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

Richmond District Plant Mix Schedule-Goochland Schedule

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Table of Contents

USE OF HIGH RAP ASPHALT CEMENT CONCRETE- RICHMOND DISTRICT 3
Goochland Schedule Information 3
Schedule Quantities for SM-12.5D in Goochland County: 3
Schedule Quantities for IM-19.0D in Goochland County: 3
RAP Processing and Plant Description Branscome Powhatan 4
Rap Processing 4
The Powhatan HMA Plant 8
Job Mix Formula and Production 10
Conventional and High Rap Job Mix Formulas 10
Quality Control and Plant Observations 11
Plant Temperatures: 11
Materials Acceptance and Variability 12
Mix Volumetrics 12
Process Control and Capability 13
Rut Testing 17
Extraction, Recovery and PG Grading 17
Field Operations and Monitoring Issues 18

List of Figures

Figure 1: Backhoe operations on unprocessed RAP stockpile at Powhatan 5
Figure 2: General asphalt construction waste to the left and 'Clean' millings to the right are kept separate 5
Figure 3: Asphalt Plant waste is separated into a third distinct source 5
Figure 4: Processed RAP stockpiles at the Powhatan crushing site 6
Figure 5: Mobile Crushing Equipment at the Powhatan Plant 7
Figure 6: Processed RAP material being produced from Mobile crushing equipment at the Powhatan Plant 7
Figure 7: Final processed product stockpiled at the plant 8
Figure 8: Half Barrel overview 8
Figure 9: RAP transported through scalping screens to Drum 9
Figure 10: Pug Mill detail 9

List of Tables

Table 1: Placement Quantities and Dates for the SM-12.5 4
Table 2: Placement Quantities and Dates for the IM-19.0 4
Table 3: SM-12.5 Conventional and High RAP Bin Percentages and Job Mix Formulas 10
Table 4: IM-19.0 Conventional and High RAP Bin Percentages and Job Mix Formulas 11

Table 5: Average Plant Temperatures for Both Mixes 11
Table 6: Price Adjustments per Lot for both the Conventional and High RAP Mixes 12
Table 7: Control Chart Nomenclature..... 13
Table 8: Comparison of VDOT and Contractor Testing 16
Table 9: Comparison of VDOT and Contractor Testing 17
Table 10: APA Rut Testing..... 17
Table 11: Field Acceptance Data..... 18
Table 12: Rideability Data 19

USE OF HIGH RAP ASPHALT CEMENT CONCRETE- RICHMOND DISTRICT

Goochland Schedule Information

A high RAP Asphalt concrete SM-12.5D mix and IM-19.0D mix (Reclaimed Asphalt Pavement which make-up 20% or more of the asphalt mix) were incorporated in Plant Mix Schedule PM-4N-07 and placed on Route 6 in Goochland County. The combined estimate from the plant mix schedule for the SM-12.5D mix with 25% RAP was 5,640 tons and the IM-19.0D mix with 30% RAP was 2,494 tons. The schedule breakdown is shown below:

Schedule Quantities for SM-12.5D in Goochland County:

Route	Pavement Description	From (MP)	To (MP)	Length (Mi)	Width (ft)	Tonnage
6 EBL	Mainline Pavement	29.46	30.72	1.26	26	2,114
	Connections &Crossovers			0.15	12	175
6 EBL	Mainline Pavement	31.79	33.40	1.61	24	1,870
	Connections &Crossovers			0.55	12	319
606 Both	Mainline Pavement	0	1.00	1.00	18	1,162

Schedule Quantities for IM-19.0D in Goochland County:

Route	Pavement Description	From (MP)	To (MP)	Length (Mi)	Width (ft)	Tonnage
6 EBL	Mainline Pavement	31.79	33.40	1.61	24	2,494

The actual tonnages placed on Route 6 deviated slightly from what the schedule reported. A total quantity of 5,250.6 tons of SM-12.5D mix was placed on Route 6 between May and September of 2007. This represents a decrease of 389.4 tons (7.6%) for the SM-12.5D mix. For the IM-19.0 mix a total of 2,584 tons was placed, this represents an increase in 88.8 tons (3.6%) for this mix. Table 1 shows the dates of actual placement and quantities of the SM 12.5D and IM-19.0D mix on Route 6.

Mix Type	Date Received	Quantity	Mix Type	Date Received	Quantity
SM-12.5D	5/8/07	742.07	SM-12.5D	8/30/07	376.56
SM-12.5D	5/8/07	225.18	SM-12.5D	8/31/07	1,070.21
SM-12.5D	8/24/07	896.77	SM-12.5D	9/4/07	42.37
SM-12.5D	8/25/07	1,045.61	SM-12.5D	9/4/07	176.88
SM-12.5D	8/27/07	39.95	SM-12.5D	9/5/07	17.00
SM-12.5D	8/29/07	16.08			
SM-12.5D	8/29/07	601.96			

Table 1: Placement Quantities and Dates for the SM-12.5

Mix Type	Date Received	Quantity
IM-19.0D	8/24/07	856.43
IM-19.0D	8/24/07	869.38
IM-19.0D	8/28/07	488.69
IM-19.0D	8/29/08	369.52

Table 2: Placement Quantities and Dates for the IM-19.0

The prime Contractor for this schedule on Route 6 was Interstate Construction/Branscome Inc. based in Richmond, Virginia. Branscome operates six plants in the Richmond, Virginia area. These two mixes were produced out of the Powhatan plant with a haul time of approximately 30 minutes to the project site.

RAP Processing and Plant Description Branscome Powhatan

Rap Processing

Branscome Richmond has their RAP (Reclaimed Asphalt Pavement) processing site adjacent to the Asphalt Plant in Powhatan Co. on Route 60.

Typically three sources of unprocessed RAP are stockpiled separately at this site. The sources are: 1) general asphalt construction waste which comes from private contractors who dump the asphalt waste at no charge, 2) plant waste which includes rejected HMA from plant production, plant calibration runs, and cleaning runs, and 3) milled asphalt from roads and parking lots. The material is almost exclusively dense-graded base and surface type mixes, there is currently no RAP from SMA (stone matrix asphalt) sources. The processing crews try to maintain a proportional combination of the three sources to create a consistent final product. The RAP is estimated to account for 35-40% of mixes on private jobs for surface and base mixes. Figures 1, 2, and 3 emphasize the three distinct sources as managed at the Powhatan facility.

Figure 1: Backhoe operations on unprocessed RAP stockpile at Powhatan

Figure 2: General asphalt construction waste to the left and 'Clean' millings to the right are kept separate.

Figure 3: Asphalt Plant waste is separated into a third distinct source

The individual processed RAP stockpiles at the processing site are not covered with any protective covering as shown in Figure 4. However there are discussions by the plant management on instituting methods to reduce the moisture content in the RAP stockpiles. The processed RAP is checked once every 2,000 tons for moisture and asphalt contents. The amount of moisture in the RAP varies between 5 and 8%, while the typical AC content is about 5%.

Figure 4: Processed RAP stockpiles at the Powhatan crushing site

As part of the process control, the gradation of the RAP is checked to ensure 100% of the processed RAP is passing the ½" sieve. High amounts of minus #200 materials are generated in this process and can affect the amount of RAP incorporated into a mix. Therefore the percent passing the #200 sieve is monitored closely. Nine to ten percent passing the #200 sieve is the limit set for the processed RAP. There is no attempt to fractionate the RAP material and the final product from this standard processing is used in all mix types.

There are two separate crews composed of a backhoe and loader operator from Branscome that work on the unprocessed RAP stockpiles, typically a backhoe operator works the raw stockpiles while front-end loaders load the processor and work the processed piles. The crews process between 1,000 and 3,000 tons a day using the Eagle Mobile crusher.

The unprocessed RAP is loaded onto the crusher, where a blow bar type crusher crushes or breaks the RAP materials into smaller pieces. This crusher can reduce the maximum aggregate size in the RAP. The crushed material passes over screens of size 9/16", and the oversized materials are returned through a loop in the mobile equipment to be re-crushed. Once or twice a day the rejected over sized particles, which may contain metals, cans and other non-RAP objects, are removed and dumped as waste.

The mobile crushing operation is detailed in Figures 5 and 6.

Figure 5: Mobile Crushing Equipment at the Powhatan Plant

The processed RAP material is then stockpiled nearby, and is then available to be trucked to the nearby asphalt plant (Figure 6) or other facilities in the region.

Figure 6: Processed RAP material being produced from Mobile crushing equipment at the Powhatan Plant

The cost of the mobile crusher is about $1,000,000.00. The front-end loaders and backhoe equipment cost almost $500,000 a piece.

Figure 7: Final processed product stockpiled at the plant

The Powhatan HMA Plant

The HMA plant located at the Powhatan facility is an ASTEC half barrel, counter flow drum plant (Figure 8). The plant has a capacity of producing approximately 400 tons per hour.

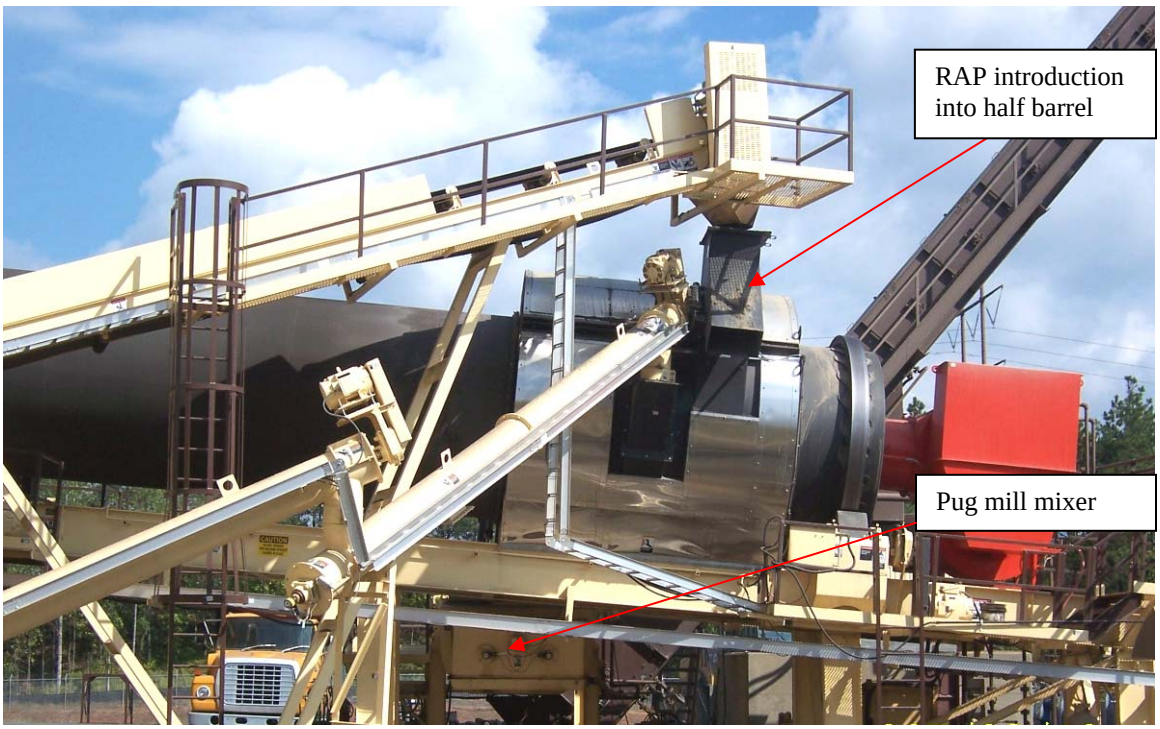

Figure 8: Half Barrel overview

RAP is introduced into two feed bins and sent by a single conveyor system through the scalping screens (3/4" size) in one passage. The oversized RAP aggregates are scalped/discarded and collected on site.

Figure 9: RAP transported through scalping screens to Drum

The screened RAP material is then sent to the drum and is introduced into the outer-half barrel where it meets the superheated virgin aggregates and the two materials are mixed. The super hot virgin aggregates melt the old asphalt in the recycle material and the aged asphalt coats the virgin aggregates before fresh asphalt is introduced into the mix at the plug mill. The total mixing time in the outer barrel and the pug mill is longer than a typical drum plant and may give the opportunity for a more thorough blending of the aged and virgin binders.

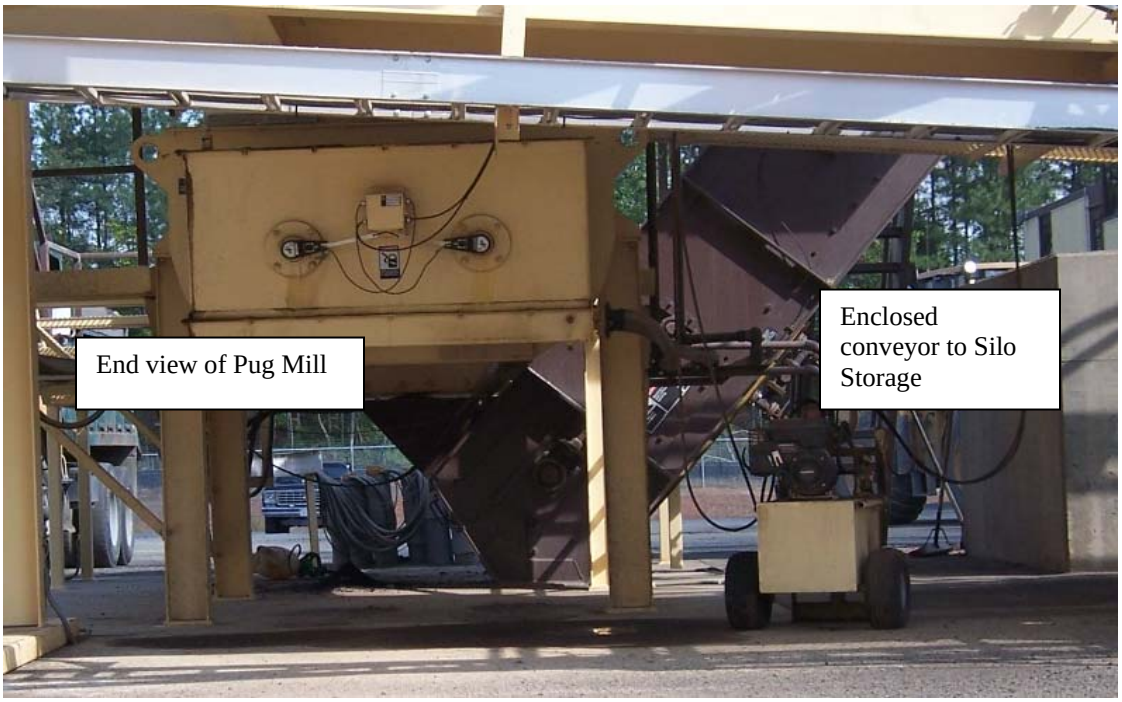

Figure 10: Pug Mill detail

The estimated maximum RAP capacity of this plant is 40%. The percentage of RAP used in VDOT high RAP mixes was 25% for the surface mix and 30% for intermediate mix. Typical plant operating temperatures depend on the mix type, air temperatures and type of binder being used. Operating temperatures range from 285 to 350 °F.

Job Mix Formula and Production

Conventional and High Rap Job Mix Formulas

The job mix formulas on the Route 6 Goochland schedule for the SM-12.5D with 25% Rap which is identified as Job Mix 739 and the IM-19.0D with 30% Rap which is identified as Job mix 738 are listed in Tables 3 and 4. The details of the final mix proportions, the material source data and Branscome's conventional SM-12.5D with 15% RAP and IM-19.0D with 20% RAP are also shown for comparison. The conventional surface and intermediate mixes are designated as Mix 712 and Mix 716 respectively. All four mixes were produced from the Powhatan facility in 2007.

SM-12.5's Material	Amount (%) Mix 739	Amount (%) Mix 712	Kind	Source
Aggregate	60	75	#29 Stone	Luck Stone Corp., Powhatan
RAP	**25**	**15**	RAP	Recycled (-1/2")
Sand	10	10	Sand	Brett Aggregates, Doswell
Asphalt Cement	5.60 (64-22)	5.60 (70-22)		Sem Materials ,Valero
Additives	0.5	0.5	Adhere HPT	

SM-12.5D w/ 25% RAP Mix 739 **Job-Mix Sieves**	**Total % Passing** **Lab JMF**	**SM-12.5D w/ 15% RAP Mix 712** **Job-Mix Sieves**	**Total % Passing** **Lab JMF**
19 mm	100	19 mm	100
12.5 mm	96	12.5 mm	98
9.5 mm	89	9.5 mm	85
4.75 mm	-	4.75 mm	-
2.36 mm	46	2.36 mm	42
.075 mm	6.5	.075 mm	6.5
.			
Asphalt (%)	5.60	Asphalt (%)	5.60

Table 3: SM-12.5 Conventional and High RAP Bin Percentages and Job Mix Formulas

IM-19.0's

Material	Mix 738 Amount (%)	Mix 716 Amount (%)	Kind	Source
Aggregate	50	65	#68 Stone	Luck Stone Corp., Powhatan
RAP	**30**	**20**	RAP	Recycled (-1")
Sand	20	15	Sand	Brett Aggregates, Doswell
Asphalt Cement	5.00 (64-22)	5.20 (70-22)		Sem Materials ,Valero
Additives	0.5	0.5	Adhere HPT	

IM-19.0D w/ 30% RAP Mix 738 **Job-Mix Sieves**	**Total % Passing** **Lab JMF**	**IM-19.0D w/ 20% RAP Mix 716** **Job-Mix Sieves**	**Total % Passing** **Lab JMF**
25 mm	100	25 mm	100
19 mm	96	19 mm	96
12.5 mm	77	12.5 mm	77
9.5 mm	-	9.5 mm	-
4.75 mm	-	4.75 mm	-
2.36 mm	34	2.36 mm	30
.075 mm	5.0	.075 mm	5.0
. Asphalt (%)	5.00	Asphalt (%)	5.20

Table 4: IM-19.0 Conventional and High RAP Bin Percentages and Job Mix Formulas

Quality Control and Plant Observations

Plant Temperatures:

VDOT specifications require the contractor to monitor the mix temperature in the truck with each acceptance sample taken at the plant. Table five compares those average readings for both the conventional and higher RAP percentage mixes.

Mix Type	Mix ID	Average Temperature at the Plant [F]
SM-12.5D w/ 25% RAP	739	313.8
SM-12.5D w/ 15% RAP	712	317.8
IM-19.0D w/ 30% RAP	738	319.3
IM-19.0D w/ 20% RAP	716	313.8

Table 5: Average Plant Temperatures for Both Mixes

The variation in temperatures recorded at the plant is not outside of the typical range of expected plant temperatures for different mixes produced at different times.

Materials Acceptance and Variability

VDOT accepts Hot Mix Asphalt based on lot averages and end of the year variability for AC content and gradations per the Road and Bridge Specifications Section 211. The following table breaks down the acceptance of each mix based on Lot averages and end of the year variability.

	SM-12.5D w/ 25% RAP Mix 739	SM-12.5D w/ 15% RAP Mix 712	IM-19.0D w/ 30% RAP Mix 738	IM-19.0D w/ 20% RAP Mix 716
Tons Produced	4285	6552	3008	3367
# of Lots (# of Lots w/ $ Adjustments)	3(0)	4(0)	2(0)	2(0)
End of Year Variability Adjustments	0.0	1.0% on AC *	0.0	0.0

Table 6: Price Adjustments per Lot for both the Conventional and High RAP Mixes

* A 1% reduction in unit price for every ton of HMA produced using this mix design was assessed because the overall standard deviation limit on asphalt content was exceeded.

Mix Volumetrics

Mix Volumetrics 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. The following chart shows the results of the contractor testing for both mixes. Results falling within the green and red volumetric boundaries on the chart meet VDOT specifications.

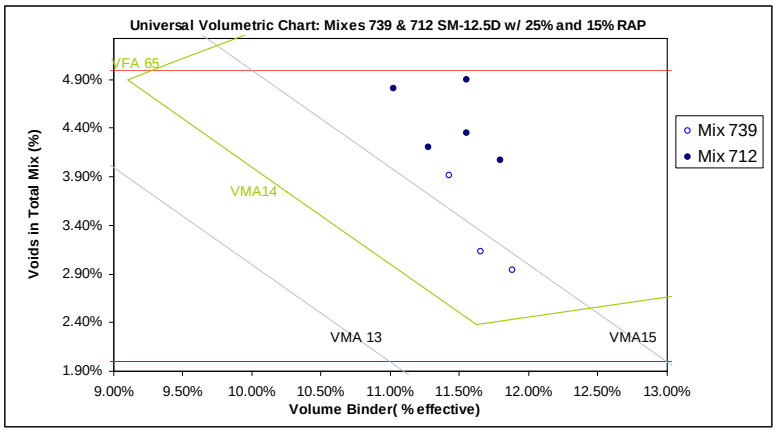

Chart 1: Surface Mix Universal Volumetric Chart

Both the conventional and the high RAP mix met the specifications for Superpave Volumetrics on all samples tested. Both mixes had relatively the same targets and based on the limited testing to date the higher RAP mix seemed to run slightly tighter on voids.

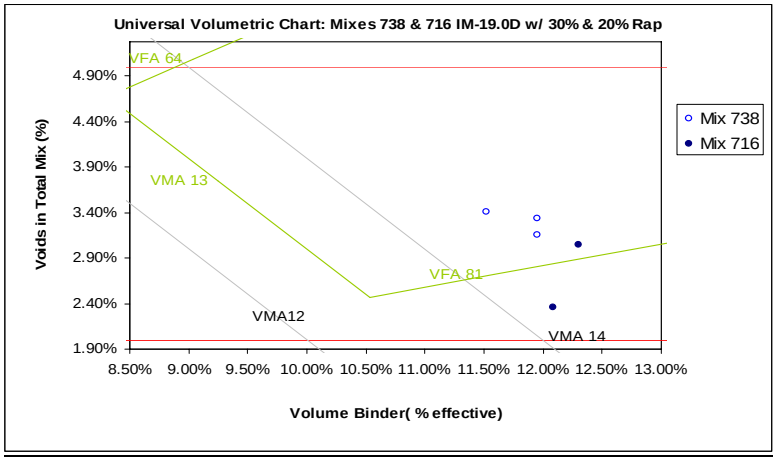

Chart 2: Intermediate Mix Universal Volumetric Chart

The IM-19.0 mixes met the Superpave Volumetric criteria except that one sample with 20% RAP failed on the high side of VFA. Both mixes had relatively the same targets and ran in the same region with respect to volumetrics, ideally VDOT would like to see the mix adjusted slightly to bring the VMA in closer to the minimum and reduce the VFA away from the failing boundary.

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 additional RAP would not affect the contractor's ability to meet specifications and control the process.

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 7: Control Chart Nomenclature

SM-12.5D with 25% Rap, Mix 739:

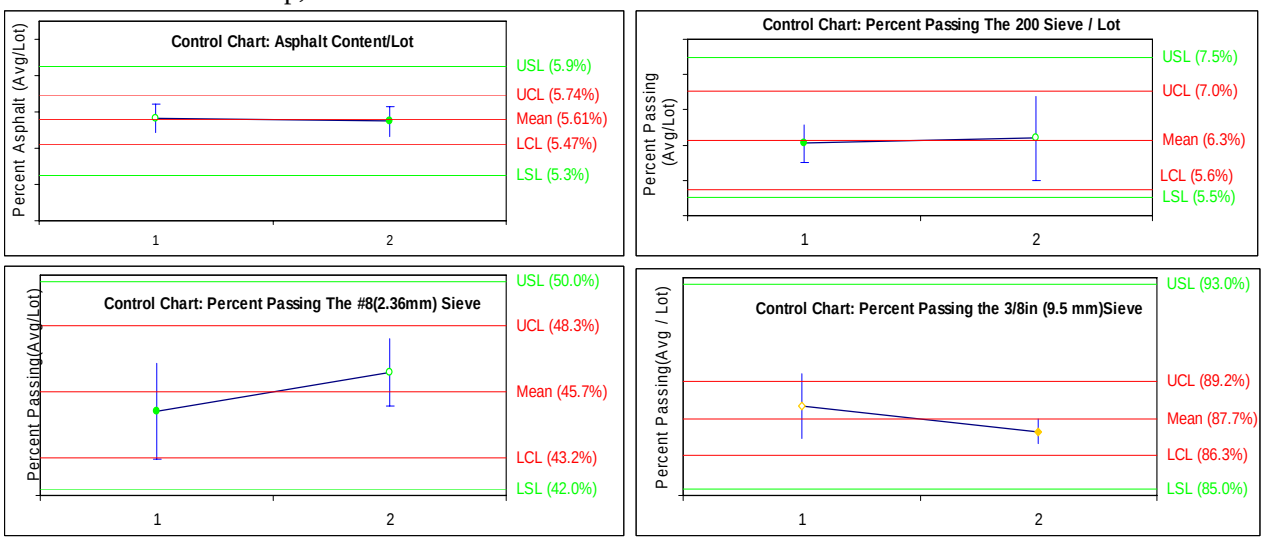

Chart 3: SM-12.5D w/ 25% RAP Control Charts

After two lots of production a process is just beginning to establish and show control and capability, Branscome's limited results on the SM-12.5 with 25% Rap do show that the targets are being met and variability is within specifications.

SM-12.5D with 15% Rap, Mix 712:

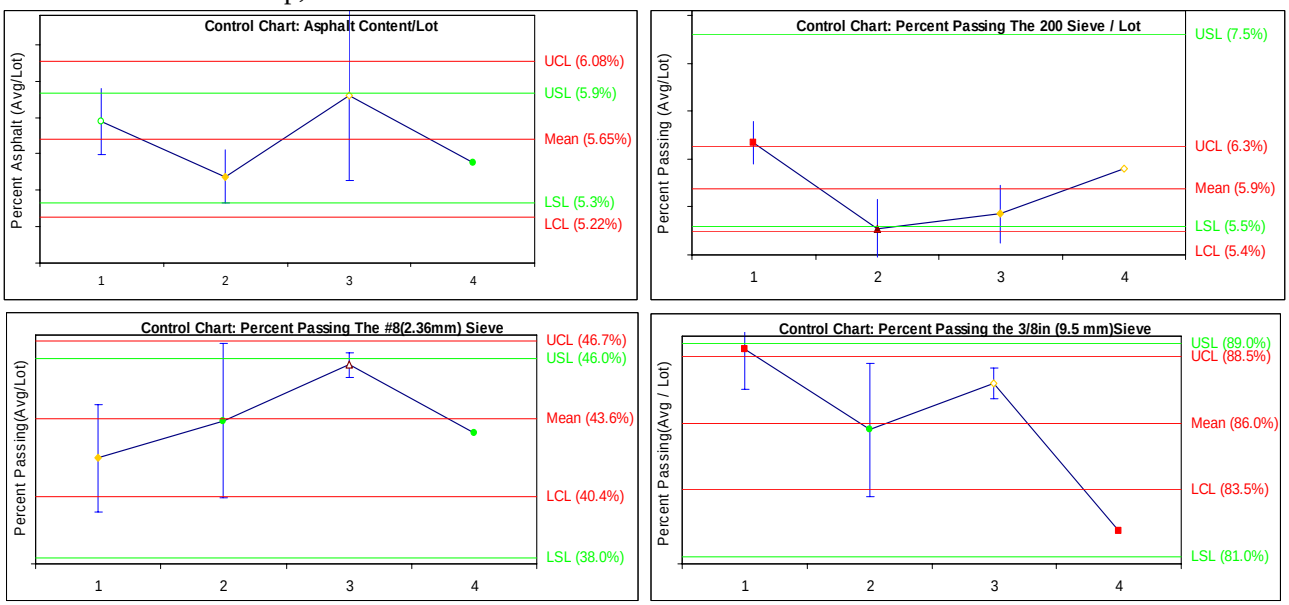

Chart 4: SM-12.5D w/ 15% RAP Control Charts

After three lots of production it can not be said that the SM-12.5D w/ 15% Rap mix had established control or is capable of meeting the specifications. It can be roughly estimated by comparing the control limits to the specification limits that 4.8% of the material was outside of

specifications for AC content, 1.1% outside on the #8 sieve and 0.38% outside on the 200 sieve. From a review of the individual test points and the job mix design information it appears that the variations are due to the contractor adjusting his target AC content and component percentages within the specifications and the fact the design includes and is therefore dependent on the variability of only three component materials.

IM-19.0D with 30% RAP, Mix 738:

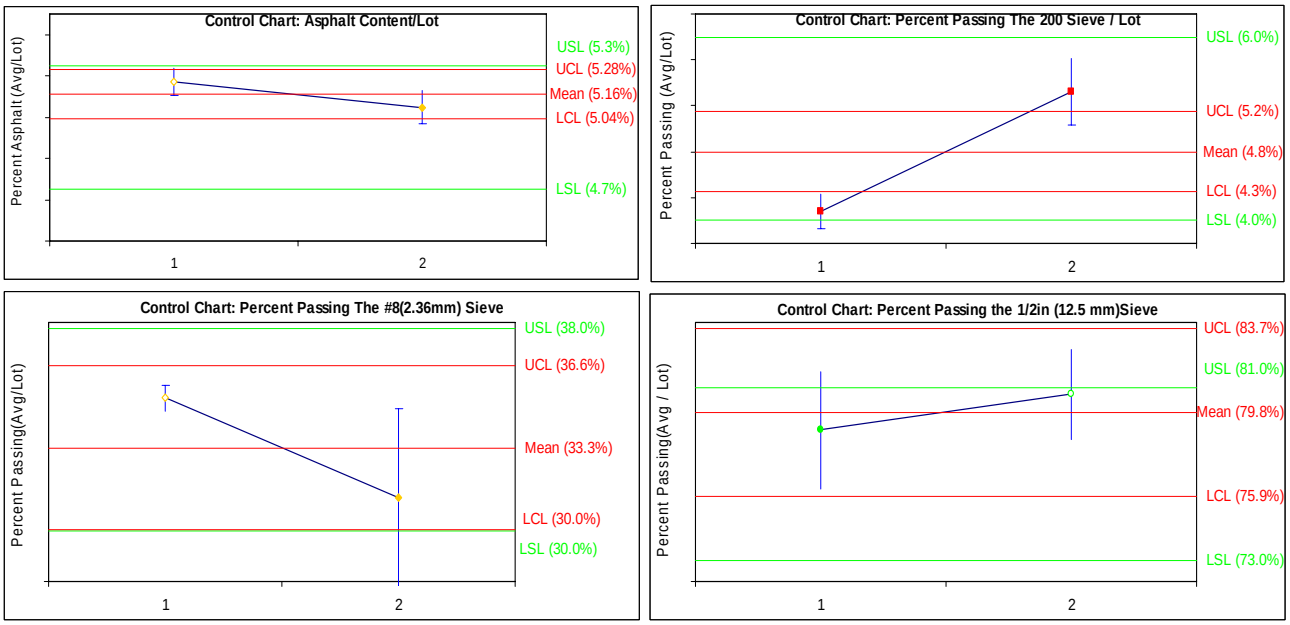

Chart 5: IM-19.0D w/ 30% RAP Control Charts

IM-19.0D with 20% RAP, Mix 716

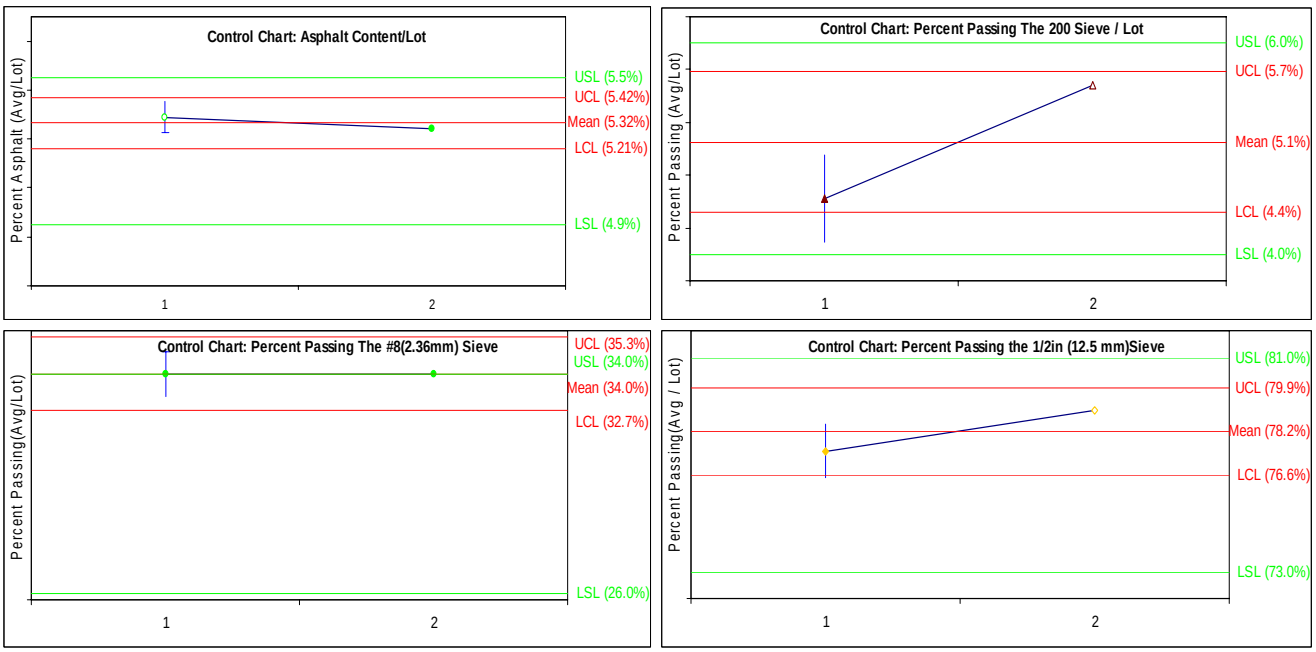

Chart 6: IM-19.0D w/ 20% RAP Control Charts

Neither IM-19.0 mix had enough information to make strong conclusions on the processes control or the ability of the contractor to meet specifications with the process. During production either initial adjustments were being made to the mix or component materials were changing and adjustments were not being made to account for this variability. Similar in structure to the SM-12.5 mixes, only three component materials were being used in both IM-19.0 mixes and the process becomes dependent on the variability of those components.

Table 8 details the results of the contractor and VDOT's Richmond District testing for the full production cycle of the SM-12.5D with 25% Rap, Mix 739:

Test Item	Mix Design	Accept Range	Producer Results			Monitor Results		
			N	Xbar	s	N	Xbar	s
19 mm	100	100	9	100.0%	0.00%	1	100%	-
12.5 mm	96	100-92		97.4%	0.73%		98%	-
9.5 mm	89	85-93		87.9%	1.05%		88%	-
4.75 mm								-
2.36 mm	46	42-50		45.8%	1.56%		47%	-
.075 mm	6.5	5.5-7.5		6.33%	0.41%		6.40%	-
Asphalt (%)	5.6	5.3-5.9		5.61%	0.07%		5.60%	-

Table 8: Comparison of VDOT and Contractor Testing

Table 9 details the results of the testing for the full production cycle of the IM 19.0D with 30% RAP, Mix 738. No VDOT production samples were drawn for this mix.

Test Item	Mix Design	Accept Range	Producer Results		
			N	Xbar	s
25 mm	**100.00%**	**100**	**7**	100%	**0**
19 mm	96.00%	100-92		97%	1.07%
12.5 mm	77.00%	81-73		79.71%	2.43%
9.5 mm				69.86%	2.27%
4.75 mm					
2.36 mm	34.00%	38-30		33.57%	2.94%
.075 mm	5.00%	4.0-6.0		4.66%	0.74%
Asphalt (%)	5.00%	4.7-5.3		5.17%	0.09%

Table 9: Contractor Testing

Rut Testing

Samples for measuring the mix's susceptibility to rutting were taken for the IM mix containing higher Rap percentages. The SM-12.5 was not sampled for rut due to plant break down on the night sampling was scheduled. The two conventional mixes used for comparison were not sampled for rut testing. The following table breaks down the testing results.

	Mix 738 IM-19.0 w/ 30% RAP
Date Sampled	08/27/07
Lot #	1
Rut Depth [mm]	2.44mm @ 8.0% Air Voids

Table 10: APA Rut Testing

There is not a VDOT specification on rutting for intermediate mixes, the most stringent rut depth criteria is 3.5mm for VDOT designated E, M and S mixes (polymer modified or stabilized mixes) and this mix would meet that specification for rutting.

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. 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 extraction 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 Steve Marks of Parsons Brinkerhoff, consultant inspectors for the Richmond District. VDOT accepts the field placement of Hot Mix Asphalt based on the average nuclear density reading on 5,000 ft lots referred to as test sections. A nuclear target for the test sections 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 (% Gmm)	Minimum Production Density (% of Nuclear Target)
270 to 350°F	92.2	98.0 to 102.0

The nuclear target and test section densities determined for the SM 12.5D with 25% RAP and IM 19.0D with 30% RAP are shown in the Table 11. Results for the IM 19.0D mix ranged from 99.0 to 100% of the established target. Results for the SM 12.5D ranged from 99.0 to 100.7% of the established target. All test sections resulted in 100% pay for the contractor based on percentage of the target nuclear control strip density. The %G_{mm} of target verification of cores was not provided for the IM-19.0D mix. The density of one core cut in Lot 1 for the SM 12.5D mix was verified and reported as 97.1% of G_{mm}.

Date of Test	Layer	Target Nuclear Density –control strip (lb/ft^3)	Test Section Density (lb/ft^3)	% of Target nuclear density
8/23/07	IM -19.0D	142.8	141.4	99.0
8/23/07	IM-19.0D	142.8	142.7	99.9
8/24/07	SM -12.5D	141.2	141.6	100.0
8/23/07	SM -12.5D	141.2	141.3	100.0
8/29/07	SM -12.5D	141.2	142.2	100.7
8/30/07	SM-12.5D	141.2	141.7	100.4
8/30/07	SM-12.5D	141.2	139.8	99.0

Table 11: Field Acceptance Data

From the data obtained from the placement operations the mix performed adequately throughout the entire production period. It must be mentioned that a portion of the Contract Schedule: PM-

4N-07 for SR-6 E, Goochland County (Mile post 31.81 to 33.37 on the Eastbound lane) was tested for rideability and analyzed according to the Special Provision for Rideability in the contract. The resulting IRI value after the improvement was 77 and 78. The pay adjustment resulting from rideability measured for the two lanes are provided in the Table 12. This information was provided by Richmond District Pavement Management Office.

SECTION FROM	TO	DISTANCE (mi)	WIDTH (feet)	DIRECTION	LANE	PAY ADJUSTMENT
31.81	33.37	1.56	12	EAST	1	-$2,725.65
31.81	33.37	1.56	12	EAST	2	-$2,414.57

Table 12: Rideability Data

TOTAL PAY ADJUSTMENT: -$5,140.22

Visual observation of Route 6 shows there are no distresses recorded after eight months of service.