Report on the use of High RAP Asphalt Concrete Mixes for 2007 in the RICHMOND DISTRICT

Richmond District Plant Mix Schedule- Dinwiddie Schedule

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USE OF HIGH RAP ASPHALT CEMENT CONCRETE- RICHMOND DISTRICT

Schedule Information for Dinwiddie County

A high recycled asphalt pavement (RAP) asphalt concrete SM-12.5D mix with 25% RAP was incorporated in Plant Mix Schedule PM-4F-07 and placed on Routes 40 and 703 in Dinwiddie County. The combined estimate from the plant mix schedule for the SM12.5D mix with 25% RAP was 12,007 tons. 8,504 tons (70.8%) was to be placed on Route 40 and 3,503 tons (29.2%) was to be placed on Route 703. The focus of this report is on Route 40 since the bulk of the High RAP mix was placed there.

Route		Pavement Description	From (MP)	To (MP)	Length (Mi)	Width (ft)	Tonnage
40	Both	Mainline Pavement	6.33	12.32	5.99	22.00	8504
703	Both	Mainline Pavement	1.50	2.24	0.74	22	1051
		Connections &Crossovers			0.03	30	58
703	Both	Mainline Pavement	3.00	4.60	1.61	23	2375
		Connections & Crossovers			0.01	30	19

A total of 8,006 tons making up 94.1% of the estimated scheduled tonnage of 8,504 tons was actually placed on Route 40. The actual tonnages and placement dates for the schedule are summarized in Table 1.

Mix Type	Date Received	Quantity	Mix Type	Date Received	Quantity
SM-12.5D	8/23/07	1398.22	SM-12.5D	8/28/07	449.55
SM-12.5D	8/24/07	607.78	SM-12.5D	8/29/07	1491.34
SM-12.5D	8/24/07	716.21	SM-12.5D	8/30/07	59.09
SM-12.5D	8/25/07	1283.79			
SM-12.5D	8/25/07	113.61			
SM-12.5D	8/27/07	1008.38			
SM-12.5D	8/28/07	878.01			

Table 1: Placement Quantities and Dates

The prime contractor for Plant Mix Schedule PM-4F-07 was B.P Short and Sons based in Petersburg, Virginia. The high RAP mix SM-12.5D with 25% RAP was produced at their Petersburg Plant. The haul time to the project site on Route 40 (from milepost 6.33 to 12.32) varied from 25 to 30 minutes.

RAP Processing and Plant Capabilities at B.P. Short's - Jack Plant

RAP Processing

The B.P. Short Plant in Petersburg (Jack Plant) supplied the SM 12.5D with 25% RAP used on Route 40 in Dinwiddie County. Most of the RAP material used at this plant is from dense graded surface and base courses. The RAP used in this project came mainly from millings off of the Battlefield Park project, which is not too far from the plant. B.P. Short manages several stockpiles of RAP: an un-processed RAP stockpile which is comprised of construction waste that includes slabs of asphalt pavements, millings and plant waste as well as separate milling stockpiles. Millings from known sources are kept separate if they can be used with limited processing. The RAP processing used at this facility produces a fine graded RAP material with conglomerates up to 2 inches in diameter. Figure 1 shows the un-processed RAP stockpile on the left and the processed RAP on the right.

Figure 1: Un-Processed and Processed Rap Stockpiles

This plant has the ability to produce either a 9.5 or 12.5 mm HMA mix containing more than 25% RAP. The plant used the PROTONGRIND (seen in Figure 2) for initial processing. The Protongrind uses a standard milling head in an enclosed chamber to break the RAP down into a

manageable consistency but does not reduce the size of the aggregates. The material is then stockpiled and can be used as a component material for HMA or it can be processed further depending on the need.

Figure 2: PROTONGRIND machine for grinding RAP materials at the Plant

Figure 3: Separate screen deck and conveyor system

B.P. Short has the ability to fractionate or scalp their stockpiled RAP with a separate screen deck and conveyor system (Figure 3) before it enters the RAP feed at the plant. This system is employed to incorporate higher RAP contents and/or to control the max aggregate size entering the mix. The plant's RAP feed bin can accept various RAP components, from straight millings to fractionated or scalped RAP.

From the feed bin the RAP material is sent through a Hammer mill that breaks the RAP material down to a specific size. The screens can be set by the panels in the hammer mill to produce the desired size of RAP. The oversize RAP material is brought back through the Hammer mill to be reground and broken down into smaller sizes. The maximum RAP size that can be used in this plant is 2 inches. The Hammer mill equipment is shown in Figure 4.

Figure 4: RAP Feed and Hammer mill to supply RAP to the plant

As part of the quality control plan, tests samples are taken from the processed RAP stockpile to be checked for gradation and moisture and asphalt contents once a day.

The estimated maximum RAP capacity of the plant ranges from 35 to 40%. The normal percent of RAP being used under the new High RAP specification in the High RAP mixes was 25% for surface and base mixes and 20% for Intermediate mixes in 2007.

Plant Description

The HMA Plant at the Jack Facility (shown in Figure 5) was installed in late 1988 and is a single barrel counter flow type drum with a capacity of 250 tons per hour. Typical operating temperatures in the plant range from 325 to 330°F. The temperature depends on the amount of moisture present in the component materials. The total tonnage produced at this plant in 2007 was about 300,000 tons of which 275,000 tons contained RAP. Recycled waste oil is being used to run the burner on this plant resulting in energy savings.

Figure 5: Single Barrel Drum Plant at B.P. Short's Jack Facility

Job Mix Formula and Production

The job mix formula for the SM-12.5D with 25% RAP (VDOT Mix ID 4015-722) was submitted and granted approval in August 2007. The mix proportions, as well as the material source data is

given in Table 2. B.P. Short did not produce a conventional SM-12.5D from this plant in 2007. However they did produce 9 lots of a conventional SM-12.5D with 20% RAP in 2006 (VDOT Mix ID 4015-612) using the same mix components as the 25% RAP mix produced in 2007. Both mixes are detailed in Table 2 for comparison. The additional 5% RAP did not require a change to the aggregate structure, percent fines or the asphalt cement content.

Material	Bin Percentage (%) Mix ID 722	Bin Percentage (%) Mix ID 612	Kind	Source
Aggregate	42	40	#8 A Stone	Vulcan Materials Jack Quarry
Aggregate	15	20	Washed Screenings	Vulcan Materials Jack Quarry
RAP	**25**	**20**	**RAP**	Various
Sand	10	5	Concrete Sand	Vulcan Materials Puddledock
Screening	8	15	Dry Screenings	Vulcan Materials Jack Quarry
Asphalt Cement	5.5	5.5	PG 64-22	Valero
Additives	0.5	0.5	Kling Beta	Akzo-Nobel

SM-12.5D w/ 25% RAP	**Total % Passing**
Job-Mix Sieves	**Lab JMF**
19 mm	100
12.5 mm	96
9.5 mm	89
4.75 mm	-
2.36 mm	41
.075 mm	5.0
.	
Asphalt (%)	5.5

SM-12.5D w/ 20% RAP	**Total % Passing**
Job-Mix Sieves	**Lab JMF**
19 mm	100
12.5 mm	97
9.5 mm	89
4.75 mm	-
2.36 mm	41
.075 mm	5.0
Asphalt (%)	5.5

Table 2: Conventional and High RAP Bin Percentages and Job Mix Formulas

Plant Temperatures

Mix 722 with 25% RAP had an average temperature leaving the plant of 302.2^{o}F and was produced in the month of August. Mix 612 with 20% RAP had an average temperature of 312.5 ^{o}F and was produced in the spring and fall of 2006. The difference in temperatures leaving the plant is mostly likely due to ambient temperatures and not related to the increased RAP percentage; both averages are within VDOT specifications for plant temperatures.

Materials Acceptance and Variability

VDOT accepts Hot Mix Asphalt based on individual lot averages and variability for AC content and gradation per the Road and Bridge Specifications Section 211. Four full 2000-ton lots of the

SM-12.5D with 25% RAP were produced for the Dinwiddie schedule and all lots were within specifications and no price adjustments were applied.

Mix Volumetrics

Superpave volumetric properties are monitored throughout production by the contractor at a minimum rate of one sample per 1000 tons produced with at least one sample per production day. The Superpave properties of Voids in the Mineral Aggregate (VMA), Voids Filled with Asphalt (VFA) and Voids in the Total Mix (VTM) are measured from samples produced at 65 gyrations in the gyratory compactor. Chart 1 shows the results of the contractor's testing for the conventional and high RAP mixes, 612 and 722 respectively. Data points on Chart 1 represent the results of one sample and data points falling within the green and red boundaries meet VDOT specifications.

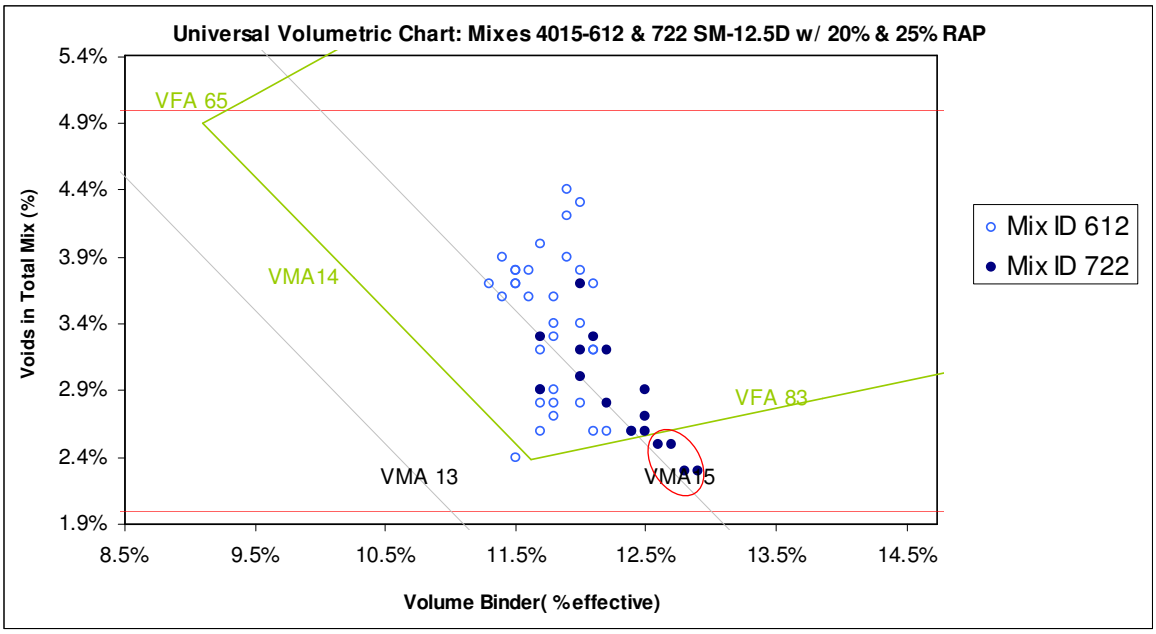

Chart 1: Universal Volumetric Chart

B.P. Short measured the volumetric properties of mix 722 in every 500 Ton sub-lot, with the only discrepancies occurring on the VFA. These four samples came from lots 1 and 3. Both lots 1 and 3 had AC contents that were outside of the mix's established control limits but within the specification limits as can be seen in the following process control charts for the mix.

Process Control and Capability

Process Control Charts (X_{bar} and s) were developed for both mixes in order to compare the production variability to current VDOT specifications. This was done to confirm that the additional RAP would not affect the contractor's ability to control his process and meet specifications.

Chart Nomenclature		Definition
USL	Upper Specification Limit	Job Mix Target + VDOT Specified Tolerance on Lot Averages
UCL	Upper Control Limit	Grand average + 3 standard deviations
Mean	Grand Average of all lots	
LCL	Lower Control Limit	Grand average -3 standard deviations
LSL	Lower Specification Limit	Job Mix Target - VDOT Specified Tolerance on Lot Average
Each point on a control chart is the average of 4 samples per 2000-ton lot. The blue error bars per lot represent one lot standard deviation in each direction.		

Table 3: Control Chart Nomenclature

Control Charts for Mix 722 with 25% RAP

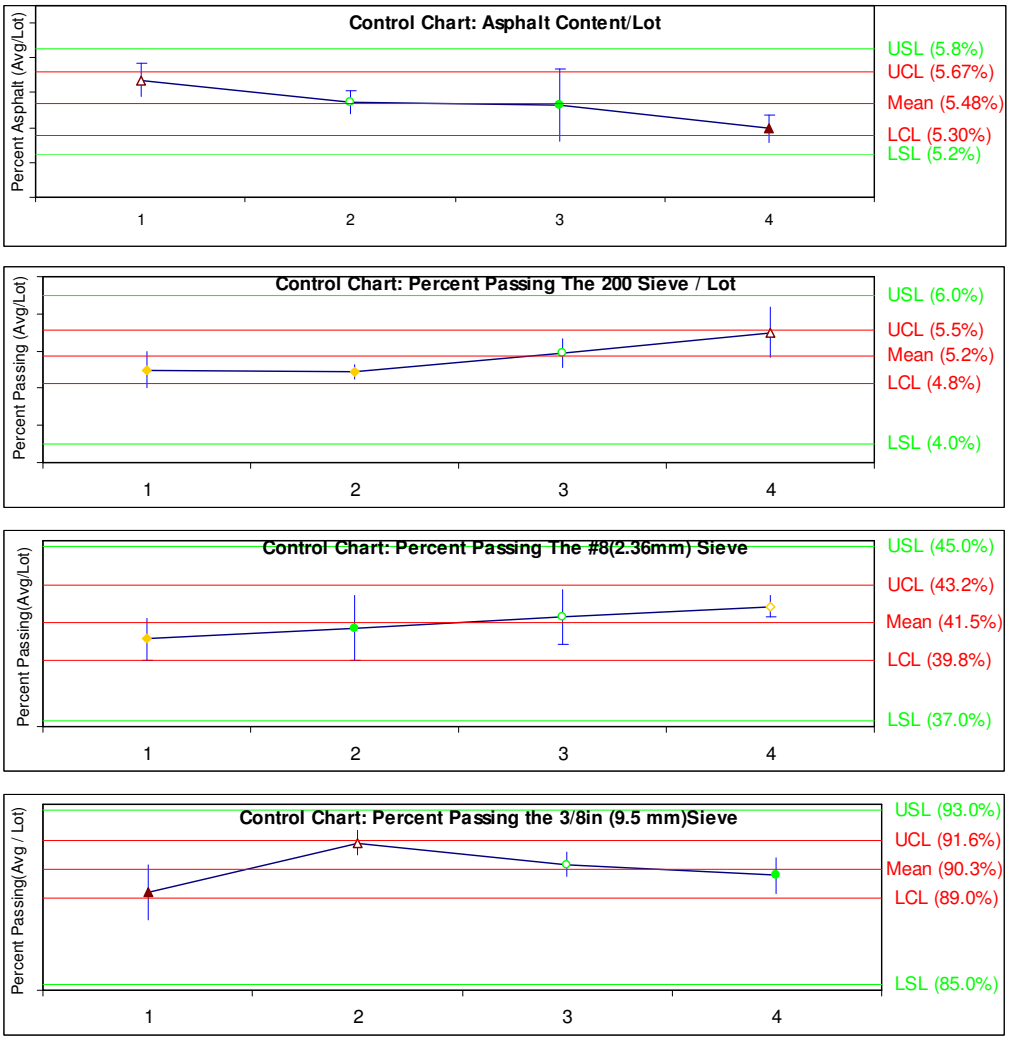

Chart 2: SM-12.5 with 25% RAP Control Charts

Control Charts for Mix 612 with 20% RAP

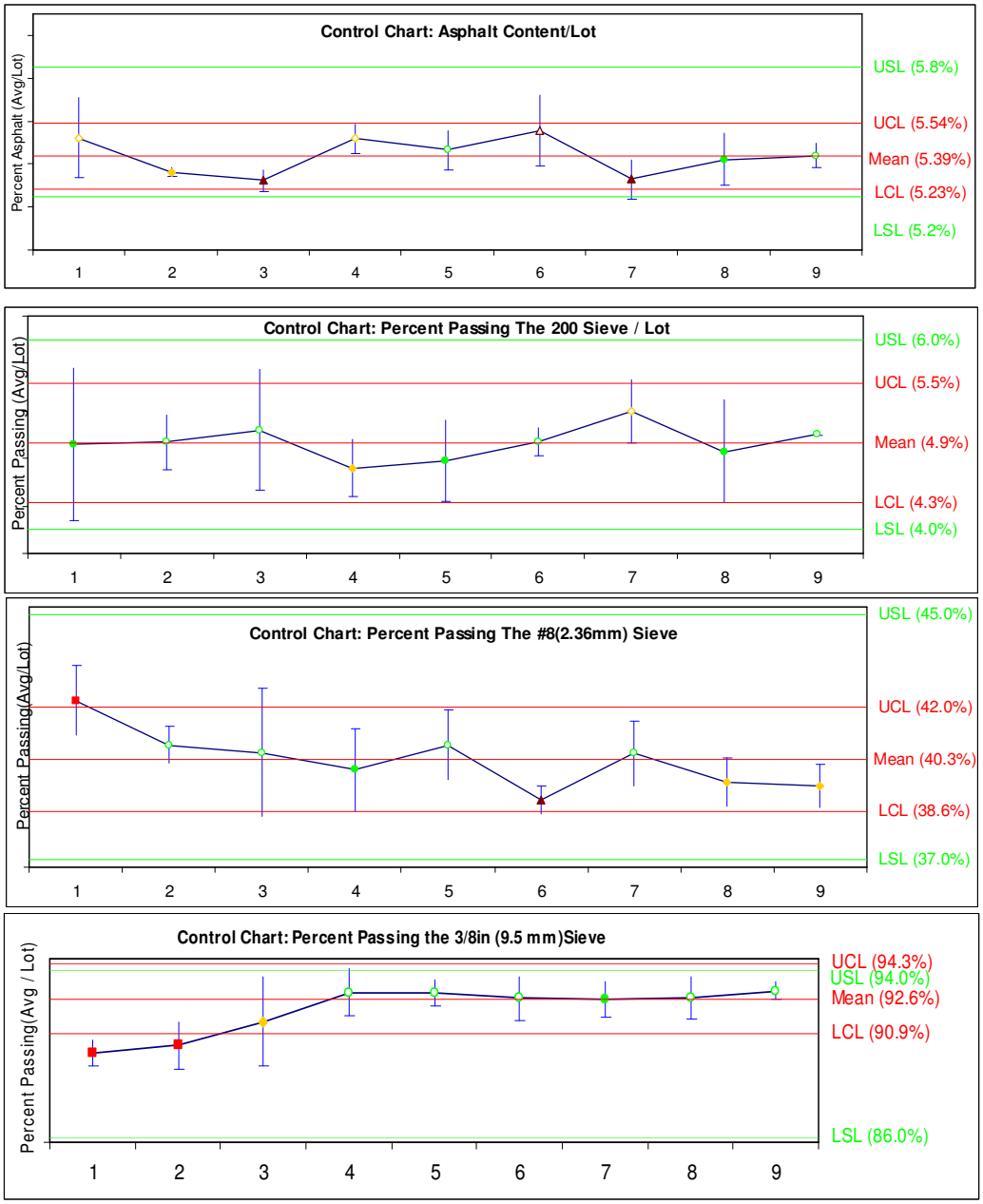

Chart 3: SM-12.5 with 20% RAP Control Charts

Both mixes showed processes that were in control and capable of meeting the specifications. The mix with 25% RAP operated higher in the specification range for AC content and seems to be sensitive to VFA issues whenever the material fell outside of the established control limits. The 20% RAP would approach the VFA limit but not exceed the established criteria. No single property of either mix exceeded using more than 62% of the established specification range. This gives the contractor the needed flexibility to make adjustments to the mix during production without risking price adjustments. The processing used for both mixes was capable of producing a controllable mix within specifications.

Statistical Comparisons

Table 4 provides a summation of the producers' results, VDOT monitor results, a statistical comparison of these test results, as well as the acceptance range.

Test Item	Mix Design	Accept Range	Producer Results			VDOT Monitor Results			Non-Matched Statistical Comparison			
									F-test		't' test	
			N	X_{bar}	s	N	X_{bar}	s	F	$F_{(99)}$	$\lvert X_m - X_c \rvert$	μ
19 mm	100	100	17	100.00%	0.00%	2	100.00%	0.00%				
12.5 mm	96	100-92		98.76%	0.75%		99.50%	0.71%	1.3	24571.8	0.77%	5.4%
9.5 mm	89	85-93		90.24%	1.15%		92.00%	2.83%	5.8	11.1	1.67%	128.8%
4.75 mm	-	-										
2.36 mm	41	37-45		41.47%	1.12%		41.50%	2.12%	3.6	11.1	0.10%	97.3%
.075 mm	5	4.0 – 6.0		5.16%	0.30%		5.65%	0.07%	16.6	24571.8	0.45%	0.27%
Asphalt (%)	5.5	5.2 – 5.8		5.49%	0.15%		5.58%	0.03%	27.0	24571.8	0.11%	0.12%

Table 4: Statistical Comparisons on Acceptance Data

The non-matched statistical comparison of asphalt content and gradation is a comparison of the VDOT monitor sample population to the producer's lot acceptance sample population in which the producer's matched split sample results are excluded from the analysis. This analysis was performed in accordance with Virginia Test Method (VTM) 59 and compares the producer variability and mean to the testing conducted by VDOT. The analysis compared two (2) monitor samples to fifteen (15) producer samples. The variation of the two data sets was not found to be different based on the F test at a 99% significance level. The means of the two data sets were found to be different for the percent passing the .075mm sieves based on the't' test at a 99% significance level. If production had continued closer monitoring and investigations would have been conducted to determine the cause of the differences.

Test Item	Accept Range	Producer Results			VDOT Monitor Results			Statistical Comparison			
								F-test		't' test	
		N	Xbar	s	N	Xbar	s	F	$F_{(99)}$	$\lvert X_m - X_c \rvert$	μ
VTM	2.0 - 5.0	16	2.86%	0.40%	2	2.30%	0.42%	1.1	10.8	0.56%	3.14%
VMA	14.0 Min		15.16%	0.24%		14.90%	0.42%	3.0	10.8	0.26%	19.49%
VFA	65 - 83		81.18%	2.45%		84.65%	2.33%	1.1	24630.2	3.47%	17.46%
F/A	0.6 - 1.2		0.98	0.09		1.06	0.02	16.3	24630.2	0.08	0.08
Gmm	NA		2.447	0.005		2.451	0.001	14.9	24630.2	0.004	0.005

Table 5: Statistical Comparisons on Volumetric Data

The F and t tests were run on all of the volumetric data as well and neither the variations nor the means were found to be different at the 99% significance level.

Rut Testing

Samples for measuring the mix's susceptibility to rutting were taken for the SM-12.5 with 25% Rap. The conventional SM-12.5 (Mix ID 612) used for comparison was not sampled for rut testing in 2006.

The testing was performed using the Asphalt Paving Analyzer (APA) using a 120lb point load, a hose pressure of 120psi, at 120°F for 8000 cycles in accordance with VTM-110.

The following table breaks down the testing results.

	Mix ID 722 SM-12.5D w/ 25% RAP
Date Sampled	08/24/07
Lot #	2
Rut Depth [mm]	3.5mm @ 7.7% Air Voids

Table 6: APA Rut Testing

This mix met the VDOT specification where the maximum mix rut depth allowed is 5.5mm for an SM-12.5D surface mix.

Extraction, Recovery and PG Grading

Samples for determining the Performance Grade of the asphalt in the mix were taken at the same time as the rut samples were taken. The asphalt cement was extracted from the mix in accordance with AASTHO T-164: Quantitative Extraction of Asphalt Binder from Hot-Mix Asphalt. The asphalt cement is then recovered from the extracted solution in accordance with AASHTO T-170: Recovery of Asphalt from Solution by Abson Method.

The asphalt cement was then sent to VTRC for grading in accordance with AASHTO R-29: Grading or Verifying the Performance Grade of an Asphalt Binder.

The material graded out to be a PG 76-22.

Field Operations and Monitoring Issues

Materials inspection and quality/independent assurance testing was provided by Kyle Crump and Jerry Richardson of the South Hill Residency in the Richmond District. VDOT accepts the field placement of Hot Mix Asphalt based on the average nuclear density reading on 5000 ft lots referred to as test sections. A nuclear target is established using the roller pattern and control strip method and this target must be verified on a %G_{mm} basis by cores sawn from the control strip. The requirements for the placement of this mix for temperature and densities were:

Minimum/Maximum Lay-down temperatures	Minimum Control Strip Target Density (% G_{mm})	Minimum Production Density (% of Nuclear Target)
270 to 350°F	92.2	98.0 to 102.0

The target control strip density of 140.6 lb/ft^3 was determined on 8/23/07 and the average %G_{mm} of the target verification cores from the control strip was 93.3%. Densities of the test sections as a percentage of the nuclear target are shown in Table 7. The percent nuclear target densities obtained during production averaged 99.49% and ranged from 99.1% to 100.6% with a standard deviation of 0.62 and a coefficient of variation of 0.62%.

Date	% of Nuclear Target Density
8/23/07	99.4
8/23/07	99.7
8/24/07	98.6
8/24/07	98.9
8/25/07	99.7
8/25/07	99.6
8/27/08	99.5
8/27/07	100.4
8/28/07	99.1
8/28/07	100.6
8/29/07	98.9

Table 7: Field Acceptance Data

Based on the data and observations obtained during the placement operations the mix performed as required throughout the entire production period. The recorded test values met and exceeded all relevant specifications.

During placement of the 2-inch thick SM 12.5D with 25% RAP it was observed that the underlying platform was distressed and fatigued at the beginning of the project, however the apparent weak base did not affect the placement and compaction operations and the finished mat looked good. This High RAP project will be monitored in the future for long-term pavement performance.