SMA 2003 - Virginia's Implementation Effort and Results

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ABSTRACT

In 2003, Virginia launched an effort to achieve longer lasting asphalt concrete (AC) surfaces on Interstate and high-volume Primary routes. Instead of using the department's conventional surface mixes (i.e., Superpave®-designed SM 9.5 and SM 12.5), selected projects in 7 Virginia Department of Transportation (VDOT) Districts received Stone Matrix Asphalt (SMA). The expanded SMA implementation included successful installations of multiple gradations (SMA 9.5, 12.5 and 19.0) and binders (PG 70-22 and PG 76-22). Many contractors (and DOT personnel) dealt with a very complicated hot mix asphalt (HMA) technology for the first time, and nearly without exception, they dealt with it successfully.

The enclosed report documents the SMA "implementation initiative" of the 2003-paving season. It discusses the specifications used and reports the quantities and types of mix used. It also summarizes production and research data that were collected over the season, and addresses problems that were encountered and lessons learned. The information in this report will serve as a future reference for engineers, managers and researchers. The detailed volumetric, density, ride quality and other data can be used to develop performance trends for SMA. Additionally, this report identifies areas for future research that may apply the data collected in 2003 to impact specifications locally and nationally. It also provides recommendations on the types of continued pavement testing necessary to track the performance of the SMA.

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EXECUTIVE SUMMARY

In 2003, Virginia launched an effort to achieve longer lasting asphalt concrete (AC) surfaces on Interstate and high-volume Primary routes. Instead of using the department's conventional surface mixes (i.e., Superpave®-designed SM 9.5 and SM 12.5), selected projects in 7 Virginia Department of Transportation (VDOT) Districts received Stone Matrix Asphalt (SMA). The tonnages and types of SMA varied by district, but the overall goal was to achieve pavement surface lives longer than the 8 to 10 years typical with Virginia's dense-graded mixes.

Virginia placed over 180,000 tons of SMA in seven of the nine districts on roads ranging from divided primary to interstate, all of which supported heavy truck traffic. This 2003 expanded deployment included successful installations of multiple gradations (SMA 9.5, 12.5 and 19.0) and binders (PG 70-22 and PG 76-22). Many contractors (and DOT personnel) dealt with a very complicated hot mix asphalt (HMA) technology for the first time, and nearly without exception, they dealt with it successfully. Aggregate supply and the corresponding quality control mechanisms were perhaps the most contentious issues of the 2003 season. Many quarries expressed concern over their ability to produce coarse material that met the stringent limit on allowable flat and elongated (F&E) particles. However, once production began, aggregate suppliers and asphalt producers worked together to produce the needed stockpiles.

For the traveling public, the functional condition of the pavement is critical. SMA has a texture and appearance different than conventional hot mix asphalt concrete surfaces. After the SMA is placed, a shine is present from the higher asphalt content and film thickness. The shine is most noticeable in the morning and evening due to the angle of the sun. As traffic travels over the SMA, the excess AC on the surface is worn off and the shine is reduced. For most SMA sites, this shine was reduced after two or three months. The ride quality of the pavement is the main criteria used by the public to assess performance. The statewide overall ride quality was good (average of 66 in/mi), but this varied within a district and between districts (lowest was 46 in/mi and the highest was 87 in/mi). A main reason for the varied ride quality was the experience of the contractor placing SMA. For several contractors, this was their first experience with SMA. Over time, the ride quality on future projects should be improved. Finally, VDOT and the traveling public are concerned with the safety of the roadway. With the higher AC content, the skid resistance of the surface after paving and over time was monitored. For a few sites, the initial skid resistance was lower than expected (low 20's). However, subsequent testing showed a dramatic increase in skid resistance for all SMA sites (average of 48.6). Therefore, from a

functional condition perspective based on pavement testing and site visits, SMA is meeting VDOT's expectations.

Of course, the true cost-effectiveness of SMA depends on its ability to provide a long life at high levels of service. In addition to monitoring annual distress/condition ratings and any corresponding maintenance requirements, ride quality and friction tests should be conducted to measure the functional service being provided by SMA pavements.

Much of what Virginia is implementing has basis in German SMA technology. The Virginia Transportation Research Council is planning to undertake research to further assess the German and AASHTO SMA to the Virginia HMA construction environment. Specific topics worthy of continued research include smaller top size stone surface mixes, processing and handling of aggregates, polymer modified asphalts, and early-age friction and related "sheen" issues.

Other topics for future research include the use of recycled asphalt (RAP) in SMA pavements. Likewise, the development of tools to help quantify, discourage, and address flushing (fat spots) in SMA pavements may prove worthwhile.

INTRODUCTION

In 2003, Virginia launched an effort to achieve longer lasting asphalt concrete (AC) surfaces on Interstate and high-volume Primary routes. Instead of using the department's conventional surface mixes (i.e., Superpave®-designed SM 9.5 and SM 12.5), selected projects in 7 Virginia Department of Transportation (VDOT) Districts received Stone Matrix Asphalt (SMA). The tonnages and types of SMA varied by district, but the overall goal was to achieve pavement surface lives longer than the 8 to 10 years typical with Virginia's dense-graded mixes.

The purpose of this report is to document the SMA "implementation initiative" of the 2003 paving season – specifications, tonnages and types per district, data collected, problems encountered and lessons learned. The information in this report will serve as a future reference for engineers, managers and researchers. The detailed volumetric, density, ride quality and other data can be used to develop performance trends for SMA placed in Virginia. Additionally, this report identifies areas for future research using the data collected in 2003 that could impact specifications locally and nationally, as well as recommends on the type of continued pavement testing to track the performance of the SMA.

BACKGROUND

Since the early 1990's, Stone Matrix Asphalt (SMA) has been used in the United States. Typically, SMA is used as a surface and/or intermediate asphalt material in the construction and rehabilitation of pavements – flexible, rigid and composite. For many states SMA is becoming the asphalt material of choice on high-volume roadways since it has proven to be durable and rut-resistant - resulting in a longer service life than conventional dense-graded mixes.[1] In the last year, numerous magazine articles have been devoted to SMA. Sessions at the Transportation Research Board's annual meetings and papers at international conferences have featured the benefits of SMA - increased service life, reduced water spray, acceptable friction properties, lower noise and reduced roughness increase over time.[2]

Early SMA Experience

For decades, the Germans have been using SMA on the Autobahn and other highway facilities. The performance of German roads caught the attention of the Federal Highway Administration and other transportation officials in the United States. This attention led to several trips to Germany by numerous transportation and industry officials in 1990. These first trips resulted in several important developments, most notably FHWA forming a SMA Technical Working Group (TWG) to provide guidance in the conversion of the European Stone Mastic Asphalt to the Americanized Stone Matrix Asphalt. Two National Highway Research Program (NCHRP) Projects to develop and validate an American mix design method for SMA soon followed. Both of these research projects were conducted by the National Center for Asphalt Technology (NCAT) at Auburn University. Throughout this period numerous SMA demonstration projects were built by a few state DOTs – most notably Maryland, Georgia and Wisconsin.

Virginia's first demonstration project to gain knowledge in SMA was more on the order of a test section. This test section was placed on US 29 in Lynchburg district in 1992 and was considered a failure. Shortly after this test section the first real SMA project was successfully placed in 1993 on I-66 in Northern Virginia District over a flexible pavement. This placement was the first SMA project in the U.S. to use AC-30 as the asphalt binder instead of AC-20 (most German SMA's of that era used 60-70 pen asphalt binder) . Two years later a group of Virginia, Maryland and Delewareasphalt pavement experts traveled to Germany. The purpose of this trip was to learn more about the mix designs, placement processes, mix types and aggregates used with SMA pavements.

After this trip, several successful SMA installations were achieved. The early notable successes were on a section of I-81 in the Salem District and a section of I-95 in the Fredericksburg District in 1995. The SMA placed on I-81 was laid on a deteriorated jointed concrete pavement (61.5' joint spacing) with moderate to severe faulting and joint deterioration. This was the first SMA multi-lift (surface and intermediate mix) overlay in Virginia. While the surface and intermediate mix used a stiffer binder, it was not polymer modified. Reflective cracks have appeared in the overlay, but the deterioration of the SMA at those cracks was slower when compared to conventional SMA. The SMA between the cracks remains in excellent condition today. Those sections where routine maintenance joint sealing has been performed continue to perform well.

The overlay on I-95 was placed on a composite pavement in poor condition. The underlying AC base mix was also in poor condition. Although cracking from the underlying rigid pavement reflected through the SMA surface, the raveling at those cracks was minimal. Crack sealing was performed after placement of the overlay to reduce the intrusion of water. While problems experienced during production and placement suggested something other than a successful project, the performance exhibited since has been remarkable. Many of these "problems" can be attributed to a general lack of knowledge of SMA appearance, texture and mix characteristics.

In addition to these SMA sites, numerous other SMA locations have been placed around the state since the mid-1990's:

- I-295 Henrico County (composite).
- I-81 Salem District (flexible and Composite)
- I-81 Staunton District (flexible), and
- I-64 Albemarle County (composite).
- I-66 NOVA District (flexible)
- I-95 NOVA District (composite)
- I-195 Downtown Expressway City of Richmond (non VDOT composite pavement).

In all, VDOT has placed over 600,000 tons of SMA since 1995.

Initial SMA Failures

As with any paving material, VDOT has had a few failures with SMA – most notably VDOT's first SMA project on US 29 in Lynchburg District (1992) and I-495 Fairfax County (2000). Upon return from the 1990 Germany trip by the National Technical Working Group, an initial set of specifications was developed. The Lynchburg District volunteered to sponsor a demonstration project in 1992 on US 29. Neither VDOT nor the contractor had any experience with producing or placing the material. The batch plant had trouble handling the fine mineral filler material and fibers, which led to clumping of the materials and flushing (fat spots) on the pavement. Even though most of the original SMA has been milled and replaced, a small portion of the 1992 SMA still exists on US 29.

Like the successful project on I-95 in the Fredericksburg District, the SMA on I-495 was placed on a composite pavement. Unfortunately, the experience was not as successful. That premature failure led to a forensic investigation, which revealed that failure to achieve density yielded a very permeable SMA pavement over a badly deteriorated AC base. Water was able to infiltrate the pavement structure and exacerbate stripping that had already begun. Further lab testing indicated the PG 76-22 binder specified for SMA was not present throughout the project. This project stressed the need for good project selection and proper lab/field inspection and monitoring. However, even with these two failures, the overall performance of SMA statewide has been very positive.

SMA Use Guidelines

Recognizing the potential benefits of SMA, VDOT developed and distributed guidelines to promote the use of SMA in Virginia. These guidelines are similar to those used by the Maryland State Highway Administration (MDSHA)[2], a lead state in the implementation of SMA technologies. For the 2003 paving season, the following guidance was developed with input from the asphalt paving industry and provided to district maintenance and materials personnel to aid in selecting and prescribing SMA projects:

- Routes should have an average annual daily traffic volume greater than 20,000
- Cumulative equivalent single axle loads over a 20-year period exceeding 10 million
- Minimum placement of 5,000 tons.

In addition to these guidelines, other suggestions were made:

- Mill existing AC surface to improve roadway profile and bonding of SMA to existing pavement
- Use of SUPERPAVE® surface mixes on the shoulders may be used to minimize project costs
- Place all SMA sites on one district contract
- Standard application rates for SMA 9.5 and SMA 12.5 of 1.5” and 2” respectively, and Limiting the construction window from May 1 to October 1, 2003 to ensure minimum temperatures are met.

SMA Specifications Used in 2003

Two different SMA Special Provisions were in place during the 2003 calendar year. The first Special Provision was dated August 25, 1999. This SMA Special Provision was a mature version of the initial Special Provision written to switch SMA design and acceptance testing from the Marshall system using a Marshall hammer laboratory compaction system to the Superpave® system using the gyratory compactor. Table 1 presents and contrasts a few of the more important criteria provided in the two special provisions that were relevant during the 2003 construction season. The table also provides the analogous criteria for the preceding "Marshall SMA."

<u>1999 Special Provision</u>

The 1999 SMA Special Provision provided for one SMA surface mix and one intermediate mix. The surface mix gradation was based on the German 16.0 mm mix; the intermediate mix was based on the German 19.0 mm mix. The surface mix called for a minimum 6% asphalt content chosen at an air void level of 3.5% at 100 gyrations. The 3.5% air void level was selected as the midpoint of the air void design and production range (2.5% to 4.5%). The asphalt content of the intermediate mix was set at a minimum of 5.5%, which was also selected at an air void content of 3.5%. The minimum Voids in Mineral Aggregate (VMA) was set at 17.0% for SMA Surface and 16.0% for SMA Intermediate mix. The asphalt binder was either a Performance Graded (PG) 70-22 or a PG 76-22. The weather restrictions for placement of SMA were a minimum ambient and surface temperature of 50ºF. Compaction of the mix required a minimum of three rollers. The minimum size (weight) roller considered necessary to successfully compact SMA was 10 tons. The initial roller pass and subsequent roller passes were all operated in the static mode unless special permission was received from the Engineer. The contractor obtained 4 core samples at random locations specified by the Engineer to perform daily density Acceptance Testing. The average in-place density for a day's production was specified as 94% of the maximum theoretical density of the mix.

Information provide by the VDOT districts indicate that approximately ten SMA overlays were installed under the "1999 Special Provision." These installations included work on I-95 (Schedule PM-6E-02) in Fredericksburg District, which began in 2002, as well as projects in Richmond District on Interstates 64 and 295 (SAAP contract through the Sandston Residency).

<u>2002 Special Provision</u>

The 2002 Special Provision revised several parts of the 1999 special provision. The SMA surface mix gradations in the 1999 spec was modified to provide two finer mixes – a SMA 9.5 and 12.5 mm. The 9.5 mm mix corresponds to the gradations of a German 8.0 mm; the 12.5 mm mix is very similar to the German 11.0 mm mix. The minimum asphalt content was set at 6.5% for the original SMA Surface, this was held constant for the now designated SMA 12.5. The asphalt content of the SMA 9.5 was set at 6.8%. The design asphalt content continued to be selected at an air void level of 3.5% at 100 gyrations. In addition to the original design range for air voids (2.5% to 4.5%), the 2002 provision provided for a production range at 2.0% to 4.0%. The asphalt content of the SMA Intermediate remained at 5.5%. The SMA intermediate mix was designated as a 19.0 mm mix in the 2002 Special Provision. The minimum VMA was set at 18.0% for both SMA 12.5 and SMA 9.5 and the VMA for SMA 19.0 mix was set at 17.0%. In this new Special Provision the PG 76-22 binder had to be polymer modified. This 2002 Special Provision expanded the gradation band on the No. 4 sieve for the SMA 12.5 surface mix by increasing the maximum percentage passing the No. 4 sieve from 28% to 35%. The rollers were now allowed to operate in the vibratory mode at the lowest amplitude and the highest frequency. The number of vibratory passes was limited to a maximum of three (3) passes. The contractor obtained 5 core samples at random locations specified by the Engineer to performed daily density Acceptance Testing. The average in-place density for a day's production was specified as 94.0% of the maximum theoretical density of the mix. Average In place density of 93.9% or less resulted in at least a 15% disincentive. Six possible pay items were included in the special provision. These pay items clearly stated the mix type and the binder required (e.g.- SMA 12.5 (70-22)). A special paragraph at the end of the coarse aggregate subsection of the Materials Section was added to clearly define the point of testing and enforcement of coarse aggregate properties. The minimum amount passing the No. 200 sieve for mineral filler was lowered to 55%.

Mix Parameter	**Marshall**	**1999**	**2002**
Binder Content Surface Intermediate	 6.0 5.5	 6.0 5.5	 6.5* 5.5
Compaction	50 Blows	100 Gyrations	100 Gyrations
Design Void Target	4.0 (Before 95) 3.5	3.5	3.5
Production Void Range	2.5 –5.5 (Before 95) 2.5 – 4.5	2.5 – 4.5	2.5 – 4.5** / 2.0 – 4.0
VMA Surface Intermediate	 17.0 -	 17.0 16.0	 18.0 17.0
Temperature	(60) 50ºF	50ºF	50ºF
Density	94%	94%	94.0 %

Mix Parameter	Marshall	1999	2002
Density Test Mode	Nuclear/Core	Core	Core
Number of Tests Rolling Mode Number Speed	10/4 Static 3 Rollers (95) 3 MPH	4 Static 3 Rollers 3MPH	5 Vibratory or Static 3 Rollers 3 MPH
Mineral Filler	70% Passing No. 200	70% Passing No. 200	55% Passing No. 200

* - Minimum 6.8% for the SMA 9.5

** - Design Void Range

Table 1 – SMA Specification Summary

2003 SMA QUANTITY AND COSTS

Quantity

In 2003, more than 180,000 tons of SMA were contracted through the normal plant mix schedule process. Seven districts awarded contracts to place SMA. An eighth district received bids on a prospective SMA site, but the cost for the material was too high and the bids were rejected. Additionally, more than 75,000 tons of SMA was placed as a result of holdover work from the 2002 paving season. Thus, as described earlier in this report, two SMA specifications were in use during the construction season. Table 2 identifies the amount of SMA placed per district and per specification.

District	SMA Placed (tons)		Specification
	Surface (Type)	Intermediate	
Salem	18,700 (SMA 12.5 (76-22))	6,100 (SMA 19.0 (76-22))	2002
Richmond	18,800 (SMA 12.5 (70-22))	11,500 (SMA 19.0 (70-22))	2002
	53,000 (SMA 12.5 (70-22))	29,500 (SMA 19.0 (70-22))	2000
Hampton Roads	8,000 (SMA 12.5 (76-22))		2002
Fredericksburg	14,500 (SMA 12.5 (76-22))		2002
	10,400 (SMA 12.5 (76-22))		2000
Culpeper	12,600 (SMA 9.5 (70-22))		2002
Staunton	40,500 (SMA 12.5 (76-22)	31,500 (SMA 19.0 (76-22)	2002
Northern Virginia	7,200 (SMA 9.5 (70-22))		2002

Table 2 – SMA Placed in 2003

Specific information on each site is provided in the appendix. Due to weather and paving problems, not all SMA contracted in 2003 was placed.

Costs

A major concern with the use of SMA is cost. The cost for SMA is higher than SUPERPAVE® mixes due to several mix and production/placement differences. The main mix differences are the higher AC content, stone requirements, mineral filler, and fibers. From a production/placement standpoint, the plant must operate at a higher temperature; a fiber machine is required; and paver speeds are generally slower to ensure that density requirements are met.

To quantify the cost differences, an analysis of the maintenance plant mix schedules and SAAP projects was performed. For each contract awarded, the SUPERPAVE® and SMA mix price and quantity was recorded in a spreadsheet. This was only done for SUPERPAVE® mixes used as a surface and had a PG (70–22) "D" designation or a PG (76-22) "E" designation binder (SMA mixes only use PG 70-22 and PG 76-22 binders). Using the contract unit price and the tonnage, an average AC cost weighted by tons was calculated. Table 3 summarizes the weighted average AC cost for those mixes placed during the 2003 paving season in excess of 10,000 tons.

Mix Type	Total Tons	Weighted Average Cost	Maximum Tonnage Cost	Minimum Tonnage Cost
SM-9.5D	552,600	$40.40	$47.81	$33.56
SM-9.5E*	10,000	$46.50	$46.50	$46.50
SMA 9.5 (70-22)	20,700	$49.38	$49.75	$49.15
SM-12.5D	151,300	$37.03	$47.84	$31.05
SMA 12.5 (70-22)	18,800	$49.20	$49.20	$49.20
SMA 12.5 (76-22)	108,000	$57.00	$59.36	$50.00

* - Placed in NOVA on One Schedule

Table 3 – 2003 Statewide SMA and SUPERPAVE® Unit Costs

The cost differential between SM-9.5D and SMA 9.5 (70-22) was approximately $9.00 per ton. These mixes were placed on similar types of roadways (non-interstates) with equivalent traffic control and hours of operations requirements. For the SMA 12.5 (70-22), the statewide average cost compared to the SUPERPAVE® equivalent mix was higher ($12 per ton). While the mix and production/placement factors contributed to part of the cost difference, another major factor was the locations were the SUPERPAVE® and SMA mixes were used. The SUPERPAVE® mixes were used on non-interstate routes where day paving may be allowed. The SMA mixes were used on high-volume interstates where nighttime paving was required with limited hours of operation. Finally, it was difficult to further compare the cost of the SMA and SUPERPAVE® mixes using statewide averages. The cost for AC materials varies greatly across the state. Except for portions of the NOVA, Richmond, Fredericksburg, Culpeper and Hampton Roads Districts, there is very little competition and experienced SMA contractors elsewhere. Additionally, contractors west of the Blue Ridge Mountains must import aggregate for their surface mixes. This adds to the unit cost of HMA materials.

SMA SITE REVIEW

In the Spring of 2004, members from the Materials Division, Research Council, District Materials Sections and Virginia Asphalt Association reviewed the SMA sites placed in 2003 and many of the sites placed prior to 2003. The following sections summarize these reviews.

2003 Activity

Fredericksburg

The on-site visit of projects began in the Fredericksburg District. In Fredericksburg, two new projects on I-95 were reviewed; an approximately 1-mile long SMA 12.5 (76-22) installation on I-95 South Bound in Stafford County, and a nearly 7-mile long SMA 12.5 (76-22) on I-95 North Bound in Caroline. The Stafford County work was new to the 2003 schedule while the Caroline County work was carry-over from the previous season. Both installations appeared to be performing well. Among the notable characteristics of both installations include the use of a tamping-bar screed paver and slightly thicker surface applications (220 pounds per square foot – 2-inch).

Staunton

The second review was conducted in the Staunton District. This review covered 6 job-mixes (surface mixes) and 7 separate projects. All the surface mixes were SMA 12.5 (76-22), and all were placed at 165 psf (1 ½-inch thick). Most of the surface mixes were placed on 2 ½-inches of new SMA 19.0 (70-22), although the Rockbridge County work was simply mill-and-replacement of the surface. Highlights of these projects include the very obvious presence of crushed river gravel (local non-polishing coarse aggregate source - very brown) in several mixes, and residual evidence of a mix production or placement malfunction that produced some fairly serious flushing (see “Lessons Learned”). There are also several examples of imperfect joint work (primarily longitudinal). Still, all projects appeared to be doing well, and there were even cases in which some localized issues (e.g., minor flushing) had resolved themselves under traffic.

Richmond

Richmond’s 2003 activity covered I-64 and I-295 in Henrico, Chesterfield, and Goochland counties. The surface mix applied in Richmond was a 1 ½-inch SMA 12.5 (70-22). Generally speaking, existing continuously reinforced concrete pavements received a 2-inch layer of SMA 19.0 (70-22) before receiving the surface mix, while flexible pavements were simple mill-and replace of the surface. Much of this work is carry-over from a special contract from 2002 and was consequently constructed as per the 1999 Special Provision for SMA. The Richmond surfaces also make use of the less-expensive PG 70-22 binder. Although more likely related to directional (east/west) orientation than binder type and amount, the Richmond projects received some comments concerning the surface "shine." Other characteristics worth noting include early cracking at the approach-slab area near bridges, and some less-than-impressive ride quality issues on several projects. The longitudinal joints were generally very neat and tight however, and most of the surfaces looked at least as good during the Spring 2004 review as they did right after placement in late 2003.

Salem

New SMA surface work in Salem District covered three projects on I-81 in Roanoke and in Botetourt counties. All of the surfaces were SMA 12.5 (76-22) with the Botetourt County work (over jointed concrete) including a SMA 19.0 (76-22) intermediate layer. Generally speaking, the longitudinal joints were neat and tight, and the ride quality was good for these projects. It was not uncommon to find a small fat spot occasionally, and there were some roller-pickup issues identified during the visit. There were two notable local issues with these projects. First, the failure of the producer to provide the specified PG 76-22 binder for a fairly critical portion of the SMA 19.0 leading up to the Botetourt County truck weigh station. The district has duly noted the limits of the discrepancy and will be monitoring the affected pavement section. Second, a section of the northbound passing lane starting at the Botetourt County line had a mix VCA exceeding the dry rodded coarse aggregate VCA that resulted in flushing. Approximately 1,500 feet of pavement had to be milled and replaced.

Culpeper/NOVA

The only two SMA 9.5 (70-22) mixes used in the state last season were produced in the Culpeper District. One of those mixes was placed in the Northern Virginia District (US 29), and the other on two projects in Culpeper (US 29 and US 17). The 9.5mm SMA mixtures were notably finer and generally more uniform. One of the mixes experienced early difficulty with flushing, but the contractor eventually produced an exceptionally smooth and uniform project. Several questions were raised regarding early age skid resistance of the smaller-stone mixes, but more recent skid tests have indicated adequate friction values.

Hampton Roads

Hampton Roads constructed one SMA project last season on a heavily traveled portion of Eastbound US 58 between Suffolk and Portsmouth. The operation was a 1 ½"mill-and-replace with SMA 12.5 (76-22) over an existing composite pavement (jointed concrete base). The mix required numerous trial sections (6) before production was allowed to proceed. Some aggregate white-capping and crushing was observed due to the high-amplitude settings on the compaction equipment. As of Spring 2004, the new surface appears to be functioning adequately, although the underlying joints in the rightmost (travel) lane (heaviest truck traffic) are beginning to reflect through to the surface.

Historical Activity

During the Fredericksburg, Staunton, Richmond, and Salem reviews, there was an opportunity to visit SMA projects from previous years. The performance of much of this earlier work provided the motivation for the expanded deployment of SMA technologies for 2003.

1995 Projects

Highlights from the historical sections included projects from 1995 on I-95 and I-81. Part of the SMA from I-81 was replaced in 2003, and a portion of the I-95 project is scheduled for replacement during the 2004 construction season due to the reduced ride quality resulting from the reflective cracks. Both projects consist of SMA over severely deteriorated jointed concrete pavement. In each case, the cracks have reflected through the SMA surface, but exhibit remarkable resistance to raveling, in spite of obvious continued settlement and faulting from the underlying pavement. Cores taken over transverse cracks (reflective cracks) on I-81 showed various stages of stripping in the SMA intermediate layer; but, the surface as mentioned did not exhibit much raveling. The SMA mixes used on I-81 were not polymer modified; therefore, they were less elastic. With polymer modification and crack sealing, the overall life of the SMA may have been extended. As with I-81 and I-95, the SMA between the reflective cracks is in good to excellent condition.

1996 Projects

Examples of SMA projects from 1996 are present on I-81 north of the 1995 SMA in Botetourt County and I-81 in Rockingham County, as well as on I-295 in Hanover County just north of the Chickahominy river bridge. Like the 1995 work on I-81 in the Salem District, the 1996 material is also covering severely deteriorated jointed concrete pavement. The present-day condition of the northbound work appears to depend on whether the underlying slabs were stabilized before being resurfaced. Slabs under the north end of that work were not undersealed, and the SMA surfaces are suffering as a result. The southbound installation is in notably better shape. However, a repainting of the edge striping over the original shoulder is provoking considerable cracking due to the insufficient pavement structure to support the truck loadings.

The Rockingham county SMA on I-81 was overlaid on approximately two miles of a flexible pavement structure. Two inches of the existing surface was removed and replaced with a SMA surface mix. After eight years of service, this section was starting to exhibit minor cracking.

The Hanover county SMA on I-295 was placed over continuously reinforced concrete pavement (also severely deteriorated), and it is doing quite well. The only notable deficiencies are found at the approach and anchor slab areas near the two bridges on the project.

<u>1998 – 2002 Projects</u>

Additional SMA projects that date since 1996 can be found on I-81 in Rockbridge County, I-81 in Frederick County, I-81 in Augusta County, I-64 in Goochland and Albemarle, and I-95 in Caroline. The most notable distresses on these projects continue to be joint opening and deterioration along the edge striping (due again to mis-placement of the edge striping). The 2001 project in Goochland county exhibits perhaps the most pronounced joint deterioration, but District pavement personnel attribute much of the premature deterioration to "late-season paving" (material was placed in late November). In contrast, the project in Caroline County continues to appear award-worthy.

DATA AND INITIAL FINDINGS

During the SMA implementation effort in 2003, vast amounts of data were captured and further analyzed. These data range from daily/nightly production to Voids in Coarse Aggregate to Skid Resistance. The following sections highlight some of the data collected and some of the results/conclusions drawn.

Production

With many contractors having limited or no experience with the production and placement of SMA, an analysis was performed to determine average production and maximum production. Table 4 summarizes daily (nightly) production totals for the various SMA mixtures placed during the 2003 construction season. The average values do not include production during test strip placement, but do include short nights due to weather or wrap-up work at the end of projects. The highest average, as well as the highest single-day placement quantity was achieved with an SMA 9.5 mix. Of course, the mix associated with these high production rates was placed during the daytime on two projects. Although average daily production was something less than 1000 tons, production close to or just over 1500 tons per night appeared achievable for nearly every mix.

Mix Type	Number of Mixes	Daily Production	
		Average (Tons)	High (Tons)
SMA 9.5 (70-22)	2	1,122	2,123
SMA 12.5 (70-22)	2	1,053	1,646
SMA 12.5 (76-22)	9	796	1,833
SMA 19.0 (70-22)	6	965	1,766
SMA 19.0 (76-22)	1	846	1,122
All Mixes	20	886*	2,123

* Weighted Average

Table 4 – Mix Production

Mix Volumetrics

The volumetric properties of a SMA mix are key indicators of production and placement quality, as well as long-term performance. Table 5 reflects average AC content as measured by the producer, the local VDOT District asphalt labs, and a single sample (per mix) taken by the Research Council. Statewide, there was exceptionally good agreement between the contractor and the VDOT District. The VTRC samples provided similar trends, but were simply too limited to offer a comparable degree of agreement.

Mix Type	Producer		VDOT District		VTRC
	Avg %	Std. Dev.	Avg %	Std. Dev.	Avg %
SMA 9.5 (70-22)	6.56	0.18	6.61	0.16	6.55
SMA 12.5 (70-22)	6.87	0.20	6.90	0.34	7.11
SMA 12.5 (76-22)	6.97	0.20	7.01	0.25	7.27
SMA 19.0 (70-22)	5.95	0.20	5.96	0.33	6.05
SMA 19.0 (76-22)	5.86	0.29	5.75	0.18	6.04

Table 5 – AC Content

The highest liquid asphalt contents were found with the SMA 12.5 (76-22) mixes. The slightly lower average values for the 9.5mm mixes, despite higher minimum values in the specification, are considered reasonable due to the heavier (higher specific gravity) stone used in these two mixes. Specification language for future SMA design allows for more or less AC depending on aggregate specific gravities.

A summary of voids in the mineral aggregate (VMA) is presented in Table 6. Once again, agreement between the Producer and VDOT was very good. VMA, which better depicts the volumetric character of the mix components (unlike percent by weight AC), reflects an expected step down with increasing nominal maximum aggregate size.

Mix Type	Producer		VDOT District		VTRC
	Avg %	Std. Dev.	Avg %	Std. Dev.	Avg %
SMA 9.5 (70-22)	19.1	1.11	19.0	0.97	18.8
SMA 12.5 (70-22)	18.1	0.48	18.5	1.05	18.5
SMA 12.5 (76-22)	17.7	0.63	18.1	0.89	19.2
SMA 19.0 (70-22)	16.5	0.81	16.5	0.69	17.7
SMA 19.0 (76-22)	16.2	0.58	16.2	0.48	18.6

Table 6 – Voids in the Mineral Aggregate (VMA)

Voids in the coarse aggregate (VCA) is summarized in Table 7. A quick review of the relative mix VCA (VCA_{mix}) values as compared to the dry-rodded condition (VCA_{DRC}) suggests that stone-on-stone contact is of little concern for the smaller (9.5mm) and larger (19.0m) SMA mixes. The ratio of VCA_{mix} to VCA_{drc} was much closer to unity, however, for the 12.5mm mixes.

In several instances, the VTRC samples identified mixes that were actually failing VCA, at least on occasion.

Mix Type	VCA_{drc}	Producer		VDOT District		VTRC
		VCA_{mix}	VCA_{mix} (S.D.)	VCA_{mix}	VCA_{mix} (S.D.)	VCA_{mix}
SMA 9.5 (70-22)	42.1	36.2	0.69	36.6	0.91	35.1
SMA 12.5 (70-22)	43.1	40.7	0.73	41.5	1.26	40.3
SMA 12.5 (76-22)	42.3	40.5	1.73	41.1	1.89	42.1
SMA 19.0 (70-22)	42.5	35.8	1.23	35.3	2.11	34.2
SMA 19.0 (76-22)	42.9	34.3	1.42	32.9	1.25	34.2

Table 7 – Voids in Coarse Aggregate (VCA)

Voids in the total mix (VTM) are presented in Table 8. Once again, the producer and VDOT values demonstrated better agreement than that provided by the limited VTRC testing.

Mix Type	Producer		VDOT District		VTRC
	Avg %	Std. Dev.	Avg %	Std. Dev.	Avg %
SMA 9.5 (70-22)	3.5	1.32	2.9	1.33	2.9
SMA 12.5 (70-22)	3.0	0.59	3.2	1.19	2.9
SMA 12.5 (76-22)	2.4	0.66	2.7	1.07	3.2
SMA 19.0 (70-22)	2.5	0.72	2.7	0.98	3.9
SMA 19.0 (76-22)	2.8	0.71	2.9	1.06	5.0
All Mixes	2.7	0.74	2.8	1.08	3.4

Table 8 – Voids in Total Mix (VTM)

Field Density

Under normal circumstances, the producer provides the sole measure of daily field density using 5 cores that are dry-cut from the freshly placed and compacted mat. Unless there are problems suspected or observed, no additional measurements of density are made. Since the VTRC field sampling also included extracting 5 wet cores from a selected test section, an additional independent measure of field density was also available for nearly every mix. Of course, the

VTRC measurements represent a very limited portion of one day's activity and hardly illustrate project-long achievement.

Mix Type	Number of Mixes	Producer		VTRC
		Average (%)	Std. Dev.	Average (%)
SMA 9.5 (70-22)	2	96.0	1.07	93.2
SMA 12.5 (70-22)	2	94.8	0.61	94.2
SMA 12.5 (76-22)	9	95.2	1.03	95.7
SMA 19.0 (70-22)	6	94.7	0.57	93.6
SMA 19.0 (76-22)	1	96.3	1.37	96.0
All Mixes	20	95.1	0.87	94.6

Table 9 – Field Density

Field/Lab Permeability

Permeability measurements were part of the regiment of field and lab tests conducted by the VTRC. For the field permeability tests, five measurements were made immediately prior to (and on top of) the cores that were to be extracted. The test was conducted using an NCAT permeameter. The cores taken were later subjected to a lab permeability tests (VTM 120). Typically, the results of permeability tests were very conclusive. A test location or specimen either passed VDOT's proposed permeability limit (125x10-5) or it failed by a significant margin. For that reason, average permeability numbers for a given mix would reveal very little (very high failing numbers tend to result in inflated average numbers). For that reason, the number of locations/cores that passed among the 5 tests conducted per project is more meaningful than the average permeability value. For Table 10, the values reported as "passing" represent an average for all the mixes of that type. For the SMA 9.5 (70-22) for example, these values represent 2 projects and a total of 10 tests. For the 2003 season, the SMA 12.5 (76-22) was the most consistent performer statewide with an average of 4 locations/cores passing the proposed limit for every 5 tests run. Because of the exaggerated surface texture of the 19.0mm mixes, it was nearly impossible to seat the field permeameter and results are considered suspect at best. The lab tests, however, should provide a fair indicator of a mix's permeability.

Note that, as expected, permeability generally followed the core void content. That is, low void levels (high density) generally corresponded with a higher percentage of passing cores.

Mix Type	Permeability		Core Void Level	
	Field, No. Passing	Lab, No. Passing	No. Passing	Avg (%)
SMA 9.5 (70-22)	2	3	2	6.8
SMA 12.5 (70-22)	2	2	3	5.8
SMA 12.5 (76-22)	4	4	4	4.8
SMA 19.0 (70-22)	0	1	2	6.2
SMA 19.0 (76-22)	0	5	5	4.0

Table 10 – VTRC Permeability and Void Content Results

Flat and/or Elongated Particles

VTRC Sampling

In addition to hot-mix bag samples and the cores extracted from the newly placed mat, the VTRC sampling also included material from each of the coarse aggregate stockpiles identified in the respective job-mixes. Standard aggregate flatness and elongation (F/E) tests were conducted on both the raw aggregate material and the mixed material after a furnace burn. Table 11 summarizes the results by mix type. The "Calculated Values" mathematically blend test results from the raw aggregate material to provide theoretical F/E content for the mix. The "Mix Values" reflect the test results from the extracted coarse aggregate of the already blended hot-mix. Generally speaking, the 5 to 1 criterion was a non-issue, and most stockpiles met the F/E criteria for allowable 3 to 1 content. However, there was one SMA 19.0 (70-22) that exceeded the 3 to 1 criteria on the "mix," as well as for one source material, and at least two instances in which one source material failed the 3 to 1 criteria for SMA 12.5 (76-22) mixes.

Mix Type	No. Stockpiles Tested	Calculated Value 5 to 1	Mix Value 5 to 1	Calculated Value 3 to 1	Mix Value 3 to 1
SMA 9.5 (70-22)	4	1.3	0.5	14.0	12.8
SMA 12.5 (70-22)	4	0.4	1.1	14.4	12.0
SMA 12.5 (76-22)	34	0.7	0.5	12.5	12.4
SMA 19.0 (70-22)	10	0.6	0.6	15.5	15.0
SMA 19.0 (76-22)	3	1.0	1.5	16.2	14.7
All Mixes	55	0.8	0.8	14.5	13.4

Table 11 – VTRC Flat and Elongated Test Results (5 to 1 tolerance was 5%. 3 to 1 tolerance was 20%)

<u>Production Testing</u>

On the production side, VDOT Materials Labs performed over 100 Flat and Elongated tests during the 2003 SMA implementation. Most of these tests were run prior to production to approve contractor stockpiles and correlate testing variability between VDOT, Aggregate suppliers and Asphalt Contractors. A brief district-by-district summary is provided in the following paragraphs.

Salem District

There were multiple SMA sites paved by one paving contractor. Ten Flat and elongated samples were taken from stockpiles and tested before and during production. All samples and the stockpiles they represented passed the F&E criteria.

Staunton District

There were three SMA maintenance projects last year involving two contractors. Two projects produced both surface and intermediate mix. One project involved seventeen tests by VDOT and the contractor to establish the best procedure for processing the stone to obtain stockpiles that met the flat and elongated criteria. Eleven samples were tested by VDOT, five before production to qualify stockpiles, and then six more after production began. Of the five samples run before production 3 failed, after adjustments 2 passing tests qualified the stockpiles. Once production began six samples were tested with the first two passing. The next two samples taken during production failed and adjustments to crushing operation had to be made. Two samples taken after these adjustments were made demonstrated compliance with the specification. Two production samples on the surface mix passed the F&E criteria. On the other two projects initial testing of stockpiles by VDOT disqualified a source of stone for these projects. The contractor was forced to run numerous tests to establish specification compliant stockpiles of stone for these projects. Over a three-week period of production six tests were run on the stockpiles. The first three samples on stockpiles passed and the fourth failed. Once adjustments were made two more samples were taken from the failing aggregate size stockpile during production and both of these passed.

Richmond District

There were two SMA maintenance projects last year. On Project A, 11 Flat and Elongated tests were performed on stockpiles. Six tests were run prior to production and five were run during production. All eleven passed the F&E criteria. Project B had nine tests performed on stockpiles. Four tests were conducted prior to production, with one passing and three failing. Once the stockpiles were approved, five tests were performed during construction with all five passing.

Hampton Roads District

There was one SMA maintenance project last year. On this project five Flat and Elongated tests were performed on stockpiles. Three tests were run prior to production and two were run during production. The three tests conducted prior to production had one passing result and two failing results. Once the stockpiles were approved, two tests were performed during construction with both yielding passing results.

Fredericksburg District

There were two SMA maintenance projects last year. A Contractor located in Richmond District constructed one project. The Flat and Elongated testing data for that project has been included in the Richmond District projects. For the other project, six Flat and Elongated tests were performed. Two tests were conducted prior to production and four during production. All six tests passed.

Culpeper District

There was one SMA maintenance project last year. Before production at least thirty Flat and Elongated samples were tested by VDOT to qualify the aggregate stockpiles. Part of this testing involved several split samples and round robin testing performed by various technicians from VDOT, the Aggregate Supplier and the Asphalt Contractor to confirm failures before rejecting stockpiles. There were 15 failing and confirmed tests before the production stockpiles were approved. Two samples were taken during production and both passed.

NOVA District
There was one SMA maintenance project last year. A Contractor in Culpeper district supplied both the aggregate and the asphalt mixture for this project. On this project fourteen Flat and Elongated tests were performed. Six tests were run prior to production. All six tests failed the F&E criteria. Aggregate was crushed to create new stockpiles. Tests on these new stockpiles passed the criteria. Eight tests were performed during production on the stockpiles and all eight passed.

Ride Quality

All SMA sites were tested for roughness in accordance with the VDOT Special Provision for Rideability and conducted in accordance with the American Society for Testing and Materials (ASTM) standard E950 and the Virginia Test Method (VTM) 106. All testing was conducted within 30 days of completion of the final surface course. Results are reported as International Roughness Index (IRI) units. IRI testing was also conducted on many of the sites in the spring of 2003 before paving, as required by the special provision, where only one lift of surface mix was placed. Follow-up testing was conducted in January 2004 on each of the sites to determine whether the roughness had changed since initial testing and significant traffic had been introduced.

<u>Test Sites</u>
A total of 22 sites consisting of 185 lane-miles were tested for roughness after completion of paving. 114 lane-miles were also tested before paving in accordance with the special provision. The majority of the sites were located on interstate routes (18 sites), while the remainder was located on 4-lane divided primary routes (4 sites). All of the interstate sites and one primary site, US 58 in Hampton Roads, consisted of the 12.5 mm surface mix. The remaining three primary sites, in Culpeper and Northern Virginia consisted of the 9.5 mm surface mix.

<u>Results</u>
After IRI testing conducted on the sites showed a wide disparity in achieved smoothness. Table 12 summarizes the measured IRI for each mix classifications. The weighed statewide average was 66 in/mi. The highest (87 in/mi) and lowest (46 in/mi) average project IRI values were found among the three projects (and 26.34 miles) that represented the SMA 9.5 (70-22) mixes. The

projects that used SMA 12.5 (70-22) did not exhibit the broad range of IRI values (87 to 61 in/mi), but did represent the roughest general category of surface.

SMA Mix	Average IRI (in/mi)	Lane-Mileage Measured (miles)
SMA 9.5 (70-22)	61.3	26.34
SMA 12.5 (70-22)	76.3	55.89
SMA 12.5 (76-22)	61.5	102.19

Table 12 – Average IRI Values by Mix Classification

The ride quality test results were also used to apply VDOT's Special Provision for Rideability, which incorporates incentives and disincentives for smoothness/roughness of the final surface. Table 13 shows the results of the amount paid in incentives/ disincentives for the SMA rideability projects in 2003. It also shows the average percentage improvement based on the results of the before and after rideability testing. As can be expected, the sites with the smallest percent improvement had the greatest disincentives. Statewide, a net disincentive of approximately $50,000 out of a total contract value (surface mix only) of $8.1 million was assessed.

District	**Total Incentive/ Disincentive ($)**	**Percent Improvement***
Salem	$ 16,863.83	32%
Richmond	$ (46,284.70)	17%
Hampton Roads	$ 4,267.50	24%
Fredericksburg	$ 3,581.00	43%
Culpeper	$ 40,164.68	48%
Staunton	$ (50,540.24)	14%
Northern Virginia	$ (17,560.13)	27%
Total	**$ (49,508.06)**	**25%**
*** Applicable to Sites where Before Testing was conducted**		

Table 13 – Incentive/Disincentive & Percent Improvement for Rideability in 2003

Follow-up Rideability Testing

In January 2004, additional testing was conducted on the SMA sites to determine if changes had taken place since initial testing due to traffic and environmental loading. The results show a slight increase in roughness since final paving. This increase in IRI was expected since the testing procedures for monitoring were different than the procedures for ride spec testing. Only one testing pass was made for monitoring; two passes were made for ride spec testing and the lowest value for each 0.01-mile section was used for averaging purposes. The IRI based on monitoring increased from 66 to 68, or about 4 percent. The difference in ride spec and monitoring results was more pronounced for the 9.5 mm mixes, increasing 6 percent, from 61 to 65, while the 12.5 mm mixes increased in IRI by 2 percent, from 67 to 68. Overall, the ride quality had not changed since initial placement.

Skid

With the high AC content (and high film thickness) of SMA mixes, early-age skid resistance was a concern. Friction testing was conducted on the SMA sites beginning in September and October of 2003 and continued through the early part of 2004. Friction testing was conducted in accordance with ASTM E-274 using a bald tire and reported as skid number.

Results

The initial tests showed the average skid number to be considerably lower for the 9.5 mm mixes. The average skid number for the 9.5 mm mixes was 34.0, while the average skid number for the 12.5 mm mixes was 44.1. The subsequent test data show a significant increase in skid number for all mix types. The largest increase occurred with the 9.5 mm mixes, which increased from 34.0 to 46.1(12 skid numbers), between October 2003 and January 2004. The 12.5 mm mixes increased more moderately from 44.1 in October 2003 to 49.5 in February 2004.

The most significant increases in skid number have occurred in the colder months, between November 2003 and February 2004. However, a steady increase in skid number has occurred during each month of testing.

Figure 1 shows the average skid number for each mix type and month tested. As can be seen from the graph, the skid numbers for the PG70-22 surface mixes have essentially leveled off since December, while the PG76-22 mixes continued to show modest increases.

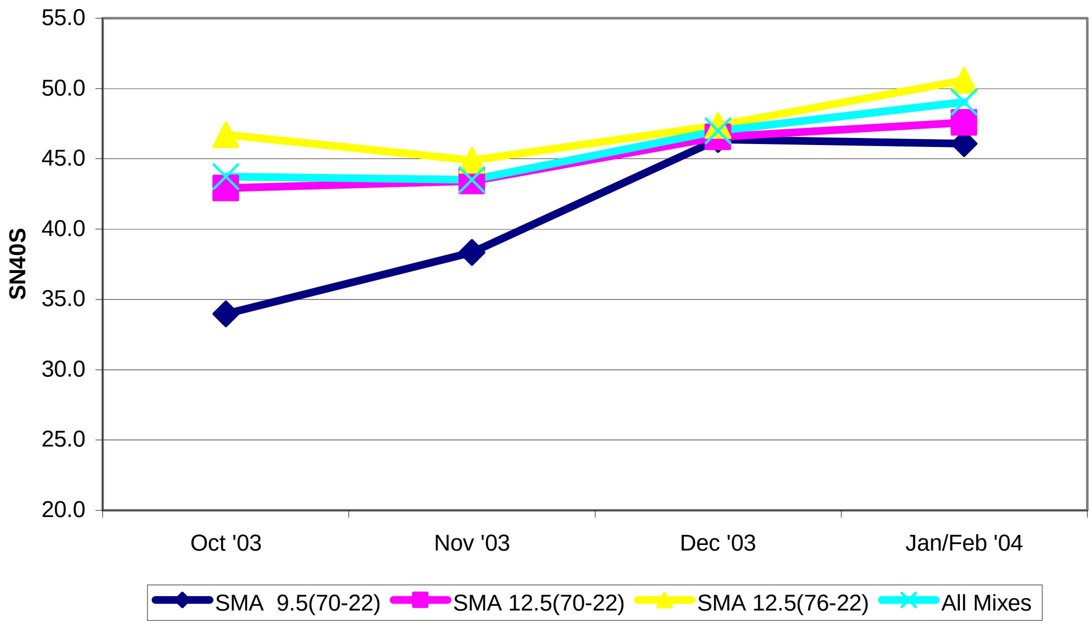

Figure 1 – Friction (SN40S) Change with Accumulated Traffic/Weather.

Conclusion

Overall, the friction numbers are good and have continued to increase with time. The initial low readings on a few sites were conducted shortly after paving and have continued to increase as the traffic has begun to wear off the initial film thickness and expose more of the aggregate texture.

Texture

In addition to ride quality (IRI), VDOT's inertial profiling equipment is capable of characterizing texture. The texture system is proprietary to the International Cybernetics Corporation (supplier of the VDOT profilers), but basically applies a root-mean-square calculation to very high-definition surface profiles to supply estimates of macro-texture. Past experience with this equipment on Virginia hot mix asphalt (HMA) surfaces has found macro-texture readings of 0.75 to 1.25mm for well-compacted 9.5mm dense-graded mixes, and 1.0 to as much as 1.5 for fairly uniform 12.5mm dense-graded mixes[3]. Table 13 emphasizes the considerably higher macro-texture typically provided by SMA surfaces. Note also the "consolidating effect" of traffic as evidenced by the lower average texture values in the wheel-paths. Since all tested surfaces were tested at approximately 3 to 5 months of age, it is difficult to assess the relative resistance of the various mixes to traffic consolidation. Texture will be monitored for some time to determine if binder grade, for example, influences the ability of an SMA to sustain desirable levels of macro-texture.

Mix Type	Left Wheelpath (mm)	Lane Center (mm)	Average (mm)	Early-Age Loss
SMA 9.5 (70-22)	1.61	1.88	1.75	15%
SMA 12.5 (70-22)	2.02	2.46	2.24	18%
SMA 12.5 (76-22)	2.16	2.67	2.42	19%
All Surfaces	2.04	2.49	2.27	18%

Table 14 – Macro-texture Estimates

PROBLEMS ENCOUNTERED AND LESSONS LEARNED

The implementation of SMA in 2003 had several success stories. The overall ride quality was good and the surface friction was high. Most mixes meet all of the volumetric criteria and only a few mixes had borderline to failing flat and elongated aggregate content. While each project may have experienced one or two localized glitches, only a few problems were encountered on a more general basis. The following sections identify those global problems, list probable/possible causes for each problem, and the lessons VDOT and the paving industry learned to eliminate/mitigate those problems.

Plant Issues

Fiber Additive

The high liquid asphalt content of SMA mixtures typically requires the use of a fiber additive to increase the film thickness. Adding fiber at the plant presents a unique challenge. It requires the use of a "fiber dispersion" machine that is interlocked into the plant control system. Essentially, when the fiber machine either runs out of fiber material or breaks, the plant is shutdown automatically. This past year, there were two distinct problems noted. One problem was equipment breakdown, which can be expected but will result in lost production. The other problem encountered was clogging of the feed line for the fibers. The cause was typically the result of a "kinked" line, which would not allow flow of the fibers. In order to reduce the possibility of this happening, it is recommended that the amount of bends in the line be minimized. In addition, a clear piece of tube can be strategically placed in the line to assure visually that the fibers are flowing freely. On night paving, one Contractor placed a light behind the line, which allowed the plant operator to view the fiber flow.

Picture 1 – Fiber Machine

Mineral Filler

Mineral filler is used in conjunction with the binder to form an asphalt mastic/mortar. The material is a very fine graded material that has a tendency to retain moisture. Therefore, it is very important to store this material in a manner to reduce the chance of moisture infiltration. Typically, Contractors have used tarps to cover the mineral filler stockpile. Although the tarps work when covering the stockpiles, there have been occasions when during production, a rainstorm has occurred before the stockpile could be covered. Once the material becomes wet, it is very difficult and in some cases impossible to dry it to a point where it will not be detrimental to the mix. What some contractors are doing now is utilizing sheds to store the mineral filler.

Picture 2 – Storage Facility to Protect Mineral Filler

Picture 3 – Storage Facility to Protect Mineral Filler

Release Agent

As with conventional HMA mixes, a release agent is required to coat the haul-truck bed in order to assure the mixture will not stick to it. The "sticky" nature of SMA mixtures makes this practice even more important. In spite of these requirements, there were cases in which the release agent or its application was not completely successful and drivers were required to spend excessive amounts of time cleaning truck beds. Unfortunately, there were reported cases of drivers resorting to diesel fuel as the release agent, which is not an acceptable practice, whether it is for SMA or conventional mixes. Consequently, it is recommended that producers not load a truck that has used diesel fuel as the release agent. If the truck is already loaded, then the material should be placed in the RAP pile. If approved release agents are not functioning adequately, then No. 10 screenings can be used to dust the truck bed in order to aid in the release of the SMA.

Picture 4 – Application of Release Agent

Flat and Elongated Aggregate

During the 2003 paving season, the growing pains associated with expanded SMA application were not strictly limited to the asphalt producers. Before and during the season, the flat and elongated criteria presented challenges for some coarse aggregate producers. In order to meet the SMA criteria, modifications to existing processes and in some cases, additional equipment was required. Modifications included changing/adjusting stone screens and reprocessing previously crushed stone. Additional equipment consisted of new crushers – vertical impact and cone.

Picture 5 – F&E Testing Device

Field Issues

Flushing Pavement

In producing SMA, it is common to have what are called "fat-spots" in the pavement. These "fat-spots" are evidence of localized flushing of the mix. As a general rule, an occasional fat-spot the size of a dinner plate is considered acceptable. If the fat-spots become larger than a dinner plate or excessive in number, then an investigation into the mix and placement operation needs to be done to determine the cause. The immediate attention and correction, as warranted, of these areas is required due to the possibility of reduced resistance to skidding.

During this past season, there were several instances of flushing pavements. The following case studies present causal and corrective characteristics for commonly observed examples:

Case 1 – Discarding first loads:

A recommended practice when starting to produce SMA is to discard the first loads of material in order to allow the plant to "settle." The number of loads that were discarded ranged from three to six before shipping material to the road. The picture below illustrates the flushing/segregation that can result if the first loads are not discarded.

Picture 6 – Flushing Pavement – Failure to "Waste" First Loads

Case 2 – Wet Mineral Filler

As mentioned before, it is important to keep the mineral filler dry. If the mineral filler becomes wet and is introduced into the mixture, the moisture present will become part of the finished mixture. The result will be flushed areas of various extents, and a consequential loss in supplied friction.

Picture 7 – Close-Up of Flushing – Excessive Moisture in Mineral Filler

Case 3 - Excess Fines or Hydraulic Leak

There was an instance this past season in which the fat spots were large, repeated, and confined to the right wheel path. Follow-up investigation failed to yield any conclusive results as to the cause of the flushing. Speculation was that a build-up of excess fines and asphalt might have been distributed consistently to the right side of the paver. A hydraulic leak of the paver or MTV was also a possibility. Some areas were severe enough to require correction to improve friction values. In this instance, pavement-marking eradicators were used to remove the excessive fine material from the surface.

Picture 8 – Flushing Isolated In Wheelpath After Placement

Picture 9 – Grinding to Correct Flushing in Wheelpath

Roller Pick-up

Roller pick-up with SMA can easily happen due to the "sticky" asphalt mastic and high mix temperature at time of placement. Therefore, it is essential to have a properly operating spray bar on the roller and to ensure that there is adequate water supply. Some contractors have indicated that they have added powdered soap to the water to prevent the mixture from sticking to the roller. Even in doing so, there have been cases of roller pick-up on SMA. In these situations, it is important to stop the roller, clean it, and check the water supply. Continuing on without cleaning will result in additional pickup and a marred surface.

Picture 10 – Roller Pick-Up

Roller Marks in Finished Mat

When compacting an SMA, aggregate interlock should take place within the first two to three passes of the roller. There should be virtually no visible "roll down" beyond these passes. If on subsequent passes, a continued "roll down" is observed, an investigation of the mix should be performed immediately because the aggregate is not interlocking. If after final rolling of the mat is performed and roller marks are still present, then an investigation of lab results should be done to ensure that the stone-on-stone contact was achieved (i.e., is VCA_{mix} less than VCA_{drc}?).

Picture 11 – Roller Marks in Mat

Fractured Aggregate

Currently, specifications allow for no more than three vibratory passes in the high frequency, low amplitude mode. During the 2003 season, the standard number of vibratory passes observed consistently was two. There were some cases where the roller was set in the high frequency, high amplitude setting to try to achieve density. In these cases, the result was fractured aggregate. If the fracturing of the aggregate penetrates beyond the surface, then the load carrying capability of the mix has been compromised. Fractured aggregate on the surface could lead to popouts.

Picture 12 – Fractured Aggregate – Surface

Picture 13 – Fractured Aggregate (Mat Interior)

CONCLUSIONS AND RECOMMENDATIONS

In 2003, Virginia placed over 180,000 tons of SMA in seven of the nine construction districts on roads ranging from divided primary to interstate, all of which supporting heavy truck traffic. This 2003 expanded deployment included successful installations of multiple gradations (SMA 9.5, 12.5 and 19.0) and binders (PG 70-22 and PG 76-22). Many contractors (and DOT personnel) dealt with a very complicated HMA technology for the first time, and nearly without exception, they dealt with it successfully. Aggregate supply and the corresponding quality control mechanisms were perhaps the most contentious issues of the 2003 season. Many quarries expressed concern over their ability to produce coarse material that met the stringent limit on allowable flat and elongated (F&E) particles. However, once production began, aggregate suppliers and asphalt producers had worked together to produce the needed stockpiles.

For the traveling public, the functional condition of the pavement is critical. SMA has a texture and appearance different than conventional hot mix asphalt concrete surfaces. After the SMA is placed, a shine is present from the higher asphalt content and film thickness. The shine is most noticeable in the morning and evening due to the angle of the sun. As traffic travels over the SMA, the excess AC on the surface is worn off and the shine is reduced. For most SMA sites, this shine was reduced after two or three months. The ride quality of the pavement is the main criteria used by the public to assess performance. The statewide overall ride quality was good, but this varied within a district and between districts. A main reason for the varied ride quality was the experience of the contractor placing SMA. For several contractors, this was their first experience with SMA. Over time, the ride quality on future projects should be improved. Finally, VDOT and the traveling public are concerned with the safety of the roadway. With the higher AC content, the skid resistance of the surface after paving and over time was monitored. For a few sites, the initial skid resistance was lower than expected. However, subsequent testing showed a dramatic increase in skid resistance for all SMA sites. Therefore, from a functional condition perspective based on pavement testing and site visits, SMA is meeting VDOT's expectations.

Proposed Future Testing and Research

Of course, the true cost-effectiveness of SMA depends on its ability to provide a long life at high levels of service. In addition to monitoring annual distress/condition ratings and any corresponding maintenance requirements, ride quality and friction tests should be conducted to measure the functional service being provided by SMA pavements.

Much of what Virginia is implementing has basis in German SMA technology. The Virginia Transportation Research Council is planning to undertake research to further assess the German and AASHTO SMA approaches to the Virginia HMA construction environment. Specific topics worthy of continued research include smaller top-size stone surface mixes, processing and handling of aggregates, polymer-modified asphalts, and early-age friction and related "sheen" issues.

Other topics for future research include the use of recycled asphalt (RAP) in SMA pavements. Likewise, the development of tools to help quantify, discourage, and address flushing (fat spots) in SMA pavements may prove worthwhile.

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