Demonstration and Evaluation of SUPERPAVE Technologies

Construction Report for Route 2

Prepared by: Donald A. Larsen, P.E.
Nelio Rodrigues

December 1997

Research Project: SPR-2219

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Bureau of Engineering and Highway Operations
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James M. Sime, P.E.
Assistant Manager for Research

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16. Abstract

A federal aid resurfacing project on CT State Route 2 in Colchester, Lebanon and Bozrah was modified to include Superpave mix designs. Six 3.2 km sections, four Superpave and two ConnDOT Class 1 62.5-mm overlays, were placed between May and September 1997. Two of the Superpave mixes and one Class 1 mix utilized 20% RAP obtained by milling the existing surface layer from Route 2. This is Connecticut's first large-scale Superpave project, as well as the first HMA project in the state where Quality Control was the Contractor's responsibility. This document reports on the construction phase of ConnDOT's research study.

FHWA's Mobile Asphalt Laboratory was on-site to perform mix design verification and simulated quality assurance as part of FHWA Demonstration #90. This project is also part of FHWA's LTPP SPS 9A study for "Verification of SHRP Asphalt Specification and Mix Design." 305-m sections within each of the six pavements will continue to be monitored, sampled and tested for at least the next four years.

17. Key Words	**18. Distribution Statement**
Superpave, LTPP-SPS9A, Gyratory Compactor, Recycled Asphalt Pavement (RAP), QC/QA, Hot-mix Asphalt, Pavement Performance	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

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The materials on SUPERPAVE mix design presented in Appendix C were provided by Mr. James Mahoney and Prof. Jack Stephens of the Connecticut Advanced Pavement Laboratory. The FHWA test results from Demonstration Project #90 as given in Appendix D were provided by Mr. Carl Gordon.

Special thanks are offered to Dr. Charles E. Dougan, whose vision based on his many years of experience leading ConnDOT's Office of Research, lead to the establishment of this SUPERPAVE research study. And finally, the assistance of all who provided constructive input and review comments for this report is gratefully appreciated. This study could not have been performed without the help and dedication of all of the above individuals.

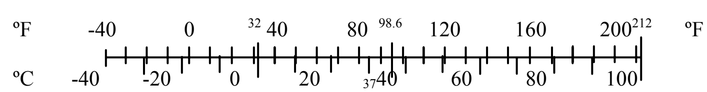
METRIC CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
mi^2	square miles	2.59	square kilometers	km^2
ac	Acres	0.405	hectares	ha
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb.)	0.907	Megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		TEMPERATURE (exact)		
ºF	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	ºC

APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
km^2	square kilometers	0.386	square miles	mi^2
ha	hectares (10,000 m^2)	2.47	acres	ac
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	Megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		TEMPERATURE (exact)		
ºC	Celsius temperature	9/5 (then add 32)	Farenheit temperature	ºF



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INTRODUCTION

Background

A new method of mix design for Hot-Mix Asphalt (HMA) paving materials was the focus of a major effort under the Strategic Highway Research Program (SHRP) beginning in the 1980's. New testing equipment to provide better estimates of field performance of HMA was also developed as part of the SHRP research. These activities, as well as the development of performance graded binder specifications and tests, are collectively designated as SUPERPAVE, an acronym for SUperior PERforming asphalt PAVEments.

The SUPERPAVE test equipment was provided to each state transportation agency by FHWA. The AASHTO Subcommittee on Materials prepared specifications for use by the AASHTO member states. These have and will continue to evolve with field experience.

The Connecticut Department of Transportation (ConnDOT), as well as other state DOTs, have expressed concern about quality control (QC) of SUPERPAVE mixes and the design and use of recycled asphalt pavement (RAP) with the SUPERPAVE system. The National Cooperative Highway Research Program (NCHRP) has attempted to address the QC issues in study Project 9-7, "Field Procedures and Equipment to Implement SHRP Asphalt Specifications." A draft study report was published in July 1996 entitled, " Quality Control and Quality Assurance Plans." A recommended procedure to adjust the SUPERPAVE mix process for inclusion of RAP entitled, "Guidelines for the Design of SUPERPAVE Mixtures Containing RAP," was prepared by the Expert Task Group on Mix Design, and distributed in early 1997. Another NCHRP study, Project 9-12, "Incorporation of RAP in the SUPERPAVE System," also started in 1997 at the North Central SUPERPAVE Center, Purdue University.

The above documents and study results were not available in February 1996, when ConnDOT proposed its first large-scale field application of SUPERPAVE mixes on CT State Route 2. However, limited field trials had been conducted to delineate placement problems. The limited trials on Route 1 in Branford, Connecticut, and Route 77 in Guilford, Connecticut, demonstrated that HMA producers in Connecticut could formulate and place mixes using modified SUPERPAVE criteria and local resources. The next logical step was the placement of a full-scale project to evaluate the full SUPERPAVE methodology, and to address the use of QC/QA and RAP.

Study Objectives

The objectives of the research study as published in the study proposal /1/ dated February 1996 are:

1. to assess the QC/QA procedures set forth in NCHRP Project 9-7; and,

2. to evaluate the performance of SUPERPAVE mixes using both virgin and recycled aggregates.

Additional benefits to be expected from the study include:

1. local contractor experience with design, placement and lab testing of SUPERPAVE;

2. participation in FHWA's LTPP Special Pavement Study #9A, "Verification of SHRP Asphalt Specification and Mix Design;" and,

3. provision of a showcase project for the New England states in conjunction with FHWA Demonstration Project #90, "SUPERPAVE Asphalt Mix Design and Field Management."

PROJECT SITE

The project that was selected for the SUPERPAVE installation is on CT Route 2 in the towns of Colchester, Lebanon and Bozrah, Connecticut. Figure 1 shows the location of Route 2. Route 2 is a four-lane, median-divided highway, functionally classified as a principal arterial. It is also part of the National Highway System (NHS) established as a result of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). This site in eastern Connecticut was selected based upon FHWA criteria required for participation in the FHWA Long-Term Pavement Performance Special Pavement Study (LTTP SPS) 9A,

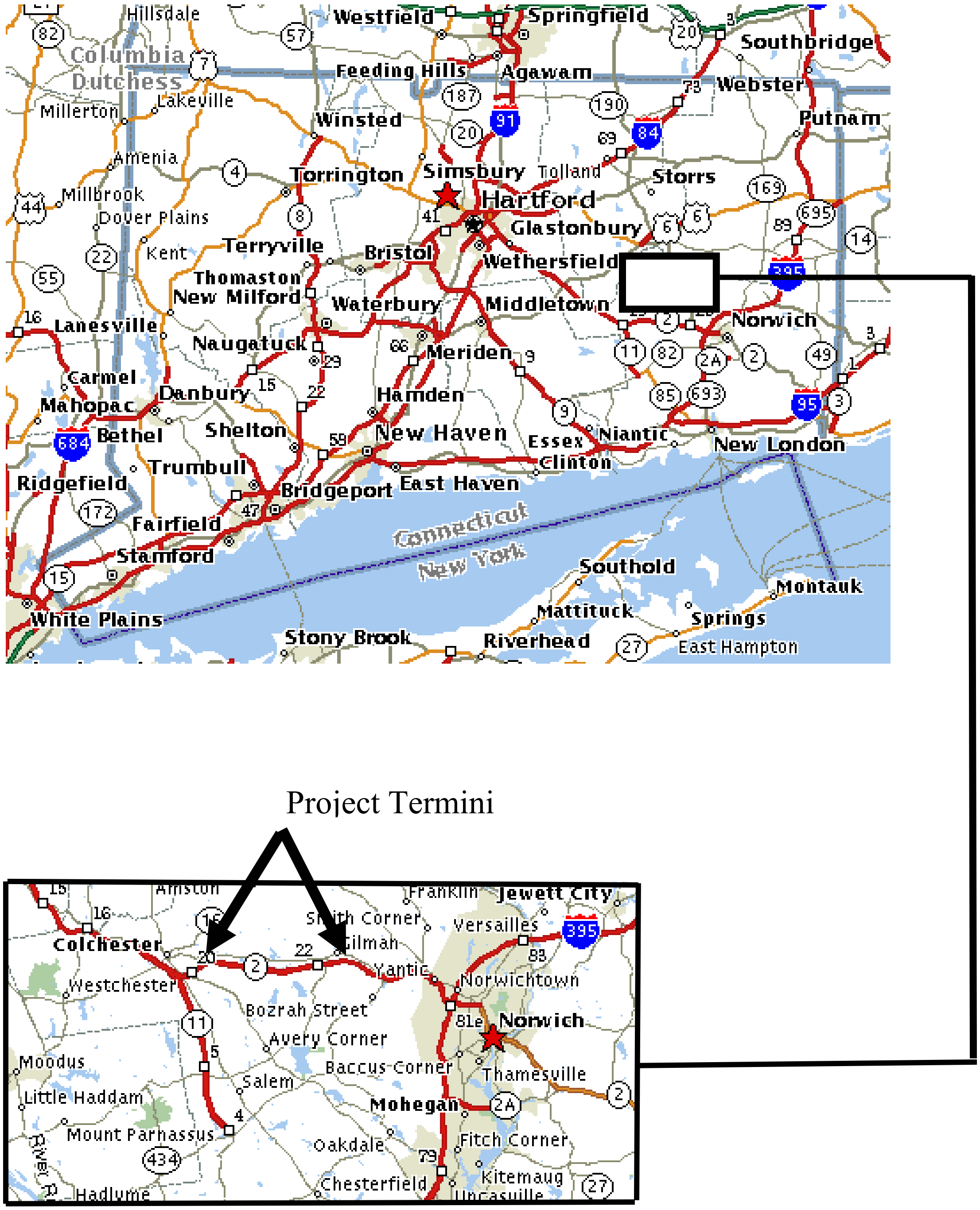


FIGURE 1. LOCATION MAP – PROJECT 28-185

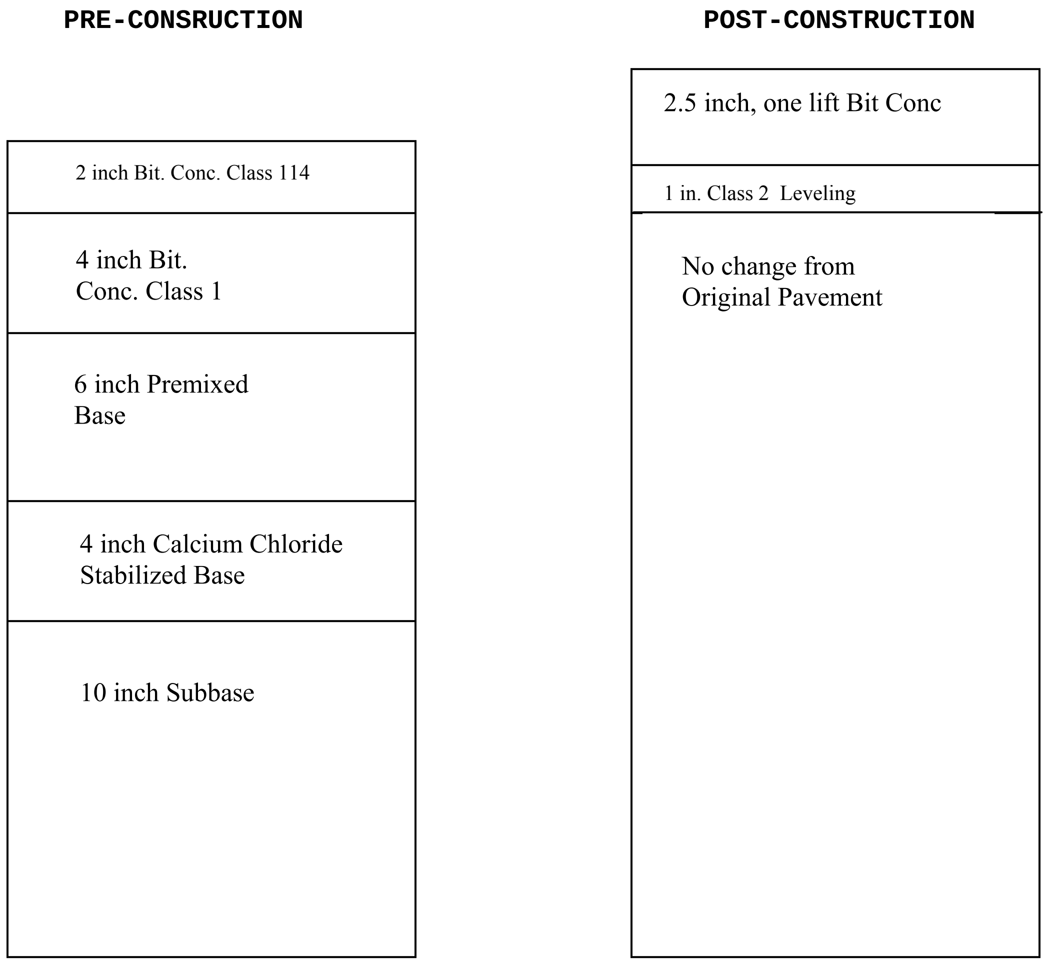
and it was a candidate for overlay in ConnDOT's pavement management system. The Route 2 project was completed under State Project #28-185, "Resurfacing and Safety Improvements to Route 2."

Route 2 was originally constructed in 1970 as a full-depth HMA pavement. It was composed of a 250-mm subbase, a 100-mm calcium chloride stabilized base, 150 mm of plant mix HMA base, and 100 mm of surface course containing ConnDOT Class 1 HMA. Class 1 is a mix with 100 percent passing the 19.0 mm sieve. In 1986, a HMA layer of Class 114 was placed on Route 2 to a depth of 50 mm. A cross section of the pavement structure is shown in Figure 2. (See Appendix A for more data on the various standard ConnDOT mixes.)

The section of Route 2 selected for the SUPERPAVE study begins in Colchester and runs easterly for a distance of 10 km through Lebanon and into Bozrah. Route 2 consisted of two 3.7-m wide travel lanes, a 3.7-m wide outside shoulder, and a 0.9-m wide inside shoulder. Truck climbing lanes existed throughout the westbound direction and for the final 4 km of the eastbound direction. However, all existing truck climbing lanes were eliminated during the SUPERPAVE construction project. Photo #1 shows Route 2 after completion of the project in September 1997. The traffic volume for this section of Route 2 varies between 15,000 and 18,000 vehicles per day, with approximately 10 percent trucks. The overlay design for Route 2 called for the removal of the 50 mm of Class 114, placement of a 25-mm layer of ConnDOT Class 2, and placement of a top course of 62.5 mm of various HMA designs (see Figure 2). The top course was to be placed in a single lift.

For purposes of the research evaluation, the 10-km project was divided into three sections in each direction (eastbound and westbound) of approximately 3.3 km each. Figure 3 shows the layout of the project using ConnDOT official highway log mileage (i.e., units of miles are shown). In theory, each of six sections was to be a different mix. These mixes as shown in Figure 3, were bid in the project as the following: 1.) Class 1 Virgin; 2.) SUPERPAVE Virgin; 3.) SUPERPAVE Alternate Virgin; 4.) Class 1 RAP; 5.) SUPERPAVE RAP; and, 6.) SUPERPAVE Alternate RAP. In reality, the SUPERPAVE Virgin and SUPERPAVE Alternate Virgin were the same mix design with only the asphalt grade substituted. The

MAINLINE



NOTE: ALL EXISTING DEPTHS ARE ESTIMATED

FIGURE 2 – TYPICAL CROSS SECTIONS FOR ROUTE 2, PRE- AND POST-CONSTRUCTION

same was true with the SUPERPAVE RAP and the SUPERPAVE Alternate RAP. The eastbound direction contained all virgin materials. The westbound direction contained all mixes with 25+/-5% RAP. (When designed, 20 percent RAP was used.) In addition to requiring the above section parameters, the asphalt grade was also specified for each section in the project special provisions. The specified asphalt grades are given in Table 1.

Photo #1. Route 2 in Bozrah, CT after Completion of Project (September 1997)

TABLE 1
STUDY SECTION PARAMETERS

SECTION DESIGNATION	TYPE OF PAVEMENT	CONNDOT LOG MILEAGE	SECTION LENGTH (KM)	FINAL ASPHALT GRADE DESIRED
EB 01	Class 1 Virgin	25.48-27.48	3.2	AC-20
EB 02	SUPERPAVE Virgin	27.48-29.70	3.6	PG 64-28
EB 03	SUPERPAVE Alternate Virgin	29.70-31.72	3.3	PG 64-22
WB 60	Class 1 RAP	31.72-29.64	3.3	AC-20
WB 61	SUPERPAVE RAP	29.64-27.56	3.3	PG 64-28
WB 62	SUPERPAVE Alternate RAP	27.56-25.48	3.3	PG 64-22

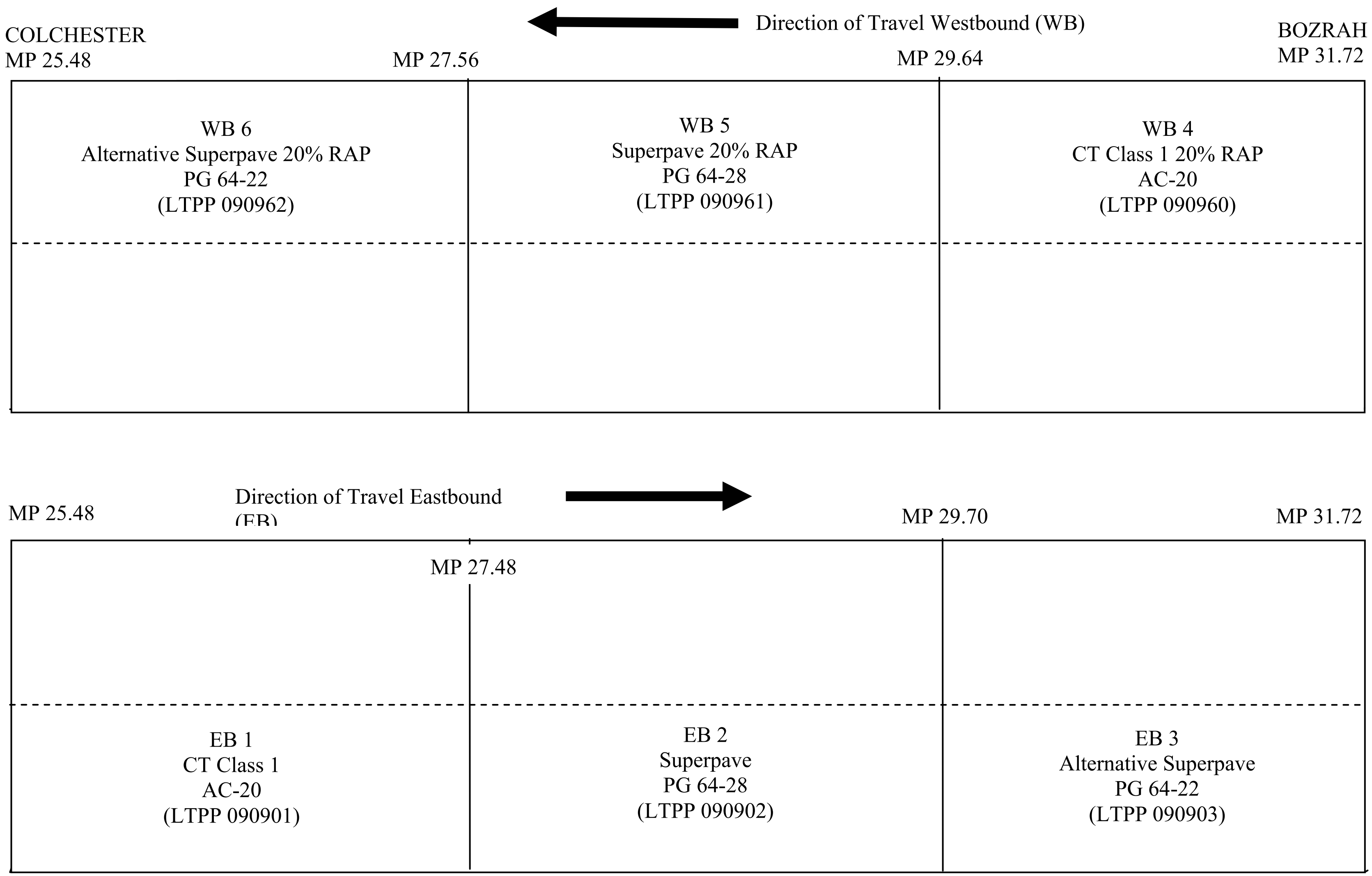


FIGURE 3
SPS 9A TEST SECTION LAYOUT
CONNECTICUT ROUTE 2, LOG MILE 25.48-31.72
TOWNS OF COLCHESTER, LEBANON, BOZRAH

PARTICIPATION IN FHWA LTPP SPS 9A STUDY

In addition to being a ConnDOT Research Study, the Route 2 project was nominated and selected for participation in the FHWA LTPP SPS 9A study, “Verification of SHRP Asphalt Specification and Mix Design.” The criteria used to select the site included projected traffic and 80kN equivalent single axle loads, horizontal and vertical curvature, grade, consistency within cuts and fills, lack of major drainage structures within test sections, and other LTPP specified requirements. The purpose of the SPS 9A study is to verify the performance of the SUPERPAVE System. Each participating project, of which there were supposed to be 35 for the design of the original study matrix, was to have a control section containing a standard agency mix design, a SUPERPAVE design using a PG asphalt with 98 percent reliability, and a SUPERPAVE section with PG asphalt offering 50 percent reliability. As of October 1997, there were 26 SPS 9A projects in seventeen states and four Canadian Provinces as shown in Figure 4.

Upon approval by FHWA-LTPP of the Route 2 test site in 1995, ConnDOT agreed to provide certain measurements and data, and to provide traffic protection at the site for other vendors under contract to FHWA. The first phase of field data collection occurred in the summer and fall of 1996. During the summer, ConnDOT research personnel met with FHWA and representatives from the North Atlantic Region Contractor, ITX-Stanley, to select 305-m monitoring segments within each of the six 3.3-km sections. These 305-m segments will be used to monitor the performance of the pavement for the life of the test study. The SPS study is proposed to last up to ten years. Table 2 shows the types of tests and data to be performed and collected.

All of the “pre-construction data” collection occurred during September 1996 and April 1997, as indicated in Table 2. These data were collected for the SPS 9A study for entry into the LTPP database. There was a considerable amount of sealed longitudinal and transverse cracks visible before construction. Occasional areas of raveling and patching, possibly as a result of isolated areas of segregation, were also noted (see photos #2 and #3). 305-mm diameter pavement cores removed in September 1996 revealed no indication of stripping within the 1970 or 1986 pavement layers.

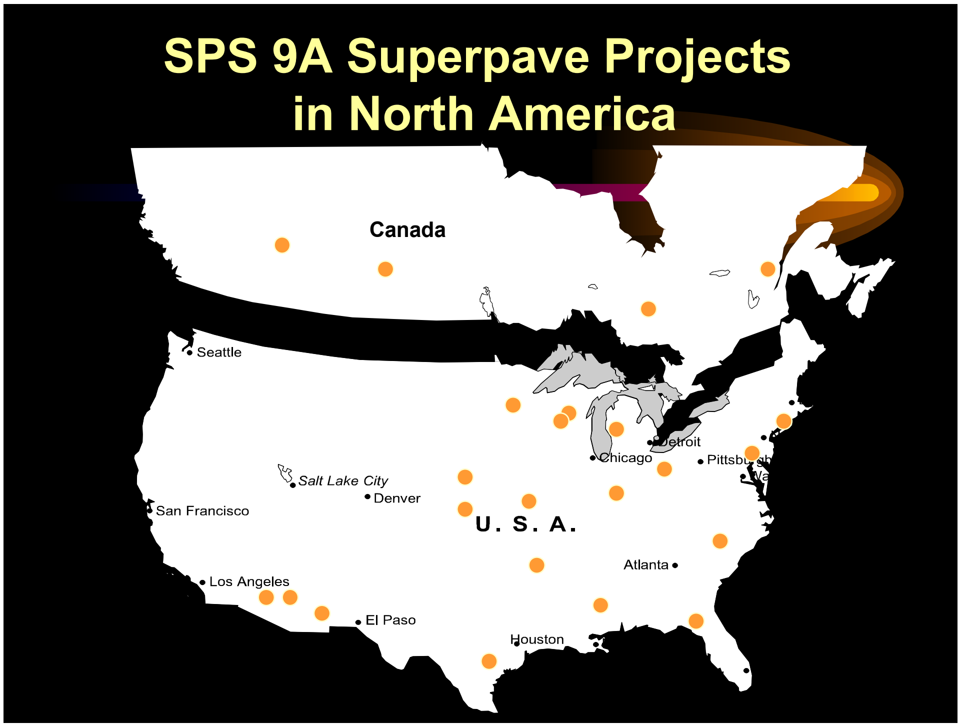


Figure 4. FHWA LTPP SPS 9A Sites in North America

The "During Construction" data are discussed in a later section of this report. The "post-construction" testing began at the completion of the paving, in late September 1997. ConnDOT performed friction testing of both lanes of all six sections with both ASTM E501 ribbed and ASTM E524 blank test tires. ConnDOT's Photolog Unit ran the Automatic Road Analyzer (ARAN) vehicle through the section in September to collect roughness, cross slope, grade, curvature, transverse profile, and GPS data. The "post-construction" roughness data in International Roughness Units (IRI) and the friction data are presented in Table 3.

ITX-Stanley performed deflection measurements, transverse and longitudinal profile, and manual distress surveys during October 27-30, 1997. 150-mm pavement cores were obtained by ConnDOT in September 1997. ConnDOT's Materials Testing Laboratory tested the cored materials for

TABLE 2
DATA COLLECTION REQUIRED FOR CONNDOT RESEARCH AND/OR FHWA LTPP SPS 9A

ACTIVITY	DATA OBTAINED	FREQUENCY	COMMENTS
100 mm Auger Probe	Distance to Subsurface Bedrock	Preconstruction; One time	ConnDOT; Sept 1996
305 mm Pavement Cores	Moisture Induced Damage & Layer Thickness	Preconstruction; One time	ConnDOT; Sept 1996
Bulk Soil Samples	Particle Size Distribution, Soil Classification, Moisture Content	Preconstruction; One Time	ConnDOT; Sept 1996
Friction Testing	ASTM Locked –wheel Friction Number	Preconstruction; One Time	ConnDOT; April 1997
ARAN Survey	Roughness, Rutting, Geometry, Images	Preconstruction; One Time	Roadware Corp.; April 1997
Profilometer	Longitudinal Profile and Roughness	Preconstruction; One Time	ITX-Stanley, April 1997
Falling Weight Deflectometer	Pavement Deflections	Preconstruction; One Time	ITX-Stanley, April 1997
Distress Surveys	Cracks, Patches, Ravelling, etc	Preconstruction; One Time	ITX-Stanley, April 1997
Manual Transverse Profile (Dipstick)	Rut Depths	Preconstruction; One Time	ITX-Stanley, April 1997
Nuclear Density	Pavement Density	During Construction; (3 per section)	ConnDOT
Bulk Asphalt Cement	Ship to LTPP MRL Sparks, Nevada	During Construction; (1 per section)	ConnDOT
Bulk Combined Aggregate	Ship to LTPP MRL Sparks, Nevada	During Construction; (1 per section)	ConnDOT
Bulk Surface Course Sample	Make Gyratory Molds in Lab & Run SHRP Protocol Tests	During Construction; (1 per section)	ConnDOT
Friction Testing	ASTM Locked –wheel Friction Number	Post Construction; (Annual)	ConnDOT; Every September
ARAN Survey	Roughness, Rutting, Geometry, Images	Post Construction; (Annual)	ConnDOT
150 mm Pavement Cores	Laboratory Tests	Post Construction; (0, 6, 12, 18, 24, 48 months)	ConnDOT
Profilometer	Longitudinal Profile and Roughness	Post Construction; (Annual)	ITX-Stanley
Falling Weight Deflectometer	Pavement Deflections	Post Construction; (Annual)	ITX-Stanley
Distress Surveys	Cracks, Patches, Raveling, etc	Post Construction; (Annual)	ITX-Stanley
Manual Transverse Profile (Dipstick)	Rut depths	Post Construction; (Annual)	ITX-Stanley
Traffic Data	Volume, Classification & Weights (ESALs)	Post Construction; (Continuous)	ConnDOT
Weather Data	Daily High and Low Air Temperature	Post Construction; (Daily)	ConnDOT

Photo #2. Route 2 Eastbound Prior to Construction (August 1996)

Photo #3. Route 2 Westbound at the Colchester/Lebanon Town Line, Just Prior to Milling (May 1997)

TABLE 3
POST_CONSTRUCTION FRICTION AND ROUGHNESS DATA FOR THE SIX 3.3-KM SECTIONS

SECTION DESIGNATION	SKID NUMBER AT 64 KM/HR (RIBBED TIRE)	SKID NUMBER AT 64 KM/HR (BALD TIRE)	ROUGHNESS M/KM (IN/MILE) LEFT WHEEL PATH	ROUGHNESS M/KM (IN/MILE) RIGHT WHEEL PATH
EB 01	54.9	38.2	1.29 (81.81)	1.17 (73.92)
EB 02	57.8	45.0	1.08 (68.48)	1.12 (70.78)
EB 03	57.2	40.4	1.24 (78.44)	1.11 (70.10)
WB 60	52.7	39.9	1.15 (73.17)	1.24 (78.88)
WB 61	52.9	47.3	1.15 (72.86)	1.18 (74.78)
WB 62	53.5	47.5	1.15 (72.58)	1.11 (70.54)

pavement thickness, bulk specific gravity, maximum specific gravity, asphalt content, aggregate gradation, air voids, VFA, VMA, and the recovered asphalt for penetration, viscosity, dynamic shear, and creep stiffness.

MIX DESIGNS

The construction contractor, SONECO/Northeastern Inc., was responsible for all quality control (QC), while ConnDOT was responsible for quality assurance (QA). The Special Provisions for the project indicate that the "contractor shall design and submit for approval, designs that meet all requirements of SUPERPAVE for hot mix asphalt containing a 12.5-mm nominal maximum aggregate size. The selection criteria of the SUPERPAVE mix design shall conform to traffic levels between 1 x 10^6 and 3 x 10^6 80-kN equivalent single axle load (ESAL) applications."/2/ The Special Provisions on SUPERPAVE for Route 2 are reproduced in Appendix B.

The Special Provisions require the submittal of a 0.45–power gradation chart for all SUPERPAVE virgin mixes. Table 4 shows the master range, aggregate and void requirements for the SUPERPAVE mixtures. Aggregate passing each standard sieve was required to pass within the specified control points and stay outside of the restricted zone as indicated by the Master Range of Table 4. The mix

TABLE 4
SUPERPAVE MASTER RANGE AND AGGREGATE REQUIREMENTS

SIEVE	CONTROL POINTS		RESTRICTED ZONE	
Mm	Min	Max	Min	max
19.00	-	100	-	-
12.50	90	100	-	-
9.50	-	-	-	-
4.75	-	-	-	-
2.36	28.0	58.0	39.1	39.1
1.18	-	-	25.6	31.6
0.600	-	-	19.1	23.1
0.300	-	-	15.5	15.5
0.150	-	-	-	-
0.075	2.0	10.0	-	-
VMA 14% Min.	VFA 65-78%	Dust to Asphalt Ratio (%) 0.6 to 1.2 (1)	Air Voids at N_{des} 4%+/-1.2	Tensile Strength Ratio 80% Min. (2)

(1) Dust is considered to be the percent of material passing the 0.075-mm sieve
(2) Tensile Strength ratio: AASHTO T-283

AGGREGATE REQUIREMENTS
M.04.04

TRAFFIC LEVEL	COARSE AGGREGATE ANGULARITY ***PENN.DOT. TEST METHOD NO. 621***		FINE AGGREGATE ANGULARITY ***AASHTO TP33(ASTM C1252***)	
(80 kN) ESALs	DEPTH FROM SURFACE <100 mm	DEPTH FROM SURFACE >100 mm	DEPTH FROM SURFACE <100 mm	DEPTH FROM SURFACE >100 mm
<3 x 10^6	75/--	50/--	40	40
	Note:"75/--" denotes that a minimum of 75% of the coarse aggregate has one fractured face.		Note: Criteria are presented as minimum percent air voids in loosely compacted fine aggregate passing the 2.36 mm sieve.	

FLAT, ELONGATED PARTICLES **ASTM D4791**	CLAY CONTENT **AASHTO T-176**	Gyratory % of compaction at (N) number of gyrations in a geographic location where the 7 day average temperature is < 39°C **AASHTO TP 4**		
>4.75 mm	SAND EQUIVALENT	(≤89%) Ni	Nd	(≤98%) Nm
10	40	7	86	134
Note: Criteria presented as maximum percent by weight of flat and elongated particles of materials retained on 4.75 mm sieve.	Note: Criteria is presented as a minimum for fine aggregate passing the 2.36 mm sieve.	N_i = Initial number of Gyrations; N_d = Design number of Gyrations; N_m = Maximum number of Gyrations.		

Compiled from SHRP-A-407: The SUPERPAVE Mix Design Manual for New Construction and Overlays designs were to be submitted 60 days prior to anticipated commencement of work. The design and submittal to ConnDOT was to include the following: /2/

A. The target value (in compliance with the master range in Table 4) for percent passing each standard sieve for the design aggregate structure;

B. Source of supply and percent of each stockpiled aggregate to be used in the design aggregate;

C. Average gradation of each aggregate stockpile;

D. The bulk specific gravity (G_{sb}), apparent specific gravity (G_{sa}), and absorption of the individual stockpiled aggregates, as determined in accordance with AASHTO T-84 and T-85;

E. Certified test report for each SUPERPAVE PG asphalt binder and its source of supply;

F. Temperature charts for the mixing and compaction of each asphalt binder;

G. A material safety data sheet (MSDS) for each binder;

H. Name, manufacturer, material data and MSDS for antistrip agent, if used;

I. Summary of the consensus property test results for the design aggregate blended;

J. Plot of the percent asphalt binder (P_b) by total mass of the mix at design number of gyrations (N_d) versus VMA, VFA, Percent of G_{mm}, Percent of air voids;

K. SUPERPAVE Gyratory Compactor densification curve plotting percent maximum theoretical density versus N_i, N_d, and N_m; and,

L. Tensile Strength ratio test results when tested in accordance with AASHTO T-283.

The University of Connecticut Advanced Pavement Laboratory (CAP Lab) was responsible for the pavement design. Their designs were based upon a maximum 7-day air temperature of less than 39 ^{o}C, a traffic level of less than 3 million 80-kN ESALs, and Gyratory Mix Compaction of N_i = 7, N_d = 86, and N_m = 134. The weather data used for the design was obtained from National Weather Service records for Colchester, Connecticut. The required PG asphalts of 64-28 and 64-22 provided 98% and 50% reliability for the low temperatures. For the high temperatures, the PG 64 asphalt approached 100 percent reliability, since PG 58 would have provided 98 percent reliability. For the virgin sections, the requested binders, namely AC-20, PG 64-28 and PG 64-22 were selected. However, for the RAP designs, the binders used were AC-10 for the Class 1 mix, PG 58-34 for the SUPERPAVE RAP section, and PG 58-28 for the

Alternate SUPERPAVE RAP section. These PG binders were selected to offset the aged effects of the existing binders attached to the RAP. All asphalt cement was supplied and certified by Hudson Companies of Providence, Rhode Island. Table 5 lists the asphalts used for the three RAP mixes.

TABLE 5
PG ASPHALTS USED IN RECYCLED MIXES

SECTION DESIGNATION	THE DESIRED FINAL GRADING OF THE ASPHALT IN THE MIX	ASPHALT USED IN RECYCLED MIXES	THE ACTUAL GRADING OF THE FINAL PRODUCT
WB 60	AC-20	AC-10	AC-20
WB 61	PG 64-28	PG 58-34	PG Not Graded
WB 62	PG 64-22	PG 58-28	PG 76-22

The PG58-34 could not be obtained as a neat asphalt. A modifier was used for this one asphalt only. The modifier used was Styrelf/Styrene and the asphalt was obtained by Hudson Companies from Petro-Canada in Toronto, Ontario.

For the virgin mix designs, the CAP Lab tried three different gradations: coarse, medium and fine. The medium gradation worked the best and resulted in a mix that was above the restricted zone. For the RAP mixes, thirteen trial gradations were performed. A mix with the gradation below the restricted zone was selected. The gradations for the virgin and RAP mixes plotted on a 0.45-power gradation chart are given in Figures 5 and 6.

The contractor provided the aggregates used in the mix design from their Montville plant and quarry. The aggregates were composed of ½-inch and 3/8-inch crushed stone, natural sand and washed manufactured sand. The specific gravity, gradation, and angularity were performed on both the fine and coarse aggregates. In addition, the coarse aggregate underwent tests for flat and elongated particles, abrasion resistance and soundness. The fine aggregates were tested for sand equivalence and fine aggregate angularity. The RAP materials were tested for asphalt content, specific gravity of aggregate, and gradation.

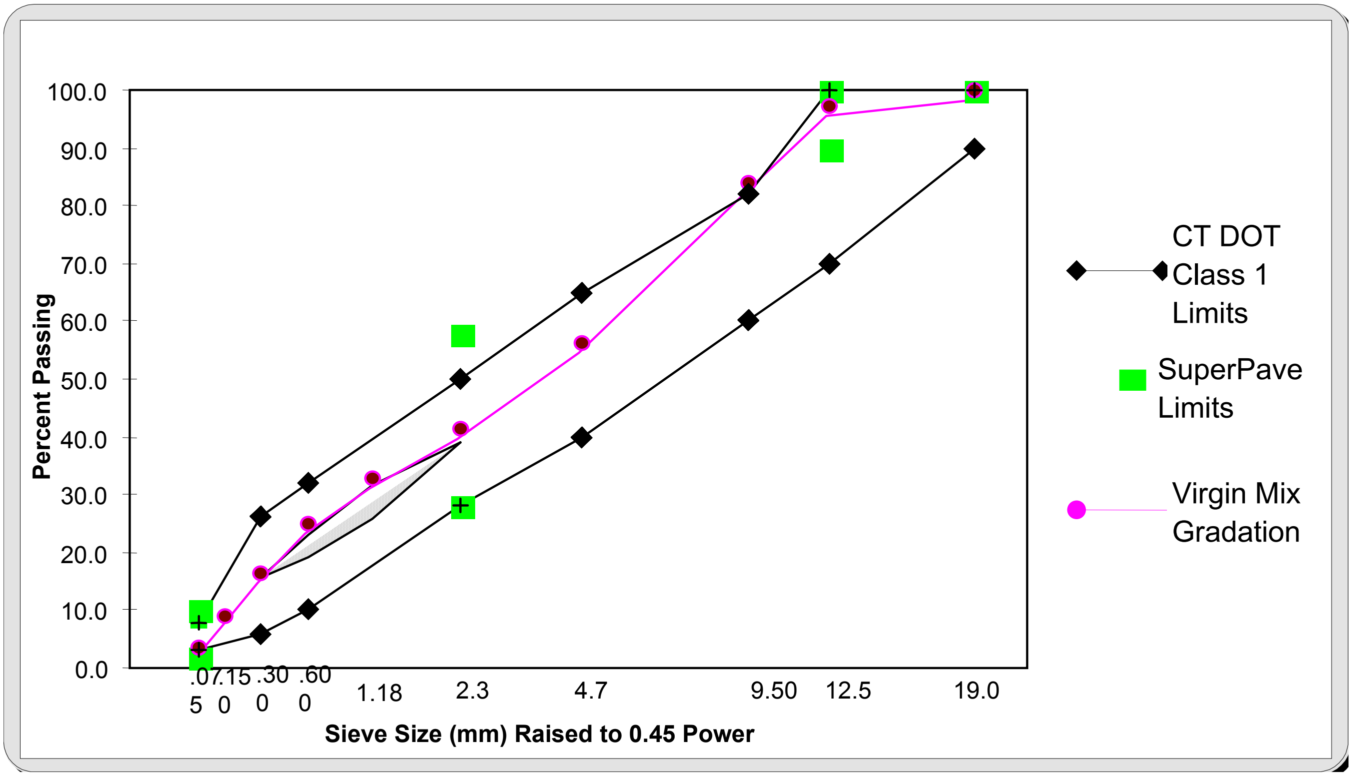


Figure 5. SUPERPAVE Virgin Mix Gradation

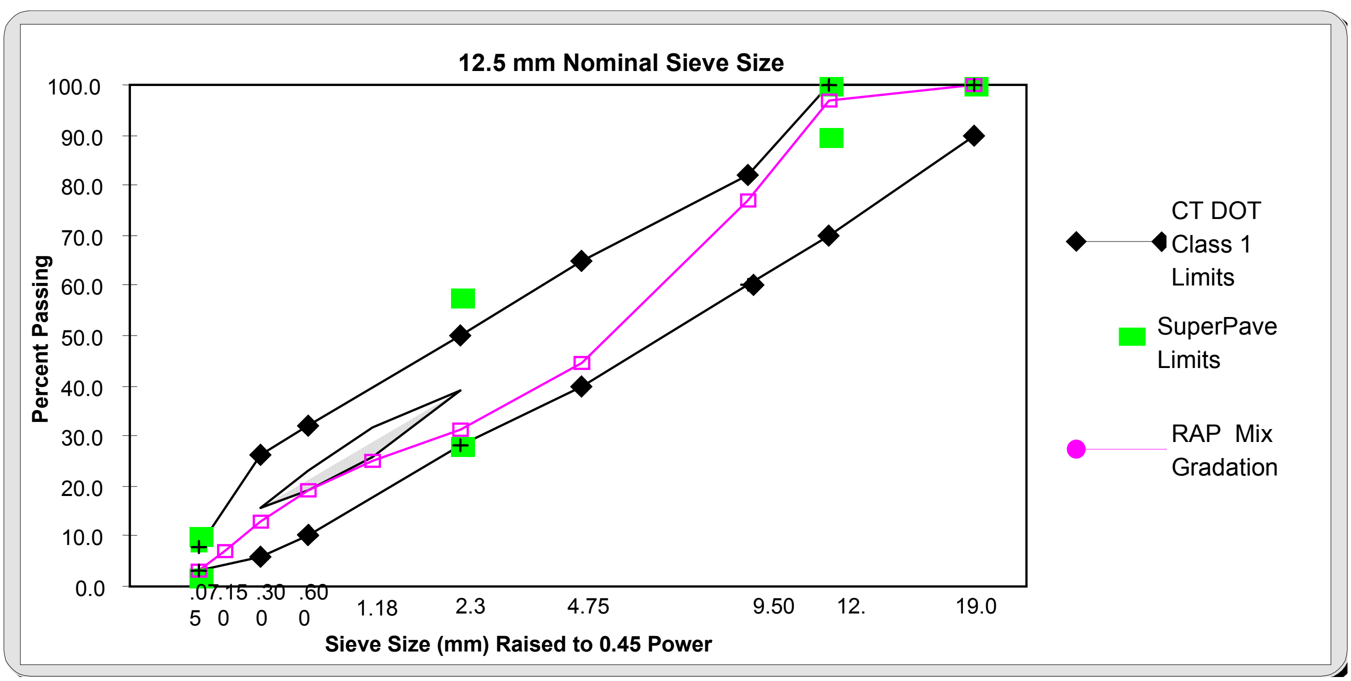


Figure 6. SUPERPAVE RAP Mix Gradation

The designs for the two virgin SUPERPAVE mixes and the two SUPERPAVE mixes with RAP are given in Appendix C. The design procedure was SHRP A-407, "The SUPERPAVE Mix Design Manual for New Construction and Overlays, Level 1, Volumetric Design." The Moisture Susceptibility Test, AASHTO T-283 was performed after the mixes were designed. The results of the test for tensile strength ratio did not produce the required 80 percent. As a result, an anti-strip agent was needed. The anti-strip agent used was Kling Beta LV. It was introduced by Hudson at their facility in Rhode Island. The asphalt grade had to be re-certified as a result of the addition of the anti-strip agent. It was found that the use of as little as 0.5 percent by weight of the binder of anti-strip agent changed the grading of the asphalt. Table 6 shows the amount of anti-strip agent ultimately used in each of the six sections.

TABLE 6
PERCENTAGE OF ANTI-STRIP AGENT USED IN EACH MIX

SECTION DESIGNATION	TYPE OF PAVEMENT	PERCENT OF ANTI-STRIP AGENT USED
EB 01	Class 1 Virgin *	0
EB 02	SUPERPAVE Virgin	0.25
EB 03	SUPERPAVE Alternate Virgin	0.25
WB 60	Class 1 RAP *	0
WB 61**	SUPERPAVE RAP	0.375
WB 62	SUPERPAVE Alternate RAP	0.375

*AASHTO T-283 not required by ConnDOT for HMA mixes.
** Most of Section 61 used the same mix as section 62; only 988 m, including the 305 m monitoring section, contained the PG 58-34 with modifier.

The mix designs were verified by ConnDOT before approval was given to begin paving. Also, ConnDOT evaluated the plant-produced materials in accordance with AASHTO PP-19.

Representatives from the FHWA were on-site at the contractor's HMA plant during the period of June 3 – June 30, 1997, and August 19 – September 5, 1997 with their Mobile Asphalt Laboratory. The mobile laboratory is part of Demonstration #90 entitled, "SUPERPAVE Asphalt Mix Design and Field Management." The purpose of Demonstration #90 is to demonstrate the concept of volumetric properties for field quality control. Also, in a field simulation study, laboratory personnel perform the latest testing procedures on field-produced mixes. In addition, the lab personnel provide technical assistance to personnel from State Highway Agencies desiring to evaluate equipment and techniques. /3/

While at the Montville plant, technicians from the FHWA laboratory obtained production samples of the approved mix design, ran volumetric property tests and compared these with the approved mix design. Two samples per day were obtained to compare with acceptance testing that was being performed by ConnDOT. They also carried out a complete verification of the mix designs for the SUPERPAVE Alternate Virgin, the SUPERPAVE RAP, and the SUPERPAVE Alternate RAP mixes. A selection of the test results from the FHWA Laboratory is included in Appendix D.

PRODUCER'S HOT MIX ASPHALT PLANT

The contractor awarded State Project # 28-185 was SONECO/Northeastern Inc. of Groton, Connecticut. Their HMA plant in Montville, Connecticut, was used for production of all the HMA mixes (Class 1 and SUPERPAVE, as well as the RAP mixes). The plant is a 3.6 metric-ton Cedar Rapids batch plant. Photo #4 shows the facility with two 182 metric-ton Standard Havens silos. The plant is computer operated. All production and placement for the virgin mixes was real-time. The silos were used part of the time for the RAP mixes. The batch plant was modified to allow for the RAP to be incorporated into the pugmill. The process used to incorporate RAP into the SUPERPAVE mixes was essentially the same as

Photo # 4. SONECO/Northeastern Inc., Montville CT.

would be done for any conventional mix. The RAP was loaded via payloader from the stockpile to aggregate bins at prevailing moisture. It was sieved through a 50-mm scalper screen and then transferred to the weigh hopper via an aggregate conveyor belt. In the batch plant, the virgin aggregate was heated to 215-230 ^{o}C; then, the RAP was added so that heat was transferred from the virgin aggregate.

CONSTRUCTION

Construction involved three phases: removal of the existing surface course of Class 114; placement of a leveling course of Class 2; and, placement of the surface layer for the six sections utilizing Class 1 and SUPERPAVE mixes. During milling of a bridge deck that was to be rehabilitated as part of Project 28-185, raised pavement markers were discovered under the existing Class-114 surface course. To ensure no damage would be incurred to the milling machine cutting heads, it was decided to remove the buried raised pavement markers before milling continued. ConnDOT located approximately 2000 markers with a metal detector, and the contractor removed them using jackhammers.

Milling

The milling was performed by a subcontractor using a CMI model PR 800-7 Rotomiller (see Photo #5). Approximately 900-1200 m per day were milled in six passes. Each pass was 2.2-m wide, with a 75-mm overlap of adjacent passes. (The total width of the paved roadway varied from 11.5-14 m throughout the 10-km project.) The design called for removal of 50 mm of pavement (all of the Class 114 mix.) The actual depth of milling varied from a minimum of 50 mm to a maximum of 84 mm. The milling started on April 29, 1997 in the westbound direction, and the entire project was milled by June 11, 1997. Milling operations were routine and uneventful; however, there were delays caused by inclement weather, conflicts with raised pavement marker removal, use of hauling vehicles for multiple operations, the fact that the state imposed a 1.6-km minimum separation distance requirement between multiple sign patterns (as well as maximum sign pattern length criteria), and re-mobilization of the milling machine.

The time required for actual milling was only about 20 days. However, after completing 66 percent of the westbound direction by May 16, 1997, the contractor, in conjunction with the state, elected to begin milling eastbound, so that the surface paving could be done in the eastbound direction first. This decision came about as the result of scheduling an open house for Demonstration Project #90, between June 16 and June 27, 1997 at Montville. A goal was established to have paving being performed in a SUPERPAVE section for the open house. By mid-May, it became apparent that the mix designs for the RAP mixes would not be approved in time for the westbound sections to be paved in late June. Therefore, milling shifted to the eastbound direction on May 28, 1997. Milling in the eastbound direction was completed on June 6, 1997. The final section of the westbound direction was milled between June 9 and June 11, 1997. A total of 276 000 square meters of pavement millings was removed from the mainline and eight ramps at two complete interchanges. Upon each milled pass, the pavement was swept with a Athey-Topgun M-9D sweeper prior to being opened to traffic.

The original contract required that the milled pavement be open to traffic no longer than 48 hours prior to paving the leveling course. This requirement became highly impractical considering the restrictions on multiple lane closures and the maximum allowable distance between lane closures. The contractor was relieved of the 48-hour requirement. However, most sections were open no longer than 1 week prior to being overlaid. The only notable exception was 3 weeks for a portion of Section 60 westbound.

A post-milling pavement condition survey was performed the same day as milling for each 305-m monitoring section. Any visible cracks or patches that were deeper than the removed surface layer were identified. This information will be useful in studying the cause of any cracks that may form in the new surface layers during the next five years. It is possible some fine cracks were not visible immediately after milling due to dust that remained on the surface. This was confirmed for Section 60, which was open to traffic for three weeks prior to placement of the leveling course. A second survey found additional cracks that were not observed immediately after milling.

Leveling Course

The original plan of the contractor was to place the leveling course layer of ConnDOT Class 2 mix at the same time as the milling operation. The purpose of this was to optimize the use of the haul vehicles.

The vehicles would haul millings to the plant and then haul HMA from the plant to the paving site, and thus, be fully utilized in both directions. This process was also put in place to ensure that the maximum 48-hour requirement for exposed milled pavement would be met. Due to a shortfall of onsite trucks, and the delay caused to the milling operation when trucks could be filled sooner than they could return from the plant, this procedure proved not practical. Truck cleanliness was also a concern of the project inspectors. The practice was abandoned after the first few days.

Photo # 5. CMI Rotomill Model PR 800-7 at Route 2 Westbound

The paving of the Class 2 to the design depth of 25 mm was initiated in Section 60 on May 14, 1997. The last section to be paved was Section 62 on June 12, 1997. The specific dates when the 305-m SPS monitoring sections were milled, and paved with the leveling course, are given in Table 7. All material was from SONECO/Northeastern, Inc., in Montville, with one exception; due to a plant breakdown, part of the day's production on June 5, 1997 was provided by AEN Asphalt Inc. in Franklin, Connecticut.

TABLE 7
DATES OF MILLING AND PAVING THE LEVELING COURSE

SPS9A SUBSECTION DESIGNATION	TYPE OF PAVEMENT	DATE MILLING OCCURRED	DATE LEVELING COURSE APPLIED
EB 090901	Class 1 Virgin *	05/29/97	06/03/97
EB 090902	SUPERPAVE Virgin	06/03/97	06/05/97
EB 090903	SUPERPAVE Alternate Virgin	06/04/97	06/06/97
WB 090960	Class 1 RAP *	05/01/97	05/21/97
WB 090961	SUPERPAVE RAP	05/16/97	05/22/97
WB 090962	SUPERPAVE Alternate RAP	06/09/97	06/10/97

A tack coat of SS1 emulsion at the rate of 0.09-0.18 Liters per square meter was applied prior to paving the leveling course. This was applied with a pressurized sprayer attached to a tanker truck. The asphalt for the tack coat was supplied by Chevron from Portland, Connecticut. A Blaw-Knox PF 180-H paver was used to place the pavement 32 mm thick before rolling. Because this was a leveling course, the actual final thickness varied between 25 and 50 mm. A Hyster C766A double-drum vibratory roller was used for breakdown rolling. The frequency was generally between 2000 and 2700 vibrations per minute at high amplitude. A Caterpiller CB 534 double-drum roller in the static mode was used on most of the project for finish rolling.

Three passes were made with the paver. The passing lane and left shoulder generally were paved first to a width of 4.25 m. The low speed lane was paved next, to a width of about 4 m. Finally a paving pass was made on the outside shoulder. The width of this pass varied from 3.4-4.6 m, depending on whether the section previously included a truck climbing lane. All existing truck climbing lanes on the project were converted to shoulders. However, the through lanes were replaced (i.e., striped) in the same location as the original lanes had existed since 1970. All longitudinal paving joints were placed within 0.5 m of the edges of the lanes. Approximately 1.6 km (in three passes) per day were paved for the Class 2 mix. This worked out to about four days of paving for every five days of milling. All of the Class 2 mix was virgin material. Typical hauling times from the plant to the paver ranged from 20-60 minutes.

Normal Marshall Mix Design procedures and ConnDOT testing were employed for the laydown. The density was checked by ConnDOT using a Campbell Pacific MC-3 nuclear density gauge. Typically, ConnDOT does not require density measurements for thin overlays. Therefore, no criteria exists for minimum density requirements. Most of the Class 2 met the minimum 92 percent of maximum theoretical density that would be required of a thicker mix.

Surface Layer

Although NCHRP 9-7 study recommendations on QC/QA were to be evaluated as part of this project, the document entitled, "Field Procedures and Equipment to Implement SHRP Asphalt Specifications – Quality Control and Quality Assurance Plans," was not published until July 1996. Because the ConnDOT bid specification was already released by then, many of the recommendations, including one for using a 1000-ft (305-m) test strip, could not be incorporated into the project. The contract for Project 28-185 required that a 300 ft x 12 ft (91m x 3.7 m) test strip be placed and approved prior to the continuation of production paving. For the SUPERPAVE sections, the test strips were acceptable only if all SUPERPAVE specifications for gradation, percent of binder content, percent air voids, VMA, VFA, and field density were met. These strips were also to be used for the contractor to establish a rolling pattern and achieve target densities.

The test strip for the Control Class 1 section in the eastbound direction was placed and approved on June 16, 1997. Prior to this section, a test section was placed for the SUPERPAVE alternate virgin (PG64-22) eastbound without success on both June 12, 1997 and June 13, 1997. On June 12th, the correct field density could not be achieved. On June 13th, the voids from the laboratory compacted molds did not meet the specifications. Both of these sections were removed by the contractor per the contract specification. It was also found on June 10, 1997 that an anti-strip agent would be required per the results of AASHTO T-283, "Resistance of Compacted Bituminous Mixtures to Moisture Induced Damage." This was a surprise, in that the same aggregates had been used before in ConnDOT HMA mixes without occurrences of stripping. As a result of the tests, ConnDOT required that an anti-strip agent be used for the SUPERPAVE mixes. Since AASHTO T-283 is not normally performed in ConnDOT, the use of an anti-strip agent in the Class 1 mix was not mandated.

When the anti-strip agent called Kling Beta was added to the PG64-22 asphalt at 0.5 percent by weight of the binder, it was found that the PG grading changed slightly. The change was enough so that the asphalt could not be certified as a PG 64-22. Thus, additional Moisture Susceptibility tests were performed with 0.25 percent and 0.33 percent anti-strip agent. These amounts did not affect the grading of the asphalt. The 0.25 percent was ultimately selected, as it produced a mix that met the T-283 test requirements.

Paving of the surface layers for the entire project, excluding the ramps, occurred between June 17, 1997 and September 9, 1997. Paving of the 305-m monitoring sections was performed on the dates indicated in Table 8. In a fashion similar to the paving of Class 2, paving was generally performed from left to right (i.e., left shoulder and high speed lane in the first pass, low-speed lane in the second pass, and right shoulder in the third pass.) This again resulted in paving widths of approximately 4.25 m, 4 m, and 3.4-4.6 m, for each pass, respectively. All paving was performed with a Blaw-Knox PF 180-H paver. A tack coat was placed prior to paving.

TABLE 8
DATE AND WEATHER CONDITIONS AT TIME OF PAVING
THE 305-M SPS MONITORING SECTIONS

SPS9A SUBSECTION DESIGNATION	TYPE OF SURFACE PAVEMENT	DATE PAVING OCCURRED	AIR TEMPERATURE AND WEATHER
EB 090901	Class 1 Virgin	06/23/97	26.7 C, Sunny
EB 090902	SUPERPAVE Virgin	07/15/97	32.2 C, Sunny
EB 090903	SUPERPAVE Alternate Virgin	06/28/97	26.7 C, Sunny
WB 090960	Class 1 RAP	08/07/97	22.8 C, Sunny
WB 090961	SUPERPAVE RAP	09/08/97	18.3 C, Cloudy
WB 090962	SUPERPAVE Alternate RAP	08/12/97	22.8 C, Cloudy

During the paving of the slow-speed lane, 152-mm wide (3-M Stamark Pliant Polymer Pavement Marking Film # A380I) skip lines were placed by a subcontractor. The contractor rolled these in place while the pavement was still hot. For the most part, the longitudinal paving joints were away from where the skip lines were placed. On a few occasions, however, the lines were placed directly above the joints.

All 100-mm wide solid stripes for shoulder delineation were placed using sprayed epoxy resin paint and glass beads.

There were no transverse cold joints established within any of the six 305-m monitoring sections. No paver breakdowns occurred within these sections either. The time of hauling from the plant until depositing to the paver varied from a minimum of 19 minutes to a maximum of 81 minutes. The variation occurred as a function of truck queue length at the site or at the plant. Also, the distance from the plant to the site varied from 16-29 km, depending on which section was being paved.

Silos at the plant were used on only one of the days that paving occurred within the 305-m monitoring sections. They were used on subsection 090962 WB (SUPERPAVE RAP). The silos were not in use for any of the virgin mixes placed in the eastbound direction. Silos were in sporadic use for other days when the RAP mixes were paved (outside of the monitoring areas).

The pavement-lift thicknesses after the screed, but prior to rolling, for each SPS 9A monitoring section are given in Table 9.

TABLE 9
PAVING MAT THICKNESSES PRIOR TO COMPACTION
FOR THE 305-M SPS MONITORING SECTIONS

SPS9A SUBSECTION DESIGNATION	MAXIMUM THICKNESS (MM)	MINIMUM THICKNESS (MM)	AVERAGE THICKNESS (MM)
EB 090901	79.4	76.2	76.7
EB 090902	88.9	73.0	80.4
EB 090903	76.2	63.5	70.4
WB 090960	85.7	76.2	80.5
WB 090961	Not Available	Not Available	71.1
WB 090962	76.2	70.0	71.8

Table 10 contains other pertinent information about the surface-layer paving for each 305-m monitoring section. Included in the table, is pavement temperature immediately behind the paver, type of rollers used, asphalt modifiers (other than anti-strip agents), asphalt content, air voids, VMA, and percent maximum theoretical density achieved in the field.

TABLE 10
SUMMARY OF MIXTURE LAYDOWN DATA

SPS9A SUB SECTION	MODIFIER	PERCENT ASPHALT	AIR VOIDS	VMA	FIELD DENSITY (PERCENT MAXIMUM THEORETICAL)	MAT TEMP. °C BEHIND PAVER	BREAKDOWN ROLLER	INTERMEDIATE ROLLER	FINAL ROLLER
EB 090901	None	5.4	4.4	16.8	92.8	132-157	Hyster C766A	None	Hyster C350C
EB 090902	None	5.3	3.6	14.4	93.3	143-146	Hyster C766A	None	Hyster C350C
EB 090903	None	5.3	3.3	13.7	92.7	132-141	Hyster C766A	None	Hyster C350C
WB 090960	None	5.0	2.8	13.9	92.9	130-137	Hyster C766A	None	Hyster C350C
WB 090961	Styrelf	4.8	4.8	14.9	92.1	149-162	Hyster C766A	Caterpiller CB-614	Hyster C350C
WB 090962	None	5.0	4.8	15.5	91.0	134-137	Hyster C766A	None	Hyster C350C

Generally, placement of the various mixes occurred routinely without problems. One issue that became a source of consternation was achieving the minimum field densities. ConnDOT's specifications require densities of 92-97 percent of theoretical maximum density as determined by the Rice method (AASHTO T-209). All densities were checked using a nuclear density gauge. The contractor took density readings as per the contract requirement for QC/QA (a minimum of 10 tests per day). ConnDOT's quality assurance also required a minimum of 10 tests per day. There was some difficulty involved in achieving densities in all of the mixes, including the Class 1. It appeared that there were two temperature ranges where compactive efforts resulted in an increase in density. Densification could be achieved above 126 °C and below 93 °C. There was a middle range of temperatures (94-125 °C) where rolling did not seem to help at all. It also appears that ambient air temperature and probably surface temperature prior to paving affected the ability to achieve compaction. On the days when air temperatures were above 29 °C, compaction was more difficult to achieve. When the air temperature was below 24 °C, densities were more easily achieved.

On the particularly warm days when Section 62 (SUPERPAVE with RAP) was being paved, the minimum 92 percent density was not reached. The contractor attempted many rolling patterns by varying the timing of breakdown and finish rolling, the frequency and amplitude of vibrations, and the number of coverages. At the suggestion of ConnDOT, a rubber-tired roller was obtained and used on two of the days of paving. This roller did not appear to offer much assistance, partly due to its aged condition and functionality constraints (i.e., it was in poor mechanical operating condition). But as noted above, when the weather cooled down, densities of greater than 92 percent were achieved more easily, and with reduced diligence, and without the use of the rubber-tired roller..

While paving subsection 090903, the finish roller (Hyster C350C) was down for about 90 minutes. While paving in subsection of section 090961, the Hyster C766A that was being used as the breakdown roller, broke down. The Caterpiller CB614 then was switched to the breakdown roller and the Hyster C350C became the static roller.

Photos #6-13 show the nine metric-ton Caterpiller CB534 roller used for the leveling course, the 10.9 metric-ton Caterpiller CB614 vibratory roller, the 12.7 metric-ton Hyster C350C steel-wheel tandem roller, the 10 metric-ton Hyster C766A vibratory roller, the Blaw-Knox PF 180-H paving machine, the rubber-tired roller used for the westbound RAP sections, the tack coat application, and the RAP stockpile at SONECO/Northeastern Inc.

In Section 60, there were a couple of areas where the surface layer was removed and replaced. These occurred at construction project stations 63+90 to 64+68 (log mile 30.51-30.49) in the low-speed lane and at station 89+38 to 90+38 (log mile 30.03-30.01) in the high speed lane. These were not within the 305-m monitoring lanes. The reason for removal was lack of density and raveling. There appeared to be uncoated material and/or RAP material not homogeneously mixed with virgin material, delivered from two trucks.

After the design for Section 61 (SUPERPAVE with RAP) was completed by the CAP Lab, it was determined that the appropriate binder to mix with the RAP was a PG 58-34. Hudson Asphalt could not supply an unmodified asphalt to meet PG 58-34. Prior to this time, ConnDOT had requested that no modifiers be used for the project. When it was determined that no alternative existed for using a modified asphalt, ConnDOT accepted a product that has been in use in New York State DOT called Styrelf, which

Photo #6. 9 Metric-Ton Caterpiller CB534 Double-Drum Vibratory Roller Used for Leveling Course

Photo #7. 10.9 Metric-Ton Caterpiller CB614 Double-Drum Vibratory Roller

Photo #8. 12.7 Metric-Ton Hyster C350C Steel-Wheel Tandem Roller

Photo #9. 10 Metric-Ton Hyster C766A Double-Drum Vibratory Roller

Photo #10. Blaw-Knox PF 180-H Paving Machine

Photo #11. Nine-Wheel Rubber-Tired Roller

Photo #12. Application of Tack Coat to Leveling Course

Photo # 13. RAP Stockpile at Contractor's HMA Facility.

was available from Petro-Canada. However, it was determined that this product would increase the cost of the 3.3 km of pavement in Section 61 by as much as $60,000. This amount of cost increase was not accepted by ConnDOT. Therefore, a compromise was reached to pave only one day with the more expensive asphalt, and use the PG58-28, as used in Section 62, for the rest of Section 61. The construction project stations where PG58-34 was used were from station 160+20 to 192+60 (log mile 28.69-28.07) westbound, which is a length of 988 m. The 305-m monitoring subsection 090961 is contained within this area.

The total amount of HMA material used for all sections is given in Table 11. These totals include the ramps. Each ramp was paved with the same type of material that was used on the adjacent mainline. For example, the ramps to and from eastbound Route 2 in the vicinity of Section 01 contain virgin Class 1. The ramps to and from the westbound direction at the same interchange contain SUPERPAVE Alternate with RAP, identical to that used in Section 62.

TABLE 11
TONNAGE OF MATERIAL PLACED BY MIXTURE TYPE

SECTION DESIGNATION	HMA MATERIAL TYPE FOR SURFACE COURSE	TOTAL METRIC TONS OF HMA BY TYPE WITHIN EACH SECTION
EB 01	Class 1 Virgin	5988
EB 02	SUPERPAVE Virgin	6044
EB 03	SUPERPAVE Alternate Virgin	6413
WB 60	Class 1 RAP	7087
WB 61*	SUPERPAVE RAP	1541
WB 61	SUPERPAVE Alternate RAP	5221
WB 62	SUPERPAVE Alternate RAP	6529
Project Total		**38 823**

* Most of Section 61 used the same mix as Section 62; only 988 m, including the 305 m monitoring section, contained the PG 58-34 with modifier.

MATERIALS SAMPLING AND TESTING

The contractor was responsible for all quality control measures and testing. Table 12 shows the samples and tests required for each day's production, otherwise known as "a lot." Only the nuclear density tests were subcontracted. The field laboratory tests were performed at the contractor's lab in Montville. University of Connecticut upper-class civil engineering students trained by CAP Lab and hired for the summer by SONECO/Northeastern, Inc., performed most of the tests. ConnDOT performed quality assurance tests as indicated in Table 12. Standard Marshall Tests were performed along with the SUPERPAVE tests for comparison purposes. Appendix E contains results of both the QC and QA testing for the project.

TABLE 12
MATERIALS SAMPLING AND TESTING REQUIREMENTS
DURING CONSTRUCTION

QUALITY CONTROL PERFORMED BY CONTRACTOR IN ACCORDANCE WITH ASTM 3665.

DESCRIPTION	FREQUENCY	PROTOCOL
Sampling of HMA	5/Day	AASHTO T-168
Cold Feeds – Gradation	2/Day	AASHTO T-27
Extraction and Asphalt Content	5/Day	AASHTO T-164
Gradation of Extracted Aggregate	5/Day	AASHTO T-30
Maximum Specific Gravity	5/Day	AASHTO T-209
*SUPERPAVE™ Gyratory Compacted Molds	5 Sets/Day	AASHTO TP-4
**Bulk Specific Gravities	5/Day	AASHTO T-166
**Air Voids, VMA, VFA	5/Day	AASHTO PP19
Nuclear Density	10/Day	ASTM D-2950
Extraction and Asphalt Content of RAP Material	2/Day	AASHTO T-164
Gradation of Extracted RAP Aggregate	2/Day	AASHTO T-30
Moisture Content of RAP	2/Day	AASHTO T-255

* Set = 3 150mm molds
** Average value of 1 set of 150mm molds

In addition to the QC/QA testing, participation in the SPS 9A study required considerable additional sampling and testing. All sampling from the field took place within the 305-m monitoring sections. Bulk samples of aggregates and asphalt were sampled from the plant in Montville, as well. Some of the bulk materials were shipped to the AASHTO Materials Reference Library in Sparks, Nevada, for storage and possible future use for LTPP. SUPERPAVE gyratory compacted molds were made from the

TABLE 13
QUALITY ASSURANCE PERFORMED BY CONNDOT

DESCRIPTION	FREQUENCY	PROTOCOL
Mix Verification	1/Section	AASHTO PP19
Binder Verification	1/Day	AASHTO PP6
Penetration	1/Day	AASHTO T-49
Absolute Viscosity	1/Day	AASHTO T-202
Dynamic Shear Rheometer	1/Day	AASHTO TP-5
Sampling HMA	5/Day	AASHTO T-168
Extraction and Asphalt Content	5/Day	AASHTO T-164
Gradation of Extracted Aggregate	5/Day	AASHTO T-30
SUPERPAVE™ Gyratory Compacted Molds	5/Day	AASHTO TP-4
Marshall Molds	5/Day	AASHTO T-245
Maximum Specific Gravity	5/Day	AASHTO T-209
Bulk Specific Gravity	5/Day	AASHTO T-166
Air Voids, VMA, VFA Calculations	5/Day	AASHTO T-269
Flow and Stability of HMA	5/Day	AASHTO T-245
Nuclear Density	10/Day	ASTM D-2950

HMA sampled from the paver during construction. These molds were produced by state personnel, at the contractor's laboratory in Montville. Additional molds were made from the bulk materials sampled from the plant. These were prepared in ConnDOT's Materials Testing Laboratory in Rocky Hill, Connecticut. Some of the additional tests to be performed on the molds will be done by Braun Intertec of Minneapolis, Minnesota, while others are performed directly by ConnDOT.

Table 14 shows the tests performed by ConnDOT on the bulk samples for LTPP SPS 9A. Tables 15A, 15B, 15C, and 15D show tests performed by ConnDOT on paver and laboratory samples of HMA for each of the six sections. Table 16 shows tests performed by ConnDOT on cores that were removed after completion of the paving, in September 1997. Due to the excessive amount of testing required for the SPS study, the core test results were not available as of the publication date of this report. Additional cores will be taken at time intervals of 6, 12, 18, 24, and 48 months (i.e., between the Spring of 1998 and the year 2001).

TABLE 14
SPS 9A PROJECT – CONNDOT LABORATORY TESTS ON MIXTURE COMPONENTS

LABORATORY TEST	LTPP TEST/PROTOCOL	NUMBER OF TESTS/SECTION
Aggregates		
Combined Aggregate Gradation	AG04/P14	4
Specific Gravity of Coarse Aggregate	AG01/P11	4
Specific Gravity of Fine Aggregate	AG02/P12	4
Specific Gravity of Passing 200	AASHTO T100	4
Coarse Aggregate Angularity	PADOT TM621	4
Fine Aggregate Angularity	ASTM C1252	4
Toughness	AASHTO T96	4
Soundness	AASHTO T104	4
Deleterious Material	AASHTO T112	4
Clay Content	AASHTO T176	4
Thin Elongated Particles	ASTM D4791	4
Asphalt Cement		
Penetration at 5 deg. C	AASHTO T49	6
Penetration at 25 deg., 46 deg. C	AE02/P22	12
Viscosity at 60 deg., 135 deg. C	AE05/P25	24
Specific Gravity at 16 deg. C	AE03/P23	12
Dynamic Shear at 3 temps	AASHTO TP5	12
Brookfield Viscosity 135 deg., 165 deg C	ASTM D4402	12
Rolling Thin Film (RTFOT)	AASHTO T240	As needed
Dynamic Shear on RTFOT Residue at 3 temps	AASHTO TP5	12
Prressure Aging (PAV) of RTFOT Residue	AASHTO PP1	As Needed
Creep Stiffness of PAV Residue (2 Temps) 24h Conditioning	AASHTO TP1	12
Creep Stiffness of PAV Residue (2 Temps)	AASHTO TP1	12
Dynamic Shear on PAV Residue (3 Temps)	AASHTO TP5	12

TABLE 15A
SPS 9A PROJECT – FIELD LABORATORY TESTING OF PAVER SAMPLES
FOR SECTIONS 01, 03, 60, 61, & 62

LABORATORY TEST	LTPP TEST/PROTOCOL	NUMBER OF TESTS/SECTION
Gyratory Compaction at N_{max}	AASHTO TP4	12
Bulk Specific Gravity G_{mb}	AC02/P02	12
Asphalt Content (Extraction)	AC04/P04	4
Aggregate Gradation (Extracted Aggregate)	AG04/P14	4
Maximum Specific Gravity - G_{mm}	AC03/P03	4
Volumetrics		
Volume Percent of Air Voids	AASHTO PP19	12
Percent Voids in Mineral Aggregate	AASHTO PP19	12
Voids Filled with Asphalt	AASHTO PP19	12

TABLE 15B
SPS 9A PROJECT - FIELD LABORATORY TESTING OF PAVER SAMPLES FOR SECTION 02

LABORATORY TEST	LTPP TEST/PROTOCOL	NUMBER OF TESTS
Gyratory Compactor at N_{max}	AASHTO TP4	6
Gyratory Compactor at 7 % AV	AASHTO TP4	26
Gyratory Compactor at 3 % AV	AASHTO TP4	2
Bulk Specific Gravity	AC02/P02	12
Asphalt Content (Extraction)	AC04/P04	3
Aggregate Gradation (Extracted Aggregate)	AG04/P14	3
Maximum Specific Gravity	AC03/P03	3
Volumetrics		
Volume Percent of Air Voids	AASHTO PP19	6
Percent Voids in Mineral Aggregate	AASHTO PP19	6
Voids Filled with Asphalt	AASHTO PP19	6

TABLE 15C
SPS 9A PROJECT – CONNDOT LABORATORY TESTING OF LABORATORY PREPARED SAMPLES FOR SECTIONS 01, 03, 60, 61, & 62

LABORATORY TEST	LTPP TEST/PROTOCOL	NUMBER OF TESTS/SECTION
Gyratory Compaction at Design Asphalt Content at (N_{max})	AASHTO TP4	6
Gyratory Compaction at 7% Air Voids	AASHTO TP4	12
Moisture Susceptibility	AC05/P05	2
Bulk Specific Gravity	AC02/P02	18
Maximum Specific Gravity	AC03/P03	2
Volumetrics		
Volume Percent of Air Voids	AASHTO PP19	6
Percent Voids in Mineral Aggregate	AASHTO PP19	6
Voids Filled with Asphalt	AASHTO PP19	6

TABLE 15D
SPS 9A PROJECT – CONNDOT LABORATORY TESTING OF LABORATORY PREPARED SAMPLES FOR SECTION 02

LABORATORY TEST	LTPP TEST/PROTOCOL	NUMBER OF TESTS
Gyratory Compactor at N_{max}	AASHTO TP4	6
Gyratory Compactor at 3 % AV	AASHTO TP4	2
Gyratory Compactor at 7 % AV	AASHTO TP4	32
Bulk Specific Gravity	AC02/P02	12
Maximum Specific Gravity	AC03/P03	1
Volumetrics		
Volume Percent of Air Voids	AASHTO PP19	6
Percent Voids in Mineral Aggregate	AASHTO PP19	6
Voids Filled with Asphalt	AASHTO PP19	6

TABLE 16
SPS 9A PROJECT – CONNDOT LABORATORY TESTS ON CORES
TAKEN IMMEDIATELY AFTER CONSTRUCTION

LABORATORY TEST	LTPP TEST/PROTOCOL	NUMBER OF TESTS
Core Examination/Thickness	AC01/P01	58
Bulk Specific Gravity	AC02/P02	48
Maximum Specific Gravity	AC03/P03	12
Asphalt Content (Extraction)	AC04/P04	48
Aggregate Gradation (Extracted Aggregate)	AG04/P14	12
Volumetrics		
Volume Percent of Air Voids	AASHTO PP19	12
Percent Voids in Mineral Aggregate	AASHTO PP19	12
Voids Filled with Asphalt	AASHTO PP19	12
Recovered Asphalt Cement		
Abson Recovery	AE01/P21	48
Penetration at 5 deg. C	AASHTO T49	6
Penetration at 25 deg., 46 deg. C	AE02/P22	12
Viscosity at 60 deg., 135 deg. C	AE05/P25	24
Specific Gravity at 16 deg. C	AE03/P23	12
Dynamic Shear at 3 temps	AASHTO TP5	12
Creep Stiffness at 2 temps.	AASHTO TP1	12

ECONOMICS

The additional costs associated with the use of SUPERPAVE mixes cannot be easily discerned from this construction project. Although it would seem likely that costs would be higher due to the requirements of the contractor to 1) provide a SUPERPAVE Gyratory Compactor; 2) perform the mix design; and, 3) perform quality control, the bids for this project did not reflect this directly. The bid items did not separate the costs for equipment, mix design or quality control. It could be assumed then that these costs would be buried in the unit price per ton of in-place HMA. However, on this particular project the bid price for SUPERPAVE and conventional Class 1 mix did not differ significantly. The price ranged from $30.80 to $32.04 per ton (English) with the higher bid price for Class 1 RAP and the lowest for SUPERPAVE RAP.

The actual prices paid for the asphalt do, however, provide some indication of the effect the PG asphalts had on the project. Table 17 contains the price paid per US ton of liquid asphalt. It is obvious that the anti-strip agent, which was used in all of the SUPERPAVE mixes, but none of the Class 1 mixes, and the modifier for the SUPERPAVE subsection 090961 significantly affected the cost. For example, the tonnage of asphalt for the Class 1 virgin and SUPERPAVE virgin was 343 and 346 tons (English units) respectively. The amount paid for these asphalts was $62,799 and $51,793, respectively. Therefore, the PG 64-28 with anti-strip agent that was used in the SUPERPAVE virgin section was $11,000 more than the AC-20 used in the Class 1.

TABLE 17
COMPARISON OF COSTS OF LIQUID ASPHALTS USED ON PROJECT 28-185

PAVEMENT TYPE	ASPHALT TYPE	COST ($ PER TON (ENGLISH))
Class 1 Virgin	AC-20	151.00
SUPERPAVE Virgin	PG64-28 w/0.25% anti-strip	181.50
SUPERPAVE Alternate Virgin	PG64-22 w/0.25% anti-strip	166.50
Class 1 RAP	AC-20	151.00
SUPERPAVE RAP	PG58-34 w/0.375% anti-strip & modifier	295.00
SUPERPAVE Alternate RAP	PG58-28 w/0.375% anti-strip	185.00

INSTRUMENTATION

As was noted in Table 2, ConnDOT is responsible for collecting and submitting weather and traffic data for the SPS 9A project to FHWA. ConnDOT elected to instrument all lanes (both directions) with a continuously operating weigh-in-motion (WIM) system. This is installed in Route 2, approximately 90 m west of the bridge passing over Camp Moween Road in Lebanon. A new type of sensor called the Quartz-Piezo was utilized. Data on vehicle types, counts and weights, including axle weights, will be collected continuously, and submitted to LTPP in a format required for their database.

A Roadway Weather Information System (RWIS) was also installed with the WIM system in Lebanon. This system is part of a network of RWIS stations operated by ConnDOT’s Office of Maintenance. For purposes of the LTPP SPS study, only the daily high and low air temperatures will be collected and submitted.

OBSERVATIONS, COMMENTS AND GENERAL DISCUSSION

Plant Variability vs. Tolerance Within the Specification

One of the concerns on this project from a Materials Testing perspective was the contractor's ability to produce mixtures to a tighter tolerance as specified for the SUPERPAVE mixtures. ConnDOT also wanted to look into the overall variability experienced during HMA production. One method used was to monitor the HMA gradation results. The tolerances allowed by specification for Class 1 and SUPERPAVE mixtures are shown in Table 18.

TABLE 18
TOLERANCES USED FOR PROJECT 28-185 FOR CONTROL OF GRADATION

SIEVE SIZE (MM)	CLASS 1 MIXES (ALLOWABLE TOLERANCE IN % PASSING)	SUPERPAVE MIXES (ALLOWABLE TOLERANCE IN% PASSING)
19.0	8	6
12.5	8	6
9.5	8	6
4.75	7	6
2.36	6	6
1.18	--	4
0.60	5	4
0.30	4	3
0.15	--	3
0.075	2	2

The results of gradation tests by section when compared against their respective tolerances are given in Table 19. A gradation was considered passing if all sieve results were within acceptable criteria. These results indicate that the gradations were consistent. Another conclusion is that the westbound sections containing RAP had slightly more variation, as was expected. The average for Sections 01, 02 and 03, (the virgin mixes) is 94 percent. The average for Sections 60, 61, and 62 (the RAP mixes) was 82 percent.

TABLE 19
QUALITY CONTROL GRADATION RESULTS

SECTION DESIGNATION	TYPE OF PAVEMENT	NUMBER OF TESTS RUN	% OF TESTS PASSING
EB 01	Class 1 Virgin	25	96
EB 02	SUPERPAVE Virgin	22	91
EB 03	SUPERPAVE Alternate Virgin	24	96
WB 60	Class 1 RAP	29	72
WB 61	SUPERPAVE RAP	19	84
WB 62	SUPERPAVE Alternate RAP	27	89

All of the gradations shown in Table 19 are compiled when compared to their respective tolerances as shown in Table 18. As an exercise, the percent passing is recalculated using a tighter tolerance, such as the one specified in ConnDOT's FORM 811 dated 1974. The 1974 Tolerance is given in the forth column of Table 20. The 1974 (FORM 811) tolerances are only one percent or less

TABLE 20
COMPARISON OF TOLERANCES

SIEVE SIZE (MM)	CLASS 1 (1997) (ALLOWABLE TOLERANCE IN % PASSING)	SUPERPAVE (1997) (ALLOWABLE TOLERANCE IN % PASSING)	FORM 811 (1974) (ALLOWABLE TOLERANCE IN % PASSING)
19.0	8	6	5
12.5	8	6	5
9.5	8	6	5
4.75	7	6	5
2.36	6	6	4
1.18	--	4	4
0.60	5	4	4
0.30	4	3	3
0.15	--	3	3
0.075	2	2	2

different than the SUPERPAVE tolerances, and considerably tighter than the standard conventional mixes currently used by ConnDOT. Table 21 gives the results of the recalculated data. It is apparent that when applying a tighter tolerance to production data, the contractor is able to produce less variable mixture simply because a tighter specification exists. As can be seen from the SUPERPAVE sections, the variations are still within an acceptable range. It is speculated that the only reason that Sections 01 and 60 (the Class 1 mixtures) are lower, is simply because the project contract allowed greater tolerances.

In conclusion then, there is no specific reason why tightened gradation tolerances would adversely affect production. This project provided evidence that it can be done. The contractor will conform to whatever tolerance is specified.

TABLE 21
PASSING GRADATIONS RECALCULATED USING 1974 TOLERANCES

SECTION DESIGNATION	TYPE OF PAVEMENT	NUMBER OF TESTS	PERCENT OF TESTS PASSING
EB 01	Class 1 Virgin	25	32
EB 02	SUPERPAVE Virgin	22	77
EB 03	SUPERPAVE Alternate Virgin	24	83
WB 60	Class 1 RAP	29	14
WB 61	SUPERPAVE RAP	19	74
WB 62	SUPERPAVE Alternate RAP	27	78

Moisture Susceptibility Test Methods

The AASHTO T-283 Test was performed on aggregates and asphalts used for this project by the CAP Lab and the FHWA Mobile Asphalt Laboratory. The FHWA test results are given in Appendix D. There is some question about the reliability of the AASHTO T-283 test for detecting moisture susceptibility. The results of the tests by the two organizations, i.e., FHWA and CAP Lab, are not in agreement. For the virgin SUPERPAVE alternate mix, the CAP Lab results indicated failure of the tensile strength ratio, whereas FHWA tests show passing results; therefore, anti-strip not needed. On the other hand, when anti-strip agent was used for Section 62, the SUPERPAVE alternate with RAP mix, the FHWA test failed and the CAP Lab's passed. Work needs to be performed on identifying other tests for determining moisture susceptibility. Interestingly, stripping has not historically been found to be a problem in Connecticut.

Compaction and Field Density Measurements

Overall, the pavements were placed with minimal problems. However, achieving field density of greater than 92 percent maximum theoretical required more attention than the conventional mixes. Compaction appeared to be dependent on air, existing surface, and mix temperatures. The SUPERPAVE RAP mixes were more easily compacted when the ambient air temperature was below 24 ^{o}C. The mix became tender when the mat temperature was between 93 and 126 ^{o}C. The designer has speculated that avoidance of the restricted zone of the gradation chart, particularly passing under the zone, may have contributed to designing a mix that was difficult to compact, as well.

Future QC/QA Procedures

Although the NCHRP 9-7 study report recommendations were not implemented into Project 28-185, it was learned from the Route 2 project that a control strip of 91 m is not great enough to establish a viable rolling pattern. Future SUPERPAVE projects will specify a 183-m control strip. As was done for Route 2, all future SUPERPAVE projects will require that the QC be performed by the contractor. Gradation tolerances that were used for Route 2 will be used in the future as well, with the possibility of even tighter tolerances being specified. A tolerance for Maximum Theoretical Specific Gravity (G_{mm}) and for Effective Specific Gravity (G_{se}) will also be investigated for inclusion into future SUPERPAVE projects.

SUMMARY AND CONCLUSIONS

A large-scale SUPERPAVE project was successfully deployed on Route 2 in Colchester, Lebanon and Bozrah, Connecticut, during the summer of 1997. 12 450 metric tons of SUPERPAVE with all virgin materials; 13 290 metric tons of SUPERPAVE with RAP; and 13 070 metric tons of Class 1, with and without RAP were placed in one lift thickness as an overlay of 62.5 mm in depth. Conventional paving practices were employed. The contractor (SONECO/Northeastern Inc.) was responsible for SUPERPAVE mix design and quality control tests. The University of Connecticut Advanced Pavement Laboratory (CAP Lab) was subcontracted by SONECO to prepare the mix designs. Four 12.5-mm size SUPERPAVE mixtures were required by ConnDOT; two to be of all virgin materials and two with recycled asphalt pavement at 25+/-5% by weight. The SUPERPAVE overlay was designed using an expected traffic loading of 1.0 – 3.0 million 80-kN ESALs over a fifteen year period. All of the SUPERPAVE System design and test procedures were required.

The Route 2 project is included in the FHWA LTPP SPS 9A study along with projects in other areas of North America. This project is the only participating SPS 9A study in New England. The SPS 9A study required field density measurements and materials sampling at the plant and in the field. Laboratory tests were performed on asphalts, aggregates and mixtures prepared at both the field laboratory and in ConnDOT's central test laboratory. Six 305-m sections will be monitored in the field for at least four years for friction, roughness, deflections, distress, rutting, traffic, and air temperatures. In addition, cores will be taken from these sections at several times during the next 48 months for additional laboratory testing as prescribed by FHWA LTPP.

Although the contractor experienced some difficulty achieving the minimum field density on some days during construction, particularly during hot weather, the project for the most part did not present any undue hardship. The largest surprise during the mix design was the result showing that the aggregates and asphalt were susceptible to moisture damage under the AASHTO T-283 test. These aggregates have been used in Connecticut in the past with minimal problems.

The contractor was able to design and place a SUPERPAVE mix containing 20 percent recycled material. The method used for determining the correct PG asphalt was similar to ConnDOT's conventional technique for incorporating RAP as defined in FORM 814A, "Standard Specifications for Roads, Bridges and Incidental Construction." The PG asphalt selected for the design of one section required a modifier, since neat asphalt graded to a PG 58-34 was not available in the northeast.

Overall, difficulties encounteredon this project were not inordinate, and the few that occurred would be an expected byproduct of any experimental project.

REFERENCES

1.) Dougan, C.E., "Demonstration and Evaluation of SUPERPAVE Technologies Project Proposal," February 1996, ConnDOT.

2.) Special Provisions for Project 28-185, ConnDOT.

3.) Project Summary "SUPERPAVE Asphalt Mix Design and Field Management," Demonstration No. 90, Demonstration Projects Program, FHWA, Office of Technology Applications.

COPIES OF APPENDIX A ARE AVAILABLE FROM: James M. Sime 860-258-0301

Appendix A

ConnDOT Bituminous Concrete Mixtures – Master Range-1997

COPIES OF APPENDIX B ARE AVAILABLE FROM: James M. Sime 860-258-0301

Appendix B

Special Provisions for Project 28-185

COPIES OF APPENDIX C ARE AVAILABLE FROM: James M. Sime 860-258-0301

Appendix C

SUPERPAVE Mixture Designs

SUPERPAVE Virgin PG 64-28
SUPERPAVE Alternate Virgin PG 64-22
SUPERPAVE RAP PG 64-28
SUPERPAVE Alternate RAP PG 64-22

COPIES OF APPENDIX D ARE AVAILABLE FROM: James M. Sime 860-258-0301

Appendix D

FHWA Demonstration Project #90 Test Results

SUPERPAVE Alternate Virgin - Mix Design and Moisture Susceptibility
SUPERPAVE RAP - Mix Design and Moisture Susceptibility
SUPERPAVE Alternate RAP - Mix Design and Moisture Susceptibility

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Appendix E

Quality Control and Quality Assurance Data for Route 2