8)	35–67	± 5.0%	42	42
1.18 mm (No. 16)	–	± 3.0%	31	31
600 μm (No. 30)	–	± 3.0%	21	21
300 μm (No. 50)	–	± 3.0%	10	10
150 μm (No. 100)	–	± 2.0%	6	6
75 μm (No. 200)	2–10	± 1.0%	3.0	3.0
Asphalt Content	–	± 0.3%	5.4%	5.2%
Air Voids	4.0%	–	4.0%	4.0%
VMA	15.0% min.	–	14.8%	14.1%
VFA	65–75%	–	77.0%	74.5%

5.12.6 Mixture Production Data

The data from testing of the production mixture was combined, both Contractor QC results and MassDOT Acceptance results. The averages of these production testing results for the sublots tested are shown in Table 5.12.3 for the 80 gyration mixture and Table 5.12.4 for the 100 gyration mixture.

Table 5.12.3: P12 MassDOT SSC-12.5 80 gyration production data, Route 28 Falmouth

Sieve Size	MassDOT SSC-12.5 Specification N_{design} of 80 or 100	Production Tolerance	Contractor SSC-12.5 JMF 80 Gyration	SSC-12.5 WMA 80 Gyration Average Production Data (22 Sublots)
19.0 mm (3/4 inch)	100	± 6.0%	100	100
12.5 mm (1/2 inch)	90–100	± 6.0%	98	97.2
9.5 mm (3/8 inch)	90 max.	± 6.0%	79	81.3
4.75 mm (No. 4)	–	± 6.0%	57	56.4
2.36 mm (No. 8)	35–67	± 5.0%	42	41.3
1.18 mm (No. 16)	–	± 3.0%	31	30.4
600 µm (No. 30)	–	± 3.0%	21	20.5
300 µm (No. 50)	–	± 3.0%	10	10.3
150 µm (No. 100)	–	± 2.0%	6	5.4
75 µm (No. 200)	2–10	± 1.0%	3.0	3.0
Asphalt Content	–	± 0.3%	5.4%	5.2%
Air Voids	4.0%	–	4.0%	3.3%
VMA	15.0% min.	–	14.8%[1]	14.6%[1]
VFA	65–75%	–	77.0%[1]	77.3%[1]

[1] Value outside of specification.

Table 5.12.4: P12 MassDOT SSC-12.5 100 gyration production data, Route 28 Falmouth

Sieve Size	MassDOT SSC-12.5 Specification N_{design} of 80 or 100	Production Tolerance	Contractor SSC-12.5 JMF 100 Gyration	SSC-12.5 WMA 100 Gyration Average Production Data (22 Sublots)
19.0 mm (3/4 inch)	100	± 6.0%	100	100
12.5 mm (1/2 inch)	90–100	± 6.0%	98	97.9
9.5 mm (3/8 inch)	90 max.	± 6.0%	79	82.0
4.75 mm (No. 4)	–	± 6.0%	57	58.6
2.36 mm (No. 8)	35–67	± 5.0%	42	41.3
1.18 mm (No. 16)	–	± 3.0%	31	28.6
600 µm (No. 30)	–	± 3.0%	21	19.6
300 µm (No. 50)	–	± 3.0%	10	11.4
150 µm (No. 100)	–	± 2.0%	6	6.2
75 µm (No. 200)	2–10	± 1.0%	3.0	3.2
Asphalt Content	–	± 0.3%	5.2%	5.1%
Air Voids	4.0%	–	4.0%	3.9%
VMA	15.0% min.	–	14.1%[1]	13.7%[1]
VFA	65–75%	–	74.5%	71.4%

[1] Value outside of specification.

5.12.7 Condition Data

The average condition indices (PSI, DI, maximum rut depth, and IRI) for this project with respect to in-service time (in years) are shown in Figures 5.12.3 through 5.12.6. Please note that no condition data was collected in 2015. Only northbound condition data was collected in 2013 and only southbound condition data was collected in 2014. With four years in service, the PSI for the project remained above the 2.3 threshold for non-interstate roads, therefore indicating no need for a rehabilitation at this time. The DI over time has remained above the 2.5 threshold, thereby indicating that cumulative cracking is not yet an issue. Average maximum rut depth was below the 0.5-inch threshold, indicating rutting has remained at acceptable levels. The ride quality, in terms of IRI, was larger for the northbound side. Overall, based on the indices, the two SSC-12.5 mixtures with N_{design} of 80 and 100 have performed acceptably. Since this project was placed recently, it should continue to be monitored annually to determine the longevity of these mixtures.

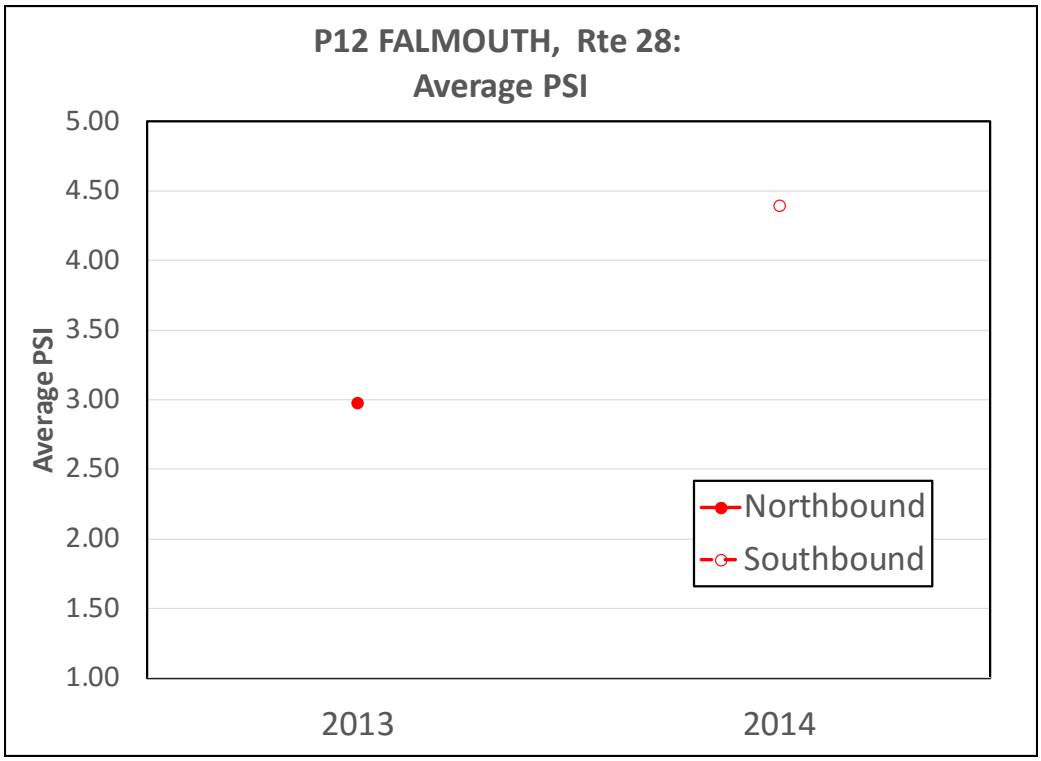

Figure 5.12.3: P12 condition data – average PSI, Route 28 Falmouth

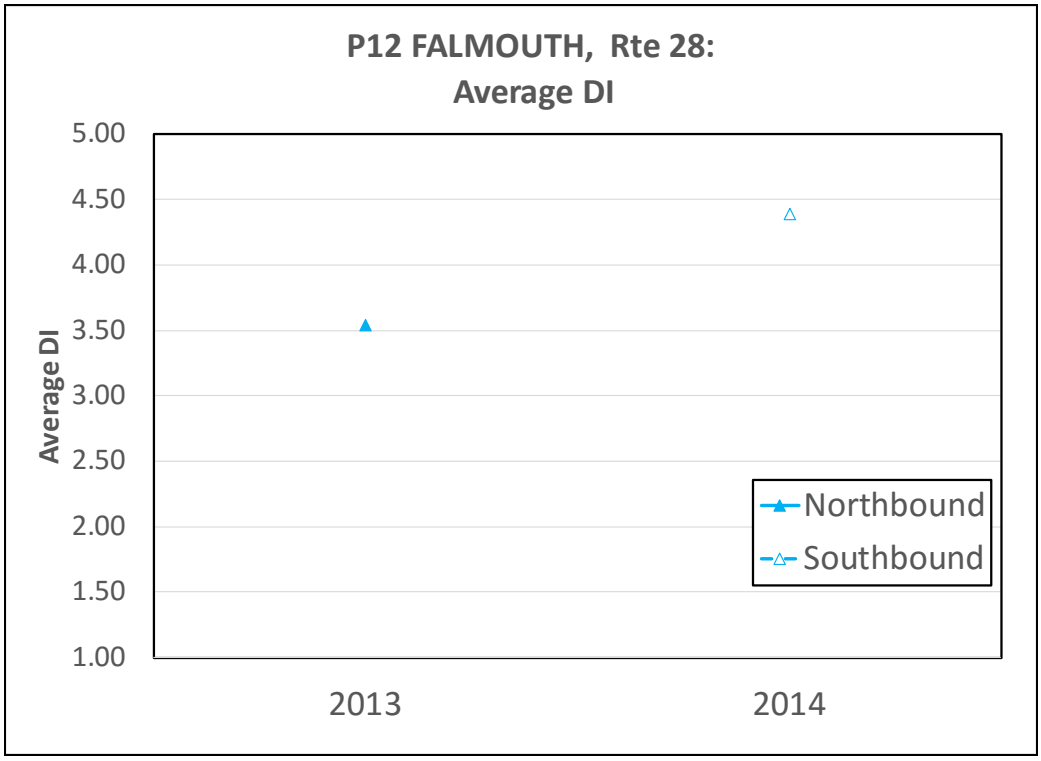

Figure 5.12.4: P12 condition data – average DI, Route 28 Falmouth

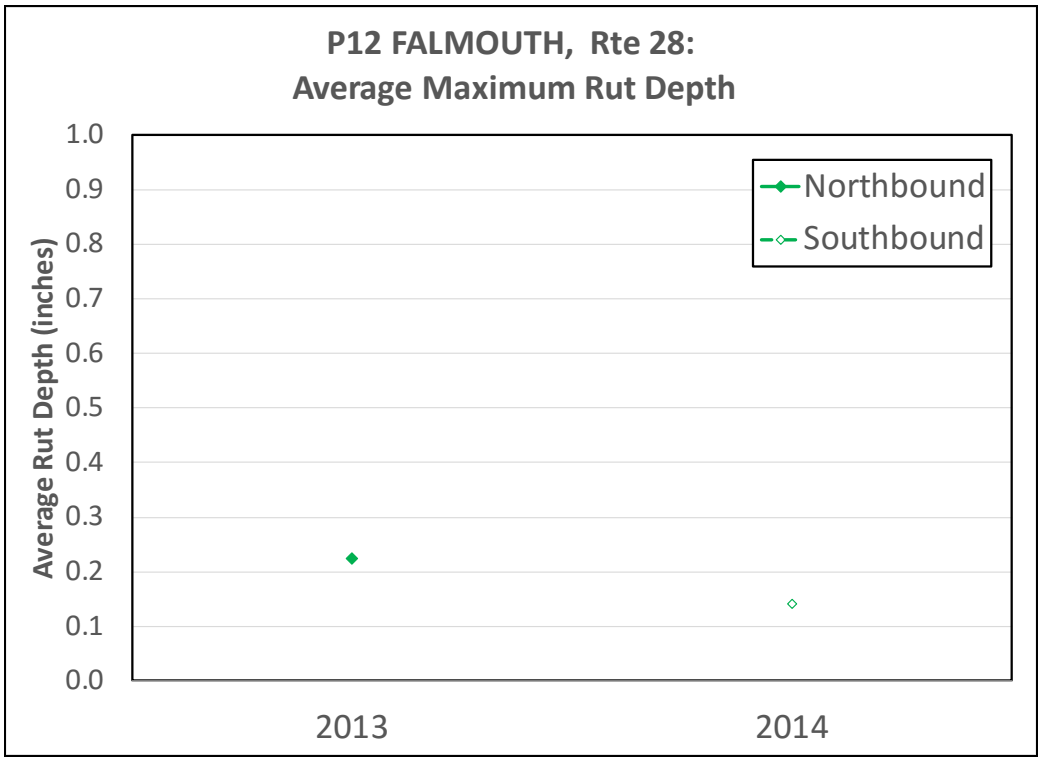

Figure 5.12.5: P12 condition data – average maximum rut depth, Route 28 Falmouth

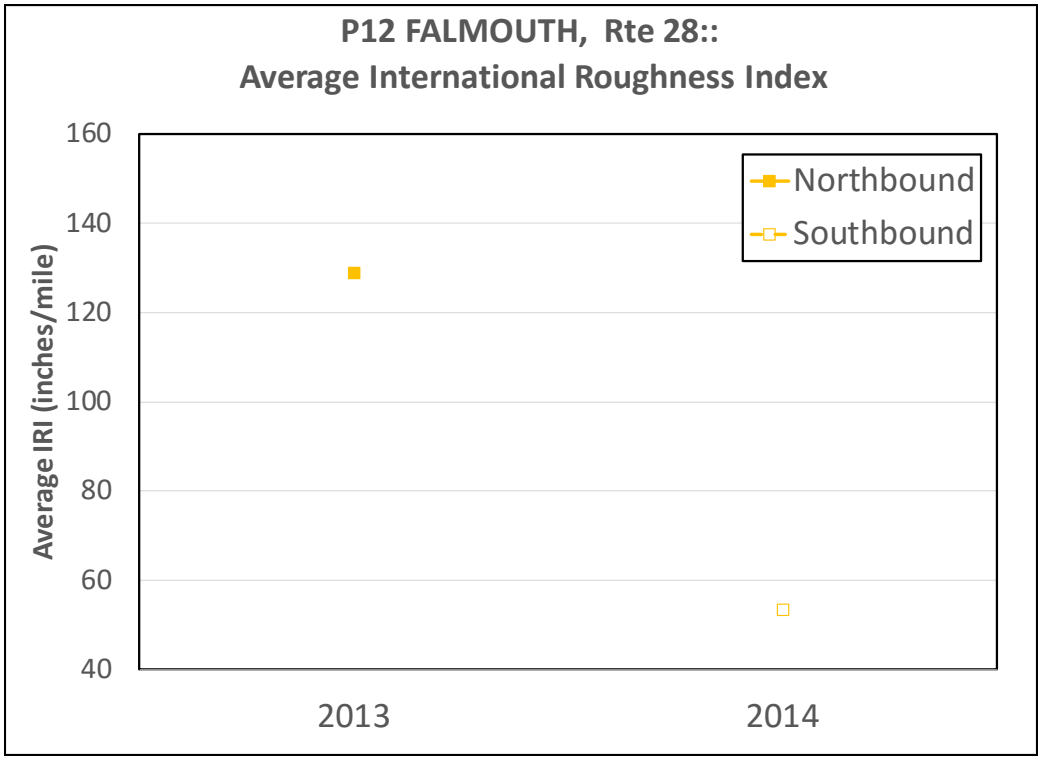

Figure 5.12.6: P12 condition data – average IRI, Route 28 Falmouth

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6.0 Conclusions and Recommendations

Based on the work conducted in this study, the following conclusions were made.

- The selected projects were considered specialized projects because new technologies were tried and/or new specifications were used. These technologies and specifications were tried for a variety of reasons, ranging from trying to mitigate reflective cracks in HMA layers placed over PCC slabs to the construction of environmentally friendly (green roads) by the incorporation of WMA and ground tire rubber. Generally, based on the monitoring plan consisting of analysis of condition data over in-service life, the projects have provided acceptable performance in terms of cracking, rutting, and ride quality based on the condition thresholds discussed previously. It is suggested if these projects continue to provide acceptable performance that a final specification be developed so the same strategies can be used in the future.
- The condition data provided by the MassDOT Pavement Management Section provided critical data required to be able to evaluate the performance monitored projects over an extended period of time.
- For future projects where new technologies might be used, it is recommended that a monitoring plan should be developed and executed prior to the commencement of the project. Devising a monitoring plan, before commencement of a project, would allow for a complete collection of data with corresponding timelines of required activities and subsequent delegation of responsibilities. With a more complete set of data, a better estimate of the true benefit of each project could be made in terms of cost, increased performance, etc. to both MassDOT and roadway users. Additionally, this data would allow for comparison of different technologies that serve the same purpose directly, thus enabling MassDOT to make more informed decisions when developing project specifications.

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7.0 References

1. National Highway Institute. Highway Pavements. NHI Course 13114.
2. Mogawer, W. S. and A. J. Austerman. Laboratory and Field Evaluation of Warm Mix Asphalt Technology to Determine Its Applicability for Massachusetts. Final Report. Massachusetts Highway Department, Dec. 2006.