

STONE MATRIX ASPHALT SR-524, 64TH AVENUE WEST TO I-5 MP 3.30 TO MP 4.88

WA-RD 504.1

Post Construction Report
November 2000



**Washington State
Department of Transportation**

Washington State Transportation Commission
Planning and Programming Service Center
in cooperation with the U.S. Department of Transportation
Federal Highway Administration

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16. ABSTRACT This report documents the first stone matrix asphalt (SMA) pavement constructed on the Washington State highway system. This documentation includes a brief summary of the required design, production and construction practices, a brief description of the existing pavement, results of a pre-contract meeting, difficulties encountered during the construction project, and lessons learned. It was anticipated that a number of difficulties would occur on this first SMA pavement project, however, through the experience obtained on this project will enhance the construction of future SMA projects.					
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Final Report

STONE MATRIX ASPHALT
SR-524, 64th Avenue West to I-5

by

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Washington State Department of Transportation

Prepared for

Washington State Transportation Commission
Department of Transportation
and in cooperation with
U.S. Department of Transportation
Federal Highway Administration

November 2000

DISCLAIMER

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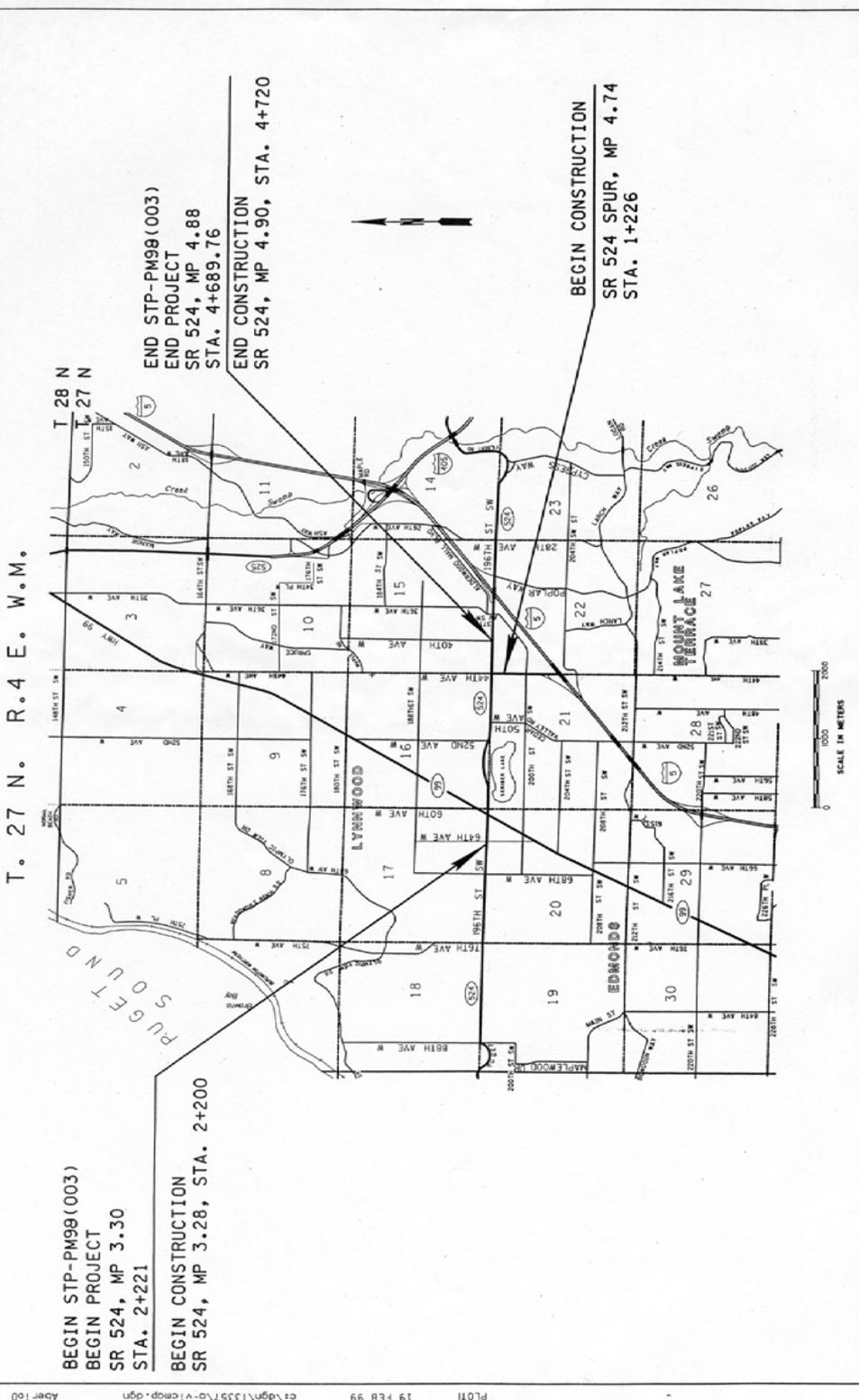
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VICINITY MAP



BEGIN STP-PM98(003)
 BEGIN PROJECT
 SR 524, MP 3.30
 STA. 2+221

BEGIN CONSTRUCTION
 SR 524, MP 3.28, STA. 2+200

END STP-PM98(003)
 END PROJECT
 SR 524, MP 4.88
 STA. 4+689.76

END CONSTRUCTION
 SR 524, MP 4.90, STA. 4+720

BEGIN CONSTRUCTION
 SR 524 SPUR, MP 4.74
 STA. 1+226

DESIGNED BY	B. DUTTINGAN	12/98
ENTERED BY	D. ASERION	12/98
CHECKED BY	G. WORNELL	12/98
APPROVED BY	M. J. OKAMOTO	12/98
REGIONAL	WASH	98A093
CONTRACT NO.		
STATE	FED. AID PROJ. NO.	10 WASH
ENVIRONMENTAL AND ENGINEERING SERVICE CENTER		
Washington State Department of Transportation		
SR 524 64TH AVE W VICINITY TO 40TH AVE W VICINITY		
VICINITY MAP		
VM1		

INTRODUCTION

Stone matrix asphalt (SMA) is a tough, stable, rut-resistant mixture that relies on stone-on-stone contact to provide strength and a rich mortar binder to provide durability [1]. These objectives are usually achieved with a gap-graded aggregate coupled with fiber or polymer modified, and high asphalt content matrix [1]. This process is fairly new in the United States, however over three million tons have been placed since 1991. Even though SMA has a higher cost than conventional dense mixes, approximately 20 to 25 percent, the advantages of longer life (decreased rutting and increased durability), reduced splash and spray, and reduced surface noise may compensate for the added cost. The higher cost of SMA is attributed to the addition of mineral filler, fibers, modified binders, and possible higher asphalt contents. European experience of more than 20 years of using SMA indicates good resistance to both studded-tire wear and rutting [1].

The SMA mixture is composed of aggregate(s), mineral filler, asphalt cement and stabilizer (as necessary). The aggregate gradation for the SMA mixture is on the coarse side of the maximum density line on the 0.45 power chart compared to a dense graded mixture (see Figure 1). Unlike an open-grade mixture, the majority of the voids between the coarse aggregates in a SMA mixture are filled with mineral filler and binder [2]. SMA is typically designed with an air void content between three and four percent. Too much asphalt will push the coarse aggregate particles apart with a drastic reduction in pavement shear deformation resistance. While too little matrix results in high air voids which reduces the pavement durability caused by accelerated aging and moisture damage [3]. In general, a SMA mixture contains approximately 10 percent minus #200 dust with a 1.5 dust to binder ratio. The high percentage of dust can easily be added in the laboratory, however an additional feed system may be needed at the hot-mix plant to

introduce this high amount of mineral filler. The aggregates must have (1) a highly cubic shape and rough texture to resist rutting and movements, (2) a hardness which can resist fracturing under heavy traffic loads, (3) a high resistance to polishing, and (4) a high resistance to abrasion [2].

Potential problems with SMA mixtures are drainage and bleeding. Storage and placement temperatures cannot be lowered to control drainage and bleeding problems due to the difficulty in obtaining the required compaction. Therefore, stabilizing additives such as fibers, rubbers, polymers, Lake Trinidad asphalt, carbon black, artificial silica, or combinations of these materials have been added to stiffen the mastic at high temperatures and to obtain even higher binder contents for increased durability [2]. Fibers (cellulose and rock wool) are commonly used stabilizing additives. Based on aggregate gradation and type of asphalt binder used, it is possible that stabilizing additives may not be necessary. A draindown test procedure (AASHTO T305) has been developed to determine the SMA mixtures susceptibility to draindown.

Figure 2 illustrates the comparison of the aggregate structure for SMA mixtures versus WSDOT standard Class A/B mixture.

As of 1997, 105 SMA projects in 17 states (Alaska, Arkansas, California, Colorado, Georgia, Indiana, Kansas, Maryland, Michigan, Missouri, North Carolina, Nebraska, New Jersey, Ohio, Texas, Virginia, and Wisconsin) had been constructed to date [4]. All of the above projects used a stabilizer (cellulose or mineral fiber) or special asphalt binder to prevent draindown of the asphalt cement.

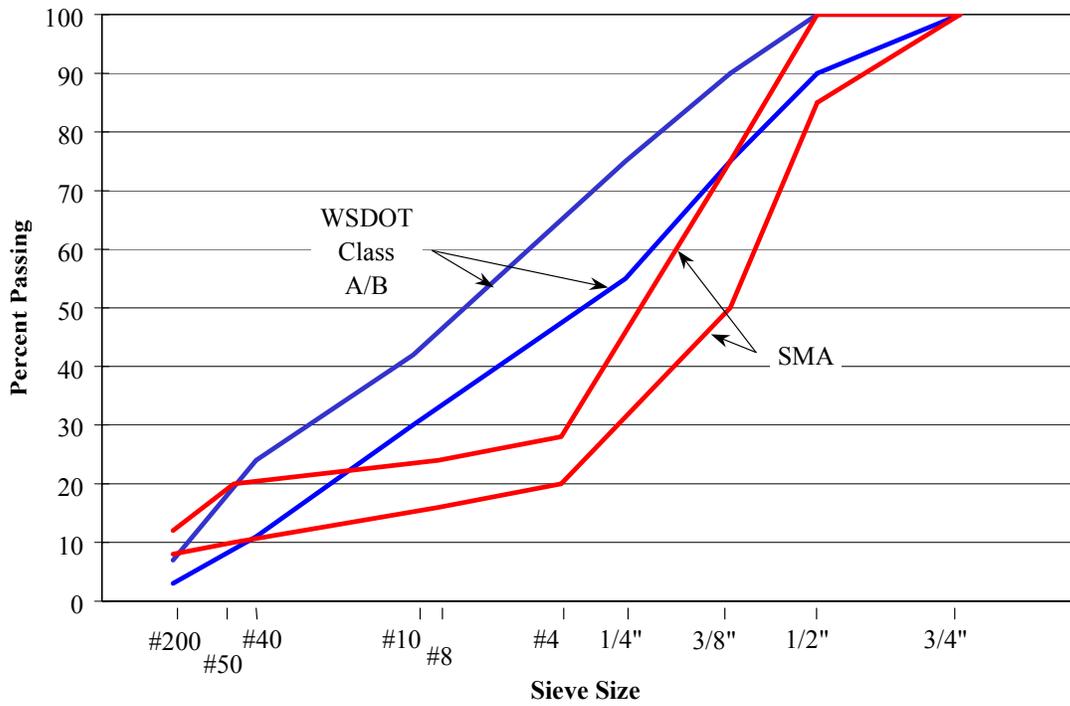


Figure 1. Aggregate gradation band for SMA and WSDOT Class A/B mixes.



SMA



WSDOT Class A/B

Figure 2. SMA and WSDOT dense graded mixture.

The SMA mixture is appropriate on pavements carrying heavy volumes of traffic or on pavements carrying heavy loads and/or high tire pressures. However, due to the stiffness of the mixture and the construction difficulties this brings, selected projects should have minimal utility adjustments or handwork requirements.

REQUIRED DESIGN, PRODUCTION AND CONSTRUCTION PRACTICES

In order for SMA to perform as expected, the following design, production and construction practices must be followed [1].

- Provide stone-on-stone contact through the selection of a proper gradation.
- Use hard, cubical, durable aggregate.
- Design at an asphalt content of at least six percent and air void content of four percent, for most mixtures.
- Design for voids in the mineral aggregate such that at least 17.0 percent is obtained during production.
- Check for and meet moisture susceptibility and draindown requirements.
- Provide proper design and production control of the SMA mixture (asphalt content, gradation, mineral filler, stabilizer, mixing temperature, and moisture).
- Maintain close control of plant stockpiles and cold feed.
- Maintain close control of plant temperatures.
- Maintain consistent paving speed and compaction effort.
 - Use the necessary number of rollers to achieve a minimum density of 94 percent of maximum density.
- Avoid hand work whenever possible.
- Minimize the number and extent (size) of fat spots that appear behind the paver.
- Use good quality assurance practices including frequent monitoring of all aspects of production, paving and compaction.

PROJECT INFORMATION

WSDOT's first SMA was constructed as an overlay project in the Northwest Region, Contract 5626, from 64th Avenue to 40th Avenue on SR 524 (MP 3.30 to MP 4.88), within the Lynnwood city limits. This section of highway is an urban principle arterial with an ADT of approximately 16,000 with three percent trucks. The contract was awarded to CSR, formally Associated Sand and Gravel. The overlay depth for the 12.5 mm (nominal maximum aggregate size) SMA was 45 mm. The total amount of SMA to be placed was approximately 5,800 tons. According to the Washington State Pavement Management System, this project consists of 0.15 to 0.39 feet of asphalt concrete pavement (ACP) over 0.83 to 1.03 feet of untreated base. Figure 3 illustrates the roadway cross-section. In reviewing Figure 3, it is apparent that several past overlays were overlooked for inclusion into the construction history database. The falling weight deflectometer analysis indicates a relatively sound pavement structure and good subgrade support.

The roadway, prior to overlay, was in fair condition, with localized areas of intersection shoving, medium to high severity flushing (wheel paths), raveling (predominately in areas that did not receive an overlay in 1985), and medium severity longitudinal, block and alligator cracking. The average daily traffic for this roadway is 37,000 vehicles with 3.8 percent trucks (estimated 15-year equivalent single axle loads of 1,700,000).

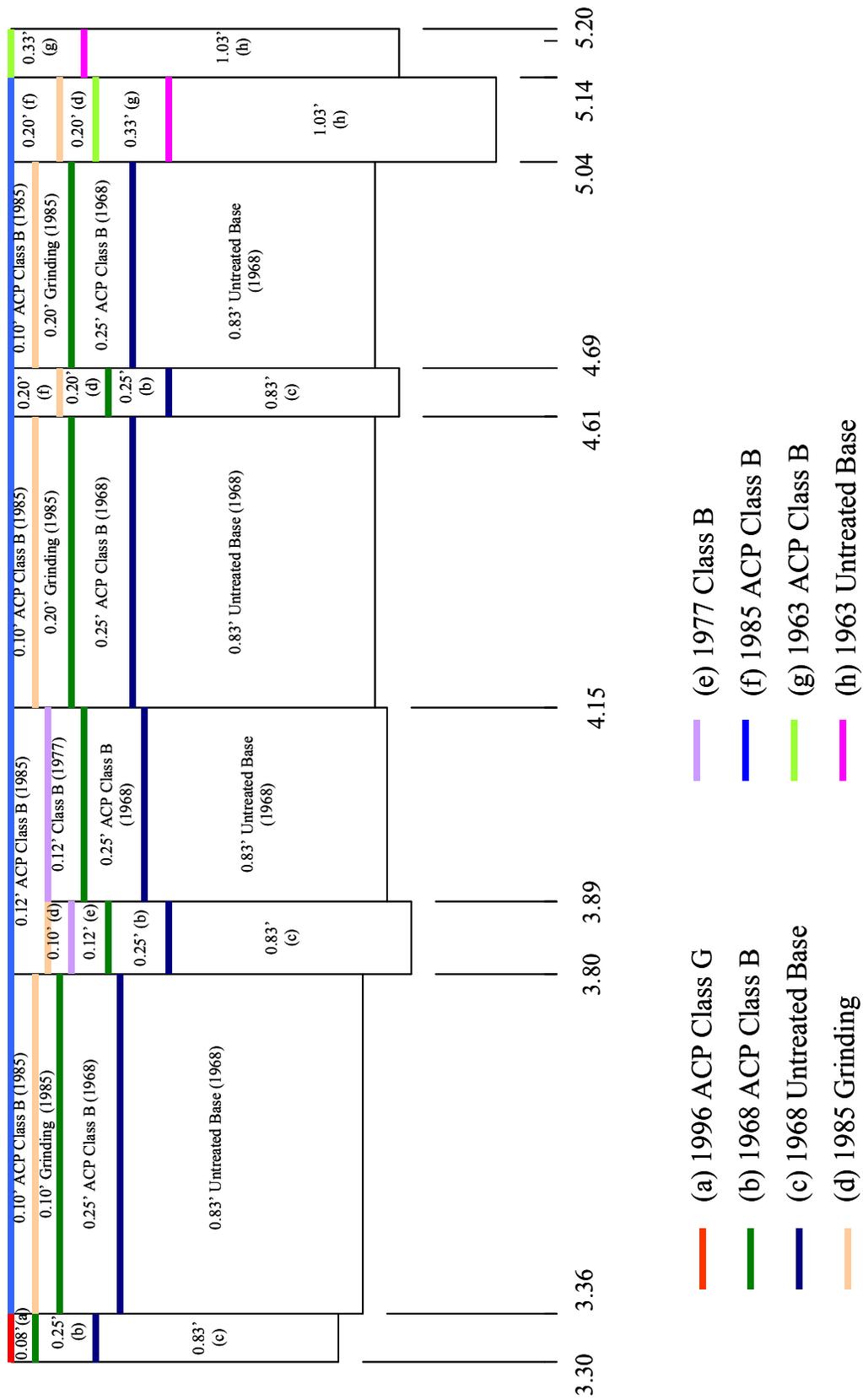


Figure 3. Pavement structural cross section

The Region recommendations for rehabilitation of this roadway included:

- Repairing all block and alligator cracked areas by removing all material to a depth of one foot and replacing with 0.65 ft of ACP over 0.35 ft of crushed surfacing base course.
- Removing 0.20 ft of the existing ACP in the intersections that exhibit shoving.
- Mill 0.15 ft of the existing ACP on the remainder of the roadway, curb line to curb line.
- Crack seal any exposed cracks after the milling operation.
- Tack coat and overlay with 0.15 to 0.20 ft of SMA.

The following photos (provided by Chris Johnson, NWR Materials Laboratory) illustrate the condition of the roadway prior to rehabilitation.



Photo 1. 64th Avenue West. Beginning of overlay project.



Photo 2. Settlement area between 52nd Avenue West and 56th Avenue West.



Photo 3. East end of settlement area looking towards 56th Avenue West.



Photo 4. Typical roadway distress.



Photo 5. Rutting (EB) 44th Avenue West.



Photo 6. WB, west of 37th Avenue West.

PRE-CONTRACT MEETING

Prior to construction, WSDOT hosted a SMA workshop. In attendance were representatives of the Northwest Region Materials Lab, Project Engineers office, FOSSC Materials Lab, and members of the construction industry. Joe Mahoney, University of Washington, presented a brief history of SMA, from the beginning use in Europe to the recent projects in the United States, (see attachment in Appendix A).

Don Watson, Georgia DOT, then talked about Georgia's experience with this complicated mix. Georgia's first project was completed in 1991. This roadway had an average daily traffic

count of 30,000 with 40 percent trucks and after nine years of service continues to perform well. SMA mixtures are being placed on all major interstate and high volume routes in Georgia. Mr. Watson explained the different areas that must be addressed to guarantee a consistent and smooth running operation. Mix gradation and asphalt content are the first area upon which to concentrate. Care should be taken to ensure a consistent aggregate gradation since the main concept of this mix is the stone on stone contact. Thought should also be given to the addition of a polymer modified asphalt, fibers, or both. Tests run in Georgia have shown that the addition of a polymer-modified asphalt doubled the shear strength of the mixture and adding both polymers and fibers doubled the strength again. Once a mix design has been agreed upon, production of a test strip is essential. The test strip is beneficial for equipment calibration, illustrating that compaction can be achieved, and allowing personnel to see how handling of the mix should be accomplished. Both delivery and placement of the mix are also critical for final job quality. Modification of truck delivery may be necessary to maintain mix temperature (insulating truck beds or placing an insulating tarp over the load). Care should also be taken not to use fossil fuel, i.e. diesel, as a release agent for lining truck beds. This will lead to flushing in the SMA due to draindown of the mix.

Pace Jordan, a paving foreman for C. W. Matthews (a Georgia paving contractor), discussed the problems and critical areas for the production of this type of mix. All of Georgia's SMA were produced by drum mixers. The main area to address is the production and control of the different aggregates. Extreme care needs to be taken to minimize segregation. This will ensure a uniform and easy to monitor mix. Prior to production it is suggested that 10 - 20 tons of dry rock be run through the plant to bring it up to mix temperature and be able to maintain it. Once mixing has commenced it is suggested that the mineral filler, fibers, anti-strip, and asphalt

all be added within 18 inches of each other. This will help with the consistency of the mixture. After the days production it is suggested that all silos and mixing drum be thoroughly cleaned out. This can be done by running hot rock through the mixing system to remove any remaining material, and make sure there is no polymer modified material sticking to the sides of the drum. Mr. Jordon also verified a few points brought up earlier by Mr. Watson. These points were (1) timing between production at plant and delivery to the street must be closely coordinated, (2) insulating truck beds and tarping of trucks help maintain mix temperature, and (3) care should be taken in use of an release agent for cleaning truck beds.

PROJECT DIFFICULTIES

Several new and unexpected problems arose during this contract due to the newness of producing, handling and placement of this mix. Most of the problems stemmed from the Contractor's production operation at the batch plant. One problem stemmed from the lack of the contractor's submitted trial blends, which limited the ability of generating an appropriate mix design. The trial blends are used to determine the appropriate combination of coarse and fine aggregate, mineral filler, stabilizing fiber, and asphalt content. The contractor stated that this had been done, but no supporting data was found. The next problem developed due to the Contractor electing to not provide a separate silo and weighing system for the mineral filler. The mineral filler was blended with the No. 4 to dust portion of the blend at the Contractor's concrete blending plant. Another problem arose due to the difficulty in maintaining the mixing temperature. During placement, the contractor had difficulty in applying a consistent rolling pattern and the aggressive compaction that SMA mixtures require.

The following photos indicate the Contractors plant operations and placement of the SMA.



Photo 7. Fibers were added by hand into the pug mill.



Photo 8. Aggregate on the cold feed conveyor. Clumping due to wet mineral filler.

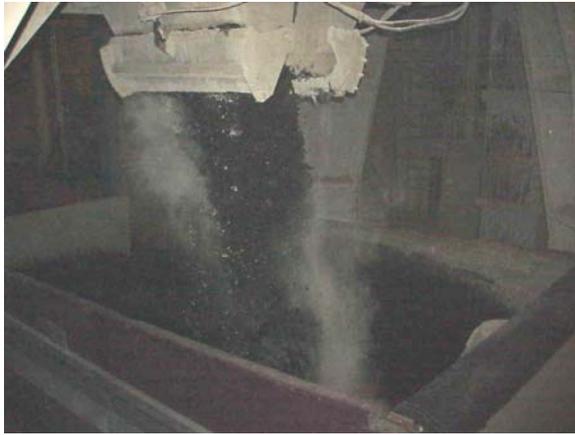


Photo 9. Mix being dumped into truck.



Photo 10. Mix in truck.



Photo 11. Mix paver hopper from Roadtec Shuttlebuggy.



Photo 12. SMA placed on roadway.



Photo 13. SMA surface.



Photo 14. Fat spots due to drain-down.

In order to minimize the potential problems with design, placement and compaction of the SMA, WSDOT received assistance from the Georgia Department of Transportation by having Don Watson present during the paving of the test sections. The following project details are a summary of Mr. Watson's reports (complete construction inspection reports are included in Appendix B).

August 25 – 27, 1999

The first attempt to manufacturer SMA resulted in the need to reduce the asphalt content from 6.5 percent to 6.0 percent. It was also determined that the Contractor needed to assure that the required amount of material passing the No. 200 sieve is achieved. In addition, the Contractor had difficulty controlling the mixing temperature.

August 28, 1999

Three loads were run through the plant and placed on the Contractor's parking lot. For the first two loads, the asphalt content was raised from 6.0 percent to 6.2 percent. For the third load, the asphalt content was left at 6.0 percent and the bin weights were changed to coarsen the mix. The Contractor continued to have difficulty maintaining a consistent

aggregate gradation. However, the Contractor was able to maintain a reasonably consistent mixing temperature.

August 30, 1999 (First Test Section)

Since a separate feed system for the mineral filler was not provided, the Contractor determined that they would not be able to produce a consistent aggregate gradation with the current plant setup. The Contractor suggested several options:

1. Eliminate the sand from the mix.
2. The No. 4 to dust/fly ash could be added through the RAP bin to bypass the bag house altogether, however there is still the possibility of dust surges in the hot bin.
3. Remove the plant screens from the screen deck and place all the material into one bin.

This would keep the dust from accumulating along the bin wall and should eliminate dust surges.

An asphalt content of 5.8 percent was targeted for the first test section. Based on the modifications to the plant, it was determined that additional dust needed to be added to the mix. This was accomplished by increasing the No.4 to dust/fly ash and the 5/8" chips by five percent each and decreasing the 3/8" chips accordingly. This modification resulted in a mix that was very rich in several areas due to drain-down. These spots were located in the wheel path and are generally caused by running the conveyor of the MTV (Roadtec Shuttlebuggy) when the hopper is empty, or by insufficient fiber content. It was found that the MTV operator continued to operate the front conveyor when the unloading bin was empty.

Results of the first test section indicated:

- Low asphalt content.
- High air voids on gyrated samples.

- Low density in the field.
- Excessive drain-down.

Sampling procedures used by state personnel also caused problems with sample testing. Hot mix samples are normally taken at the plant, placed in cardboard boxes, and transported back to the Region laboratory for testing. This normally works fine, but SMA is such a rich mixture that the asphalt was soaking into the cardboard during transportation. When the mixture was tested the asphalt content would show lower than what the contractor was producing. This problem was rectified later by placing samples in greased metal containers.

September 1, 1999 (Second Test Section)

For the start of the second test section, the following modifications were made:

- Increase the fiber content from 0.25 percent to 0.50 percent (contract change order).
- Asphalt samples should be placed in greased metal containers.
- Mix temperature to be kept below 325°F.
- Use a more aggressive roller pattern (two passes vibrating and two passes static with the breakdown roller, two static passes with the intermediate double-drum roller, and two or more passes with the finish roller.
- The Contractor replaced a defective temperature probe that was located at the plant discharge as well as making adjustments to the plant temperature sensor to obtain the correct calibration.
- Wet fly ash was found on the cold feed belt going into the drum, the loader operator was asked to avoid the edges and the bottom of the No. 4 to dust/fly ash, which was found to have enough moisture to cause problems.

Results for the second test section indicated that the asphalt content was 5.72 percent, however, the mix was still low on the percent passing the #200 sieve. The No. 4 to dust/fly ashbin was increased by six percent and the 3/8" chips were decreased by six percent to compensate for the low percentage passing the #200 sieve.

Several isolated spots of drain-down also occurred, it was determined that these spots were caused by the use of diesel fuel for cleaning truck beds and by not allowing them to drain the excess diesel prior to loading. According to the specification, diesel fuel was not to be used for cleaning truck beds.

Results from the nuclear density gauge indicated that density was not being achieved. As a result, the roller pattern was changed to three passes vibrating and one pass static with the breakdown roller. The intermediate and finish rollers made two to three passes each in the static mode. However, with this change, the Contractor was still not aggressive with the rolling operation or consistent with the rolling pattern.

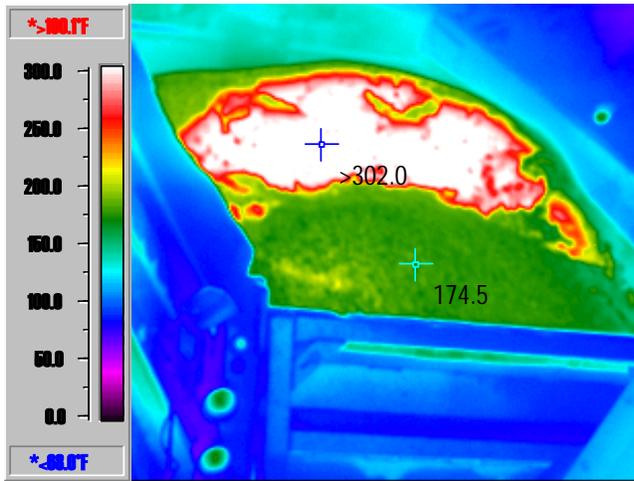
September 2, 1999 (Third Test Section)

At the completion of the third test section, mix compliance was still not obtained, however, since the roadway had already been milled, the pavement surface had to be overlaid to minimize damage to the pavement structure and to improve the customer focused construction. Therefore, the project office agreed to allow production of the SMA as long as target values could be achieved, thereby removing the WSDOT ACP acceptance requirements to meet WSDOT Standard Specifications on ACP acceptance (asphalt content, gradation and density). The target values were established as the final results of the third test section. The following target values were used for mix acceptance:

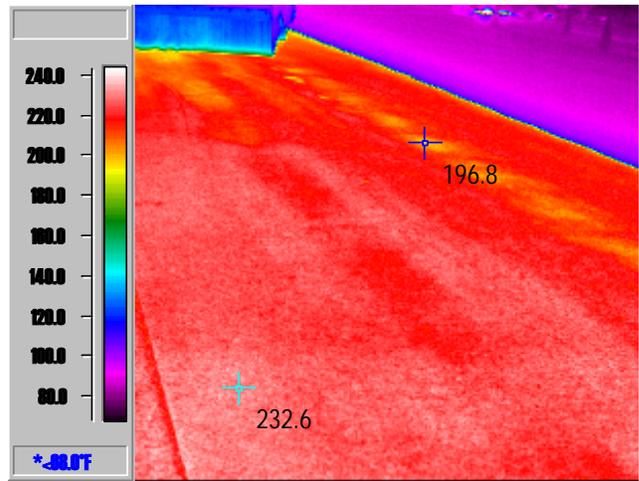
Test	Original Specification	Target Value
VMA	17 minimum	N/A
Oil Content	6.1 %	6.1%
Gradation		
1/2 inch sieve	85 – 100	92
3/8 inch sieve	50 - 75	71
No. 4 sieve	20 – 28	25
No. 8 sieve	16 – 24	20
No. 200 sieve	8 – 12	10
Density	94 percent	94 percent

Overall, draindown of the asphalt and lack of compaction were the main problems, which happened at several locations throughout the project. Several reasons attributed to the asphalt draindown problems. First it was found out that low fiber content was causing draindown in the trucks during transportation. Increasing the fiber content eliminated this problem. The second major cause of the draindown occurred by running the conveyor of the material transfer vehicle (MTV) empty. A third cause of the draindown occurred from the use of diesel to clean the beds without allowing them to drain out properly.

Another problem was attributed to the lack of an aggressive compaction train. The breakdown roller was several 100 feet behind the paver causing low compaction results and allowing the mixture to cool prior to compaction. Typical infrared images are shown in Figures 4 to 6.

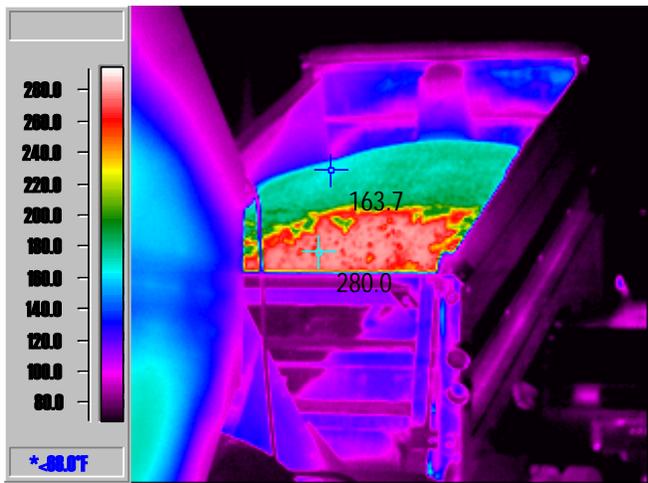


a. SMA mixture in truck bed with temperature differentials of 130°F.

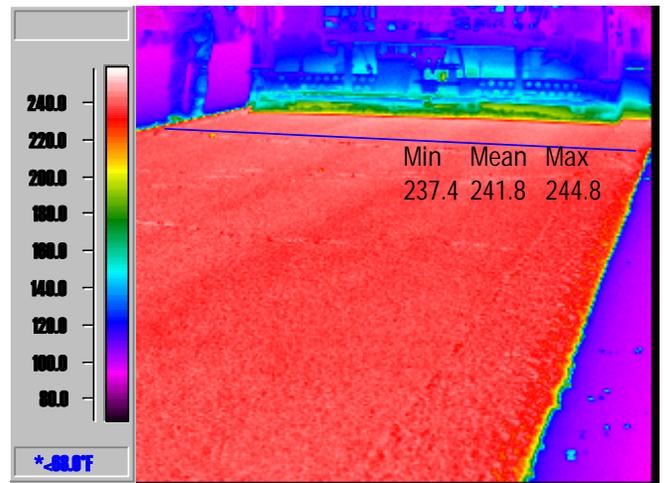


b. SMA mixture immediately after breakdown roller. Cool spots are fat spots.

Figure 4. Infrared images from second test section (9-1-99).

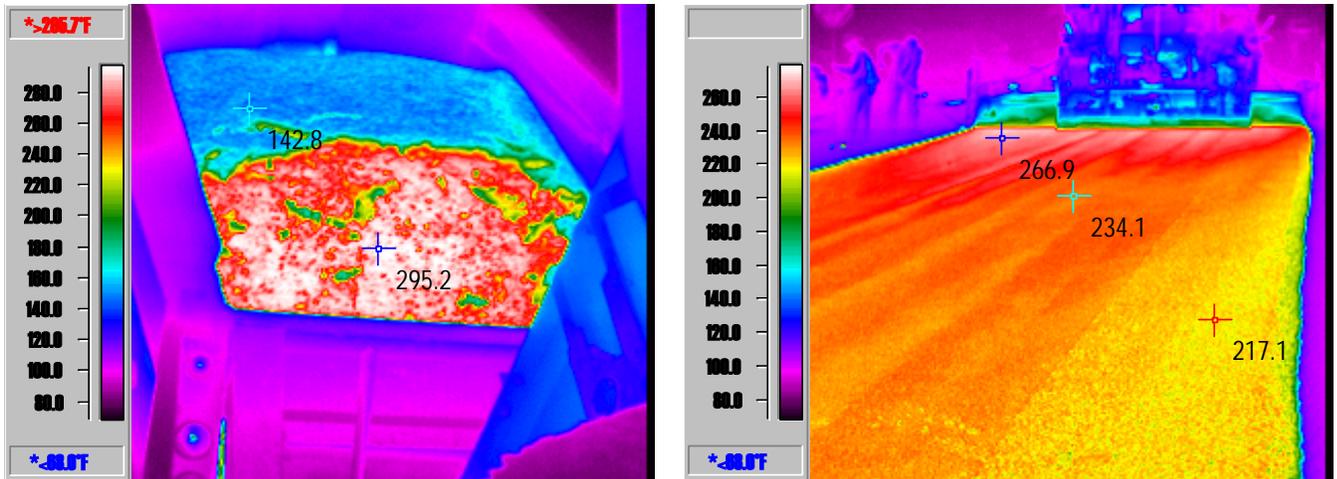


a. SMA mixture in truck bed with temperature differentials of 160°F.



b. Mat is very uniform with only a 7°F temperature differential.

Figure 5. Infrared images during production paving (9-9-1999).



- a. Stone matrix asphalt mixture in truck bed with temperature differentials of 160°F.
- b. Mat is very uniform directly behind the paver, however within about 30 feet the mat has cooled 50°F without being compacted.

Figure 6. Infrared images during production paving (9-15-1999).

Based on the final production values, both the asphalt content and VFA were lower than specified, and the VMA values were within the target values (see Figures 7 through 14). The final pay factors for this project resulted in a 1.0 pay factor with a \$600 bonus, but a \$65,000 penalty due to low asphalt content and low compaction values.

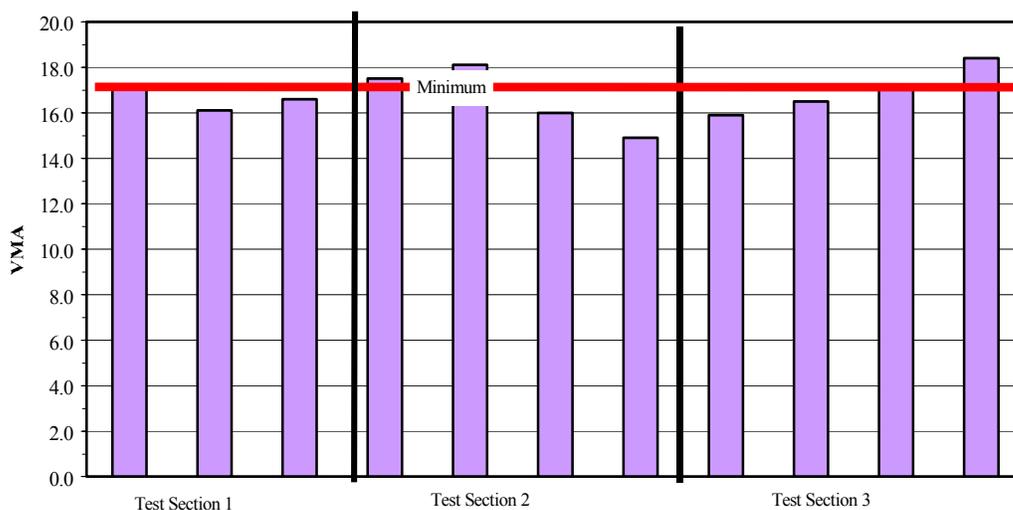


Figure 7. Test Section VMA - gyrotory compacted samples

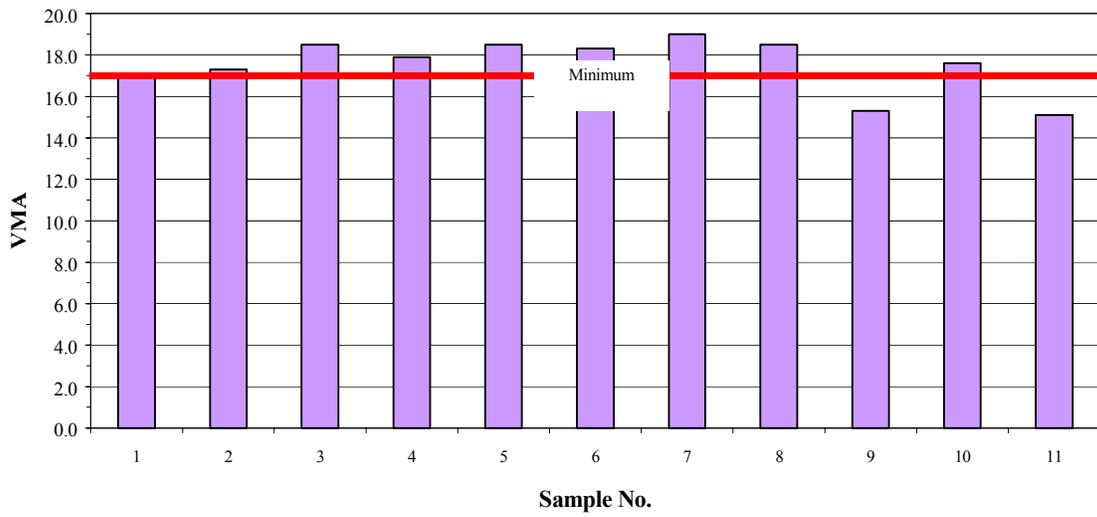


Figure 8. Production VMA - gyrotory compacted samples

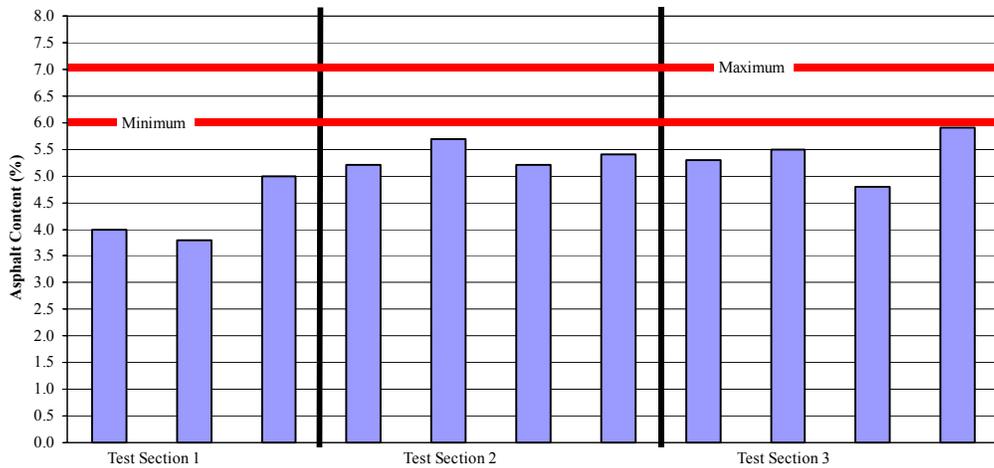


Figure 9. Test section asphalt content – gyrotory compacted samples

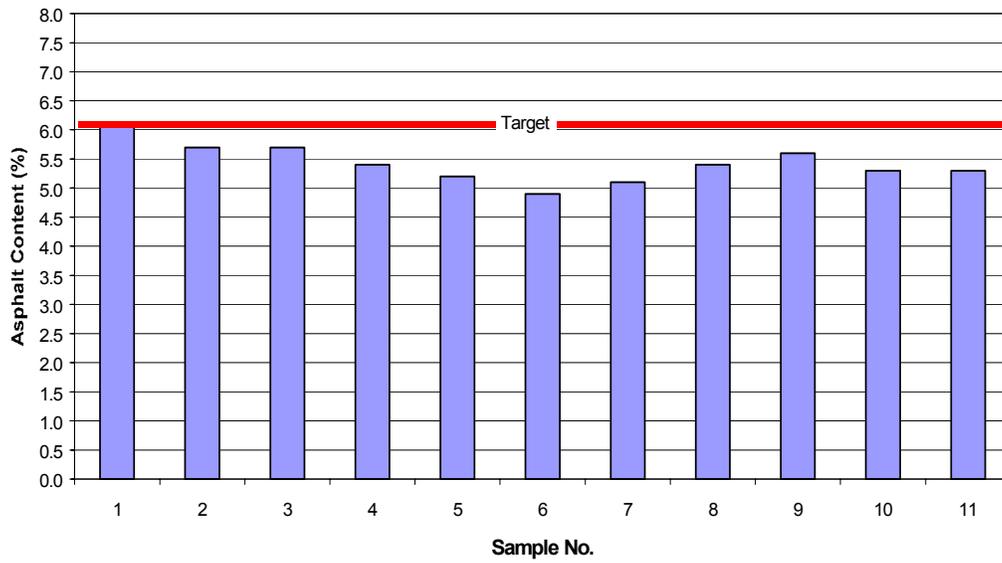


Figure 10. Production asphalt content – gyratory compacted samples

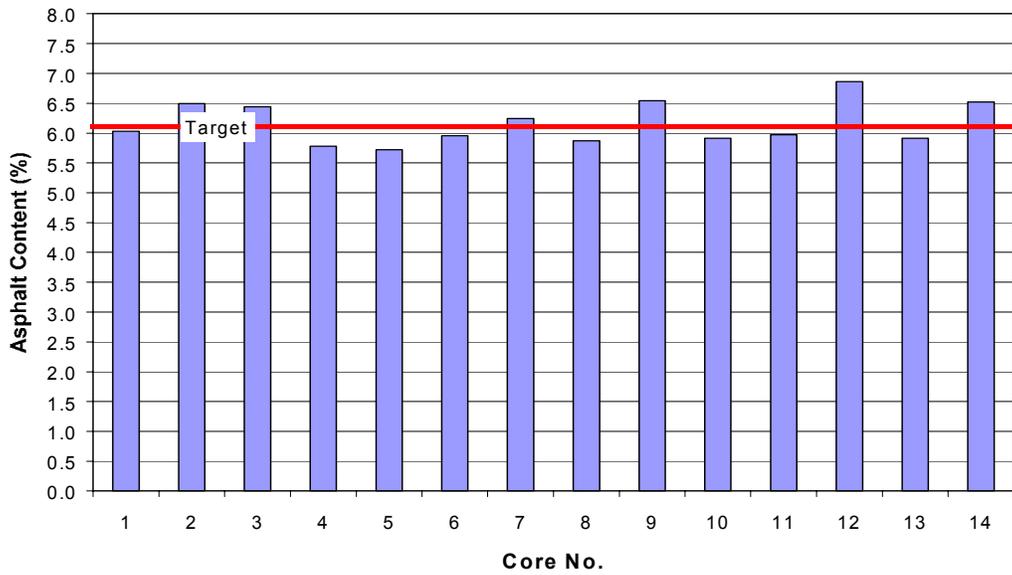


Figure 11. Production asphalt content – core samples

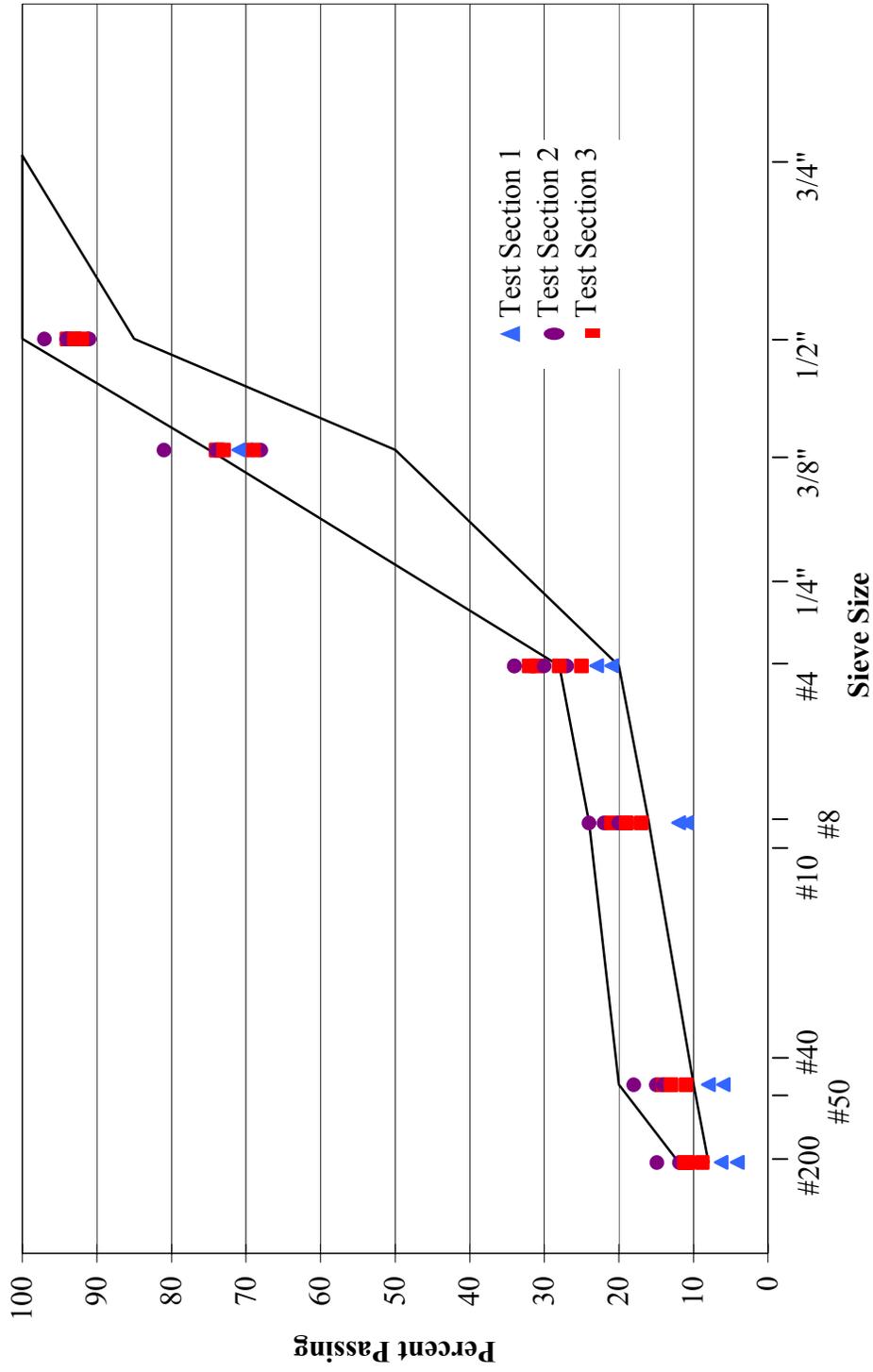


Figure 12. Test section gradation

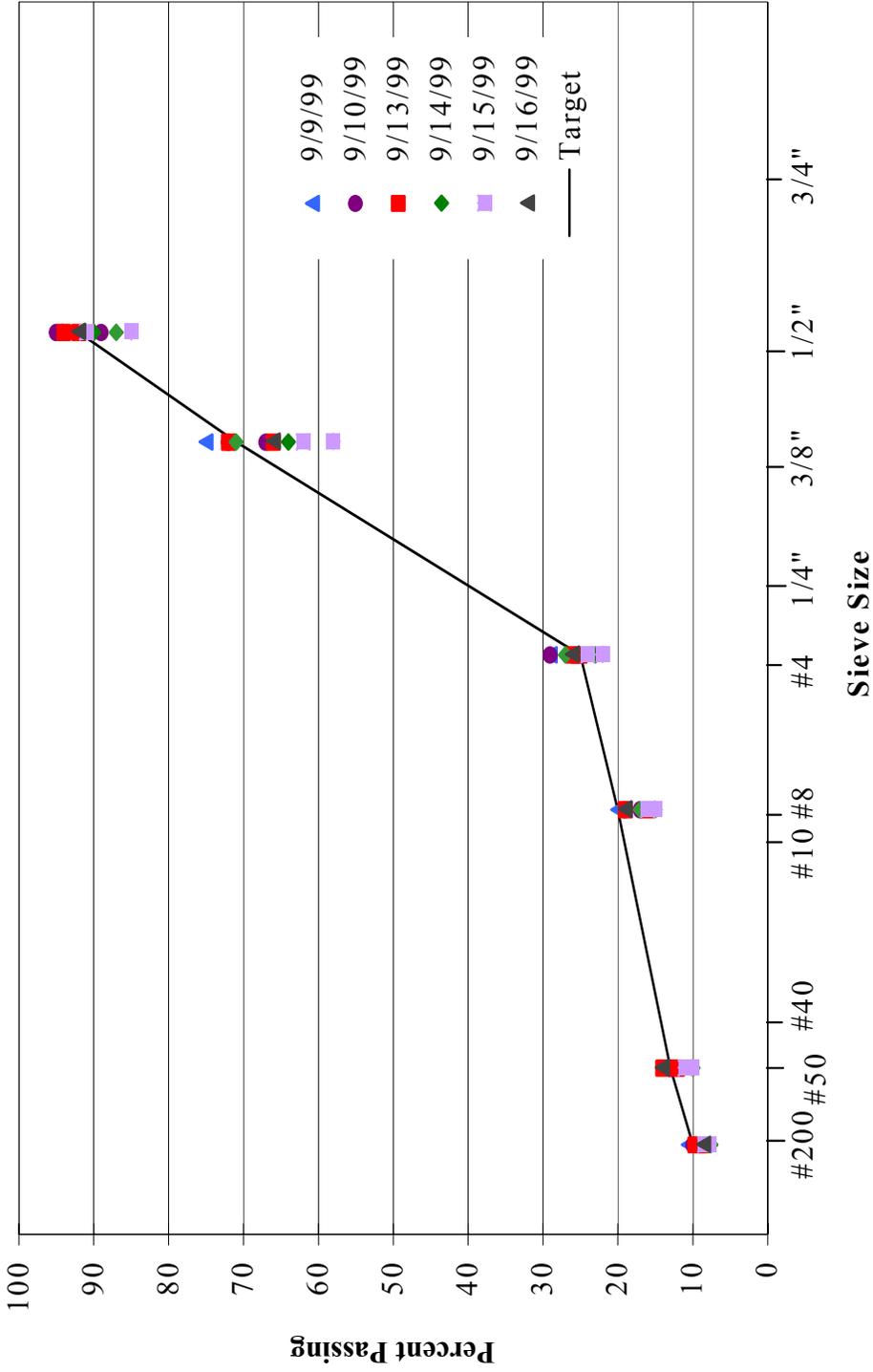


Figure 13. Production gradation

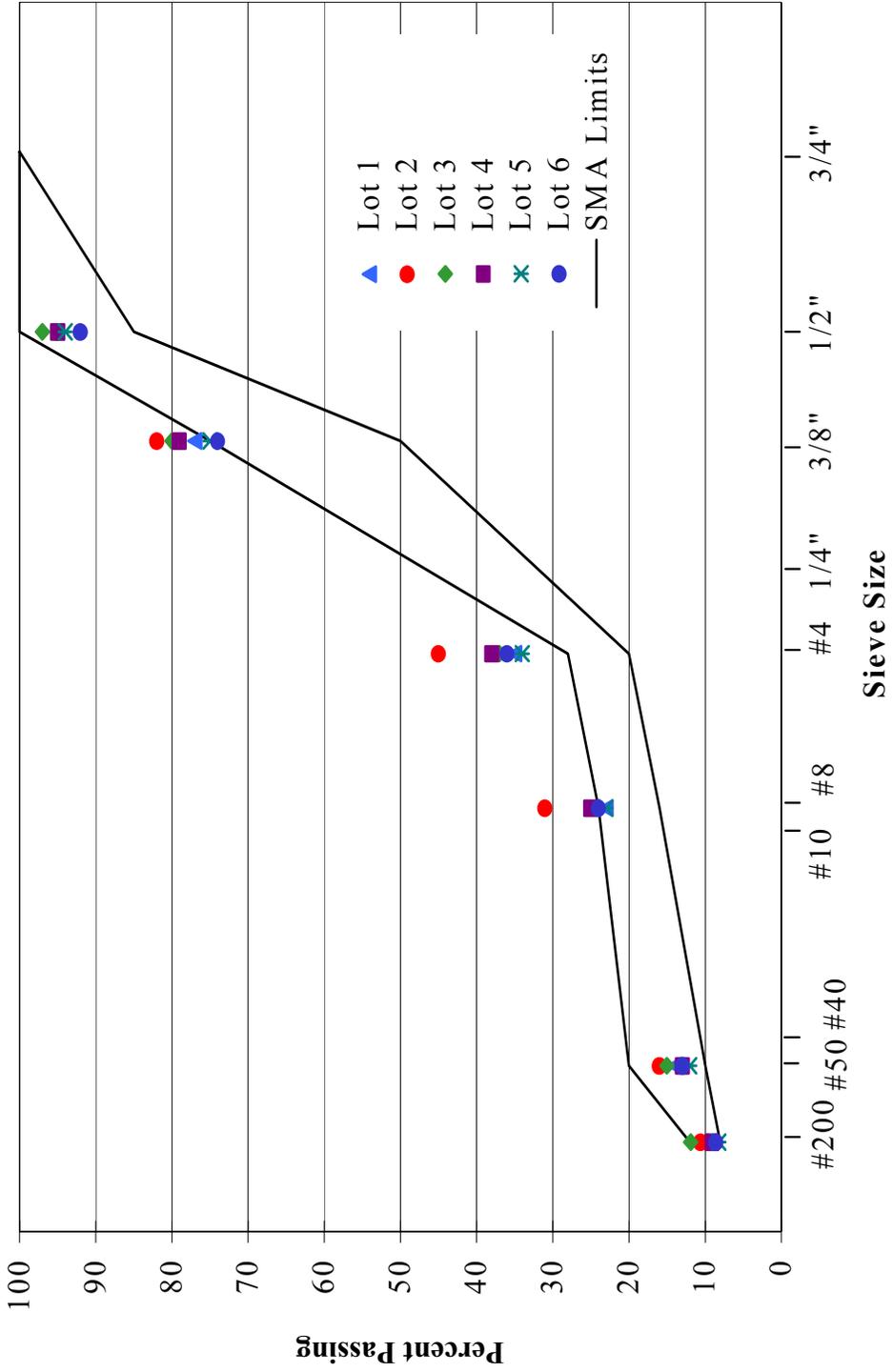


Figure 14. Production gradation – core samples

LESSONS LEARNED

The following is a list of lessons learned from this SMA project:

Design

- Adequate field study is required to ensure that SMA is being placed on sound, stable material (this was demonstrated at the 44th Street intersection where unstable ACP was known to exist and the SMA after one year, in this location only, is starting to rut).
- Clearly define which specific gravity will be used in the design process; this will minimize the conflicts in mix design acceptance.
- The three trial blends must be provided with the mix design recommendations, such that any changes in the mix gradation can be more clearly understood.

Plant Requirements

- Multiple stockpiles are necessary to improve the ability of meeting mix design requirements.
- Separate silo and feed systems are necessary for controlling the amount of mineral filler and stabilizing fibers.
- Plant production temperature must be achieved and maintained to minimize the draindown.
- Inspection and certification of the plant is necessary prior to approval of mix production. This will ensure contractor's ability to produce mix.

Sampling and Testing

- Use greased metal buckets, rather than cardboard boxes for storing mix samples to eliminate loss of asphalt binder.

- Test equipment must be thoroughly cleaned after each use to minimize error in mix design acceptance.

Haul and Laydown

- Do not run conveyors on paving machine or material transfer device empty. This leads to excessive draindown due to the build up of excess oil in the MTV.
- Keep paver moving, excessive stopping and starting may lead to cooling of mix and result in inadequate temperatures for compaction.
- Ensure tack coat has cured prior to paving to minimize the amount of material picked up by delivery trucks.
- Consider the use of insulated trucks and/or tarped trucks to minimize the cooling of the mixture.
- Make sure contractor's compaction personnel are trained and aware of the special needs to keep the compaction train closer to the paver. Aggressive compaction is necessary especially with the breakdown roller.
- Have a good location for trucks to clean out their beds, and stress that fuel oil "NOT" be used. This could also cause excessive draindown.

General Comments

- Construction must not proceed without an approved mix design.
- Conformance with Special Provision must be enforced.
- Communication between the state and contractor must be ensured.

MODIFICATIONS TO WSDOT SPECIAL PROVISIONS

Based on the lessons learned from the first SMA project constructed in Washington State, a number of modifications to the Special Provisions for the SMA mixture were necessary. These

modifications were incorporated into the second SMA project, which will be constructed in the summer of 2000 on Interstate 90 from Ritzville to Tokio. The following is a brief overview of these changes¹.

1. Modifications to mix design requirements.
 - a. Minimum degradation requirement of 30 (WSDOT Test Method 103).
 - b. VMA requirement of 17.5 ± 0.5
 - c. Air void requirement of 3.5 ± 0.5
 - d. AC content requirement of 6.0 (minimum) ± 0.5 percent
 - e. Inclusion for requirements of the voids in the course aggregate (VCA).
 - f. Modifications in the proportions of materials and the basis of acceptance.
 - g. Once the SMA test section has been constructed there will be no paving the following day to allow for analysis of test section results.
2. Prohibit the addition of mineral filler into an aggregate stockpile.
3. Prohibited the use of a conveyor belt system for adding the mineral filler.
4. Stronger language concerning the use of release agents in the delivery trucks. Specifications outlining any truck creating a hazard on the project, or adversely affecting the quality of the work, shall be removed, as directed by the Engineer. In addition, adequate provisions shall be made to assure the mixture will be delivered to the roadway at a temperature differential no lower than 25°F than the recommended compaction temperature specified on the mix design.

¹ For a current version of the WSDOT SMA Specifications please contact Jeff Uhlmeier, Pavement Design Engineer, at 360 709-5485 or uhlmej@wsdot.wa.gov

5. Acceptance testing for compliance of asphalt content will be based on the results from the FOP for AASHTO Test Method T308 and compliance of gradation in accordance with the FOP for AASHTO Test Method T30.

PROJECT COST SUMMARY

It was anticipated, due to the small quantity of SMA and the newness of the technology in Washington State, that the bid price for SMA would be substantially higher than the estimated 20 to 25 percent increase in cost over traditional dense graded mix. This project had three bids submitted by local contractors with a range in SMA mix costs of \$57.50 to \$72.50 per metric ton (\$63.40 to \$79.93 ton). The average mix price for WSDOT Class A ACP in the Northwest Region is \$34.25 per ton (price based on projects with 4,500 to 7,400 tons of ACP Class A). The successful bidder had a cost of \$79.93 per ton, which is approximately 57 percent higher than WSDOT ACP Class A.

A complete listing of the project bid tabulations is contained in Appendix C.

PAVEMENT PERFORMANCE

This pavement has been in service for a little more than one year. To date, the performance of this pavement is very good. However, there are several areas where fat spots have occurred. The 44th Avenue West intersection is showing signs of rutting, but this intersection is known to have unstable mix beneath the SMA. The best option for this intersection would have been reconstruction to remove this unstable asphalt mix, however, due to budgetary constraints; this was not a viable option.

SUMMARY AND CONCLUSION

A great deal of experience in mix design, construction, and inspection was gained on this project. The above mentioned “lessons learned” will be taken forward to the next WSDOT

contract and modifications will be made to the specifications. This project will be monitored over the next 5 to 10 years, as will all SMA pavements placed on the state highway system.

APPENDIX A

AN INTRODUCTION TO SMA'S

Joe Mahoney
University of Washington



An Introduction to SMAs



US: Stone Matrix Asphalt

Europe: Stone Mastic Asphalt



Origin

- Developed in Germany in 1960's as an overlay to achieve a more studded tire resistant pavement (EAST 1990)
- German term "splittmastixasphalt" translates to "stone-filled mastic" or "grit mastic asphalt." Sometimes termed "skeleton asphalt."

Major Features of European SMAs

- Hard, low-penetration grade of asphalt (Germany)
- Binder modified by addition of cellulose fiber, mineral rock wool, or polymers--used to prevent drainage of the mortar off the coarse aggregate.
- Coarse aggregate: 100% crushed
- Sand fraction: Large amount of manufactured sand.



European SMAs

- Enhanced resistance to rutting and studded tire damage.
- How? Stone-on-stone skeleton
- “Mastic:” Stone skeleton is filled and held together with the mastic which is asphalt rich and voidless. Mastic consists of asphalt binder, sand fraction, and aggregate fines.

European SMAs (cont.)

- Coarse aggregate size: Ranges from 5 to 22 mm but mostly 11 to 16 mm.
- Sand fraction size: 0.09 to 2 mm
- Filler material size: Passes 0.09 mm

European SMAs (cont.)

- Asphalt content: 6.5 to 7.5% by weight of mix
- Cellulose or mineral fibers: 0.3% by weight of mix
- Carbon black and polymers also allowed.
- Production control of aggregate gradation, asphalt content, fiber content is tight.

European SMAs--Germany

- Cellulose fibers preferred over polymers as stabilizing additive due to
 - Lower cost
 - Higher possible mixing temperatures
 - Increased time for compaction
 - Reduced mix segregation resulting from changes in asphalt content during production



European SMAs--Germany

- Mix design
 - Generally not done--use standard designs
 - Marshall use: Target is 3% Marshall air voids for job mix formula (50-blow compaction)
- SMA thickness
 - Depends on aggregate top size
 - 11 mm top size: thickness 25-50 mm
 - 5 mm top size: thickness 15-30 mm
 - Heavy-duty motorways: 40 mm layer with 11 mm aggregate top size.

European SMAs--Germany

- SMA performance
25% longer service than traditional dense HMA.



European SMAs--Sweden

- SMA first used in late 1960's to reduce damage due to studded tires.
- Major SMA use did not occur until early 1980's. Early SMAs used asbestos fibers as the stabilizing agent. Availability of cellulose fibers increased use of SMAs in 1980's.



European SMAs--Sweden

- Aggregate sizes are larger in Sweden than Germany. Sweden generally uses either 12 mm or 16 mm top size.
- Lab studies show a 40% reduction in studded tire wear for 16 mm top size as compared to 12 mm.

European SMAs--Sweden

- Allowable stabilizing additives
 - Mineral fibers
 - Fiberglass
 - Plastic fibers
 - Powdered rubber
 - Polymers

European SMAs--Sweden

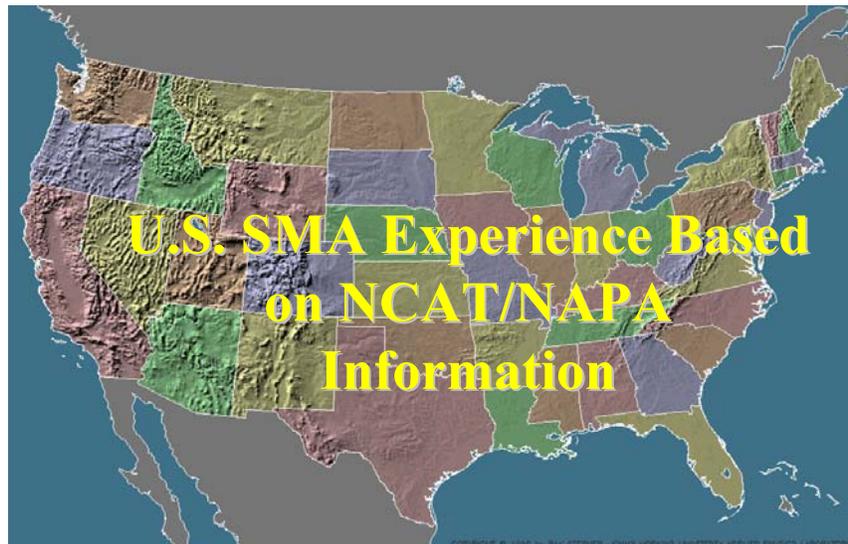
- SMA thicknesses
 - 12 mm top size: 34-43 mm
 - 16 mm top size: 38-47 mm
- Where are SMAs used?
 - SMAs advised for all roads with ADT>15,000 or where studded tire damage is the main cause of distress.
 - Overlay of choice for motorways, primary routes, urban intersections, and bridges.

European SMAs--Sweden

- Mix design
 - Use Marshall but only criterion is for air voids (3 percent).
- Construction
 - Rollers: Steel wheel without vibration
 - High mix temperatures ($\approx 160^{\circ}\text{C}$ (320°F))
 - Cessation temperature: 75°C (167°F)

European SMAs--Sweden

- Cost and Performance
 - Costs 10% more than conventional HMA
 - 20% increase in service life



U.S. SMA Experience

- NCAT: Summarized 140 SMA projects
- Major SMA states as of 1994: Alaska, Arkansas, California, Colorado, Georgia, Illinois, Indiana, Kansas, Maryland, Michigan, Missouri, Nebraska, New Jersey, North Carolina, Ohio, Texas, Virginia, Wisconsin, Wyoming

U.S. SMA Experience (cont.)

- Production: SMAs can be produced in drum or batch plants.
- Fibers: Mostly added in loose condition and blown into the plant. Occasionally, fibers added as pellets at the RAP feed.
- Most SMAs designed using Marshall at 3.5 to 4 percent air voids.
- SMA mixes should be compacted on the roadway to 5 to 7 percent air voids.

U.S. SMA Experience (cont.)

- Aggregate segregation not a problem.
- 4.75 mm sieve is critical in controlling VMA.
- Longitudinal joints more difficult to construct.
- Most SMAs placed as overlays.
- Overall performance: Very good to excellent

Draft Documents--NCHRP 9-8 “Designing Stone Matrix Asphalt Mixtures”

- Standard Practice for Designing SMA
- Standard Practice for the Construction of SMA
- Standard Specification for Designing SMA
- Standard Method for Laboratory Preparation of HMA Mortars
- Standard Method for Determination of Draindown Characteristics of Uncompacted Asphalt Mixtures

Draft
**Standard Practice for Designing
SMA**

“This standard practice covers the design of SMA using either the SHRP Gyrotory Compactor or a mechanical, static base, flat-faced Marshall hammer. The SMA design is based on the volumetric properties of the SMA in terms of air voids, the voids in mineral aggregate, and the presence of stone-on-stone contact.”

Draft
**Standard Practice for the
Construction of SMA**

“This practice provides guidance for the three main construction phases of SMA: plant production, placement and compaction procedures, and quality control/quality assurance (QC/QA).”

Draft
Standard Specification for Designing
SMA

“This specification covers the design of SMA using either the SHRP Gyratory compactor or a mechanical, static base, flat-faced Marshall hammer. The SMA design is based on the volumetric properties of the SMA in terms of air voids, the voids in mineral aggregate, and the presence of stone-on-stone contact....**This standard specifies minimum quality requirements for asphalt binder, aggregate, mineral filler, and stabilizing additives for SMA mixture designs.**”

Draft
Determination of Draindown Characteristics
in Uncompacted Asphalt Mixtures

“This test method covers the determination of the amount of draindown in an uncompacted asphalt mixture sample when the sample is held at elevated temperatures comparable to those encountered during the production, storage, transport, and placement of the mixture. The test is particularly applicable to mixtures such as porous asphalt and SMA.”

References

- AASHTO (1991), “European Asphalt Study Tour-1990,” American Association of State Highway and Transportation Officials, Washington, D.C., June 1991.
- AASHTO (1998), “Standard Practice for the Construction of Stone Matrix Asphalt (SMA),” Draft, NCHRP 9-8, June 1998.
- NAPA (1997), “Performance Evaluation of SMA Pavements in the U.S.,” Focus on HMA, Volume 2, No.3, National Asphalt Pavement Association, Washington, D.C., Fall 1997.

APPENDIX B

CONSTRUCTION INSPECTION REPORT

Don Watson
Georgia Department of Transportation

CONSTRUCTION INSPECTION REPORT

PROJECT: FAP # STP-PM98(003) **COUNTY:** Snohomish **DATE:** 8-27-99

PROJECT DESCRIPTION: SR 524 – 64th Ave W vicinity to 40th Ave W Vicinity

CONTRACTOR: CSR/Associated Sand and Gravel.

TYPE MATERIAL: 12.5 mm SMA **LOCATION:** Lynnwood, WA

OBSERVATIONS/PROBLEMS/DUTIES PERFORMED: The Contractor began on August 25, 1999 running aggregate material through the plant to see if the materials were in reasonably close conformance to the Job Mix Formula gradations from the mix design. It was found that the Contractor had decided not to provide a separate silo and weighing system for the mineral filler, but instead had blended the 4.75 mm (No. 4) to dust portion of the blend with the Fly Ash at their concrete blending plant. The two materials were blended in proportions that would yield 10 percent passing the 75 µm (No. 200) sieve in the total mix. When the Contractor started weighing the aggregates into the weigh hopper of the batch plant, fine aggregate (Fly Ash) from the No. 1 bin began flowing uncontrollably even after the bin gate had been closed. The Contractor stopped operations and decided some metal plates would need to be attached to the No. 1 bin gates to keep the fine aggregate from leaking out before continuing.

On August 26, 1999 the Contractor made repairs to the plant early in the morning and began running a couple of loads of mix to be placed on the yard at the plant site just to see if the plant could produce the mix in conformity with the JMF. These two loads of mixture had excessive drain-down of asphalt cement, which flushed to the surface during compaction with a vibratory roller. Two samples were taken by the Contractor and tested in their laboratory. Results as shown below reveal that the dust content was extremely low and conversations with plant personnel indicated that there was trouble controlling the mix temperature.

DATE	JMF	19.0	12.5	9.75	4.75	2.36	300	75	%	Roadway		Mix Gravity	
		mm	mm	mm	mm	mm	µm	µm	AC	Comp.	Voids	Theo.	T-209
8/26/99	1	100	95.5	68.1	25.2	19.6	14.4	9.7	6.50		6.3		2.447
	2	100	86.6	60.3	19.5	12.7	9.2	5.3	?		7.8		

The Contractor's test results for asphalt content after running in the ignition oven were questionable. Samples only ran about 4.5 percent AC, but it was obvious from looking at the mix that the AC content was much higher. Since the Maximum Specific Gravity of the mix checked closely with the 2.446 the Contractor obtained in an earlier mix design check, it is safe to assume the asphalt content was reasonably close to the 6.5 percent being put in at the plant.

On the morning of August 27, 1999 the plant ran 4 loads of mix to see if the dust content could be increased to match the JMF. The Contractor pulled 227 kg (500 pounds) more material from

the No. 1 bin than had been weighed on 8/26. A cold feed sample was taken at startup, but the sampling method was questionable. The Contractor caught material in a bucket off the cold feed belt as it dropped onto the belt feeding the plant. However, the sand bin is feeding so slowly, due to being such a small percentage of the blend (3 percent) that it is inconsistent; and pulling an isolated sample may or may not contain the required amount of sand.

The Contractor again had problems controlling temperature of the mix. Temperatures ranged from 313°F to 380°F. The temperature probe at the plant discharge was checked but it was free of any obstructions.

The mix was produced as follows:

- Load 1 – 6.5 percent AC with .25 percent fibers, 380°F
- Load 2 – 6.2 percent AC with .25 percent fibers, 380°F
- Load 3 – 6.5 percent AC with .25 percent fibers, 330°F
- Load 4 – 6.5 percent AC with .35 percent fibers, 313-350°F

Both the Contractor and WSDOT took samples for testing. During production it was found that an access door between bin 1 and 2 had been left open so that aggregate from bin 2 was cross-contaminating the material in bin 1. Therefore, it is doubtful that the gradation from the first samples will be useful. The problem was corrected after the first two loads.

The mixing time was checked to be sure the fibers had time to be dispersed in the aggregate before adding AC. The aggregate had a dry mixing time of 15 seconds after the fiber was added, and a wet mixing time of 30 seconds. This should be sufficient mixing time.

Upon visiting the laydown operation, the asphalt material was found to be flushing to the surface even though the mix was being rolled in the static mode. The mix had been run through a materials transfer vehicle to try to remix any liquid that may have drained down during hauling and to provide a uniform temperature. The existing surface was not tacked so the SMA layer tended to crawl under the roller. Even so nuclear density testing indicated the mix was about 94.5 percent of the theoretical density. Visual observation also indicates that there was no apparent drain-down problems as experienced yesterday but the entire surface was shiny with excessive asphalt.

It appears that the asphalt content needs to be lowered, and the Contractor plans to run another test section tomorrow morning at 6.0 percent AC. The Contractor also needs to take action to assure that the required amount of material passing the 75µm sieve is being put into the mix and that the mix temperature is controlled as well. Extraction results of today's samples are not known at this time and will be reported later.

CONSTRUCTION INSPECTION REPORT

PROJECT: FAP # STP-PM98(003)

COUNTY: Snohomish

DATE: 8-28-99

PROJECT DESCRIPTION: SR 524 – 64th Ave W vicinity to 40th Ave W Vicinity

CONTRACTOR: CSR/Associated Sand and Gravel.

TYPE MATERIAL: 12.5 mm SMA

LOCATION: Lynnwood, WS

OBSERVATIONS/PROBLEMS/DUTIES PERFORMED: The Contractor made a blend correction at the end of the day on August 27 in preparation for running more trial mix today (8/28). At that time samples were taken from the hot bins for gradation analysis and the same proportion of materials was used when the plant started up this morning.

Three loads of mix were run and placed on the Contractor's parking lot at the plant on Madison Ave. The first two loads were run using the same gradation and the only difference made at the plant was to increase the asphalt content from 6.0 percent to 6.2 percent. The third load was run at 6.0 percent AC and a change in bin weights was made to coarsen the mix (based on sample results from yesterday). After looking at the samples, it was obvious the second sample had an excessive amount of dust in the mix. Since no change in bin weights was made for the first two loads, the gradation should have been similar. There is only a couple of explanations as to why this difference could have occurred: (1) The cold feed bin for the sand may have stopped up momentarily so that mineral filler was the only fine material going into bin 1, and (2) the mineral filler may be generating surface tension along the bin walls and building up to the point that the weight of the material exceeds the surface tension resulting in a dust slide within the hot bin.

Due to obvious problems with the second sample, the first and last samples were tested for AC content and gradation. The second sample was to be run but I have not been notified of results yet. The third sample was to be gyrated to check for volumetrics and a drain-down test was to be run but results are not known yet. Sample results completed are shown below.

DATE	No.\JMF	19.0 mm	12.5 mm	9.75 mm	4.75 mm	2.36 mm	300 μm	75 μm	% AC
8/28/99	1	100	94.8	80.8	43.8	31.5	19.6	8.4	6.10
	3	100	90.3	73.0	30.6	22.0	17.0	10.6	5.80

Due to the inconsistent gradations, samples were again taken from the hot bins for comparison after running the three loads. Those results were as follows:

DATE	Bin No.	19 mm	12.5 mm	9.75 mm	4.75 mm	2.36 mm	300 μm	75 μm
8/27/99	1	100	99.0	98.0	96.0	81.5	44.4	21.4
8/28/99	1	100	100	97.2	75.1	57.3	39.6	19.8
8/27/99	2	100	98.8	83.4	6.0	0.2	0.1	0.1
8/28/99	2	100	96.6	83.1	5.7	0.1	0.0	0.0
8/27/99	3	100	69.0	33.0	4.6	1.1	0.5	0.5
8/28/99	3	100	76.4	35.9	2.1	0.3	0.1	0.1

Surprisingly, there was a range of 24.2 percent in gradation for the 2.36 mm sieve even though the blend proportions from the cold feed had not been changed. Since the 300 μm and 75 μm sieve results were similar, the conclusion is that the cold feed sand bin became stopped up and is the likely cause of mixture problems mentioned for load two above.

Visual observations of the mixture placed are that the first load was satisfactory in surface appearance except that it was somewhat finer than targeted for in the JMF. It placed easily and there was no flushing of asphalt cement to the surface. The second load appeared considerably finer in gradation and was so stiff that the Contractor had difficulty getting it through the MTV and paver. The third load appeared to have a satisfactory gradation but there was some evidence of either draindown or inconsistent mixing which caused some flushing of asphalt cement. This load was also somewhat difficult to place due to stiffness.

The Contractor was able to at least maintain a reasonable temperature today with mix temperatures ranging from 315°F to 325°F.

The Contractor was to try to repeat the last sample results late this afternoon to see if he could get some consistency within the plant. If he could get the plant to run consistently, the Contractor plans to run another test section Monday (8/30) morning.

CONSTRUCTION INSPECTION REPORT

PROJECT: FAP # STP-PM98(003)

COUNTY: Snohomish

DATE: 8-30-99

PROJECT DESCRIPTION: SR 524 – 64th Ave W vicinity to 40th Ave W Vicinity

CONTRACTOR: CSR/Associated Sand and Gravel.

TYPE MATERIAL: 12.5 mm SMA

LOCATION: Lynnwood, WS

OBSERVATIONS/PROBLEMS/DUTIES PERFORMED: I met with the Contractor this morning to discuss the plant problems they were having with inconsistent mix. Test results from mix produced Friday and Saturday were reviewed and it was determined that the plant could not consistently produce an acceptable mix with the current setup. To accurately produce this mix would require a separate feed system for the mineral filler. Since the Contractor does not have enough time to install a mineral filler silo and feed system, several other options were discussed.

It was recommended that the sand be eliminated from the mix. It does not really contribute any value to the mix and is such a small proportion of the mix (3 percent) that the feeder bin is having to run extremely slow and is feeding inconsistently. It is also so wet that the plant is having some difficulty drying the material. Since there has been inconsistency within Bin 1 of the plant, possible causes and potential solutions were discussed. It was suggested that the 3-4 loads of trial mix produced Friday and Saturday may not have been enough to allow a complete return of dust through the bag house. To remedy this problem, the No.4-dust/fly ash combination could be added through the RAP bin and would bypass the bag house altogether. However, there would still be the possibility of dust surges within the hot bin.

It was decided that plant screens could be removed from the screen deck and all the material put into one bin. The coarse aggregate would then keep the dust from accumulating along the bin wall and should eliminate the dust surges. This would require that the plant be treated as a drum plant and all proportioning would have to be controlled through the cold feed bins.

It was decided that the Contractor should start production of the test section mix at 5.8 percent AC. Gyrated samples of the mix from Load 3 Saturday gave an air void content of 4.2 percent and the AC from that sample was 5.80 percent.

A sample was taken of blended aggregate material run through the plant tonight prior to startup. Sample results are shown below.

		19 mm	12.5 mm	9.75 mm	4.75 mm	2.36 mm	300 µm	75 µm	% AC
DATE	No.\JMF	100	96	68	25	20	14	10	6.50
8/30/99	1	100	92.4	73.5	27.8	16.6	10.0	6.2	

These results confirmed visual observations that the mix needed more dust. A plant change was made to increase the No.4-dust/fly ash and the 5/8” chips by 5 percent each and decrease the 3/8” chips accordingly. Actual extraction results are not available yet.

The mixing times were set at 15 seconds dry mix and 35 seconds wet mix. Stabilizing mineral fiber is being added at 0.25 percent of the total mix and is added to the mixer during the dry mix cycle.

The first load of mix was 350°F, which is hotter than normal due to initial start up. Typical temperatures taken were 325°F in the truck, 312°F after going through the MTV, and 300°F behind the paver. The surface texture and appearance of the mix was satisfactory with the exception of several spots rich in AC due to drain-down. These spots were located between the wheel paths and are generally caused by running the conveyor of the MTV when the hopper is empty, or by insufficient fiber content to prevent drain-down in the truck. It was found that the operator of the MTV had continued to operate the front conveyor even when the unloading bin was empty.

The rolling pattern was established at one pass static, one pass vibrating and two more passes static with the breakdown roller followed by two static passes of the rear roller. Nuclear density tests were performed and cores were also taken for gauge calibration, but results are not yet available.

Approximately 210 tons were produced with 30 tons being used for pre-leveling and the remaining 180 tons used to surface the northbound outside lane from 64th Ave. West to State Route 99.

Gradation tests, volumetric tests, and density results should be available later Tuesday.

CONSTRUCTION INSPECTION REPORT

PROJECT: FAP # STP-PM98(003)

COUNTY: Snohomish

DATE: 9-1-99

PROJECT DESCRIPTION: SR 524 – 64th Ave W vicinity to 40th Ave W Vicinity

CONTRACTOR: CSR/Associated Sand and Gravel.

TYPE MATERIAL: 12.5 mm SMA

LOCATION: Lynnwood, WS

OBSERVATIONS/PROBLEMS/DUTIES PERFORMED: A meeting was held with WSDOT and Contractor personnel this afternoon to discuss problems with the first test section placed on the roadway. Several problems were experienced such as low asphalt content, high air void levels on gyrated samples, low density on the roadway, and excessive drain-down. It was decided that drain-down was the primary problem and that if that problem was resolved, some of the other effects would be resolved accordingly. Sample results obtained Tuesday night (8/31) were questionable due to the amount of drain-down and absorption of asphalt into the cardboard boxes that samples were being taken in. Therefore, WSDOT ran additional tests on the roadway cores to see how much difference the drain-down into the boxes was making. A comparison of those results is as follows:

		19.0 mm	12.5 mm	9.75 mm	4.75 mm	2.36 mm	300 µm	75 µm	% AC	Gmm	VA	VMA
DATE	No. JMF	100	96	68	25	20	14	9.7	5.8			
8-31/99	1	100	92	71	21	11	6	4.1	4.0	2.555	10.7	17.1
	2	100	92	70	23	12	8	6.3	3.8	2.553	9.8	16.1
	Cores	100	95	74	28	17	11	8.4	5.0	2.506	7.5	16.6

The core results indicated that the mixture was much closer to the target than the previous samples taken from the truck. Density results were improved as a result of using the Maximum Gravity from the cores. The corrected density from the 10 roadway cores showed average roadway voids of 8.3 percent and a range from 6.5 to 11.1 percent.

As a result of the meeting, some changes were recommended before the Contractor would start production tonight. It was decided that the Contractor should increase the fiber content from 0.25 percent to 0.5 percent to try to stabilize the asphalt film; samples will be taken in “battered” metal containers rather than cardboard boxes; and the Contractor will keep the mix temperature below 325°F. It was also decided that the compaction effort would be more aggressive by using a roller pattern of 2 passes vibrating and 2 passes static with the breakdown roller, and 2 static passes with the larger vibratory roller, with 2 or more passes with the finish roller.

Prior to production tonight, the Contractor had replaced the temperature probe at the plant discharge and it evidently was not accurately calibrated because the temperature checked at the plant varied from 335°F to as low as 265°F. An adjustment was made to the plant temperature sensor to correct the calibration.

Some balls of wet fly ash were found on the cold feed belt going into the drum. The loader operator was asked to avoid the edges and bottom of the stockpile of No.4-dust/fly ash, which was found to be wet enough for the material to ball up. After this no further such balls of fly ash were observed.

The results of the first sample the Contractor ran tonight showed the sample to have 5.72 percent AC but was still low on percent passing the 75 µm sieve. A cold feed adjustment was made to increase the No.4-dust/fly ash component of the mixture by 6 percent and reduce the 3/8" chips by the same amount in order to increase the amount of dust in the mix. Since the Contractor was able to obtain nearly the target asphalt content, it appears the "battered" metal sample cans have helped in producing reasonable sample results.

There were several isolated spots noticed tonight that appeared to be a result of drain-down. However, these spots did not have the rich asphalt appearance of the drain-down spots that occurred Monday night and odor of diesel fuel was apparent from some of these spots. It was therefore apparent that a portion of the spots were caused by truckers using diesel fuel to try to clean their truck beds and not draining the beds adequately afterward. According to specifications, fuel oil should not have been used.

The initial density results from the nuclear gauge indicated the Contractor was still not meeting density requirements. As a result, the roller pattern was changed to 3 passes vibrating and one pass static with the breakdown roller and the larger Ingersoll Rand roller was used for breakdown. The other two rollers made 2-3 passes each in the static mode. The Contractor, however, was still not aggressive with the rolling operation or consistent with the rolling pattern. The breakdown roller frequently lagged too far behind the paver and was observed rolling portions of the mat with only 3 static passes and no vibratory rolling. It is apparent the Contractor needs to have a training session with the roller operators to be sure the established rolling pattern is followed and rollers are kept up as close to the paver as possible.

A total of 390 tons of mix were placed tonight beginning in the outside northbound lane at SR 99 and extending northward.

SMA PROJECT SUMMARY AND RECOMMENDATIONS

PROJECT: FAP # STP-PM98(003) **COUNTY:** Snohomish **DATE:** 9-2-99

PROJECT DESCRIPTION: SR 524 – 64th Ave W vicinity to 40th Ave W Vicinity

CONTRACTOR: CSR/Associated Sand and Gravel.

TYPE MATERIAL: 12.5 mm SMA **LOCATION:** Lynnwood, WA

This summary is to provide some general notes as to problems and successes during the production and placement of SMA mixture for the above project. Some recommendations are also made which may be useful to both Washington DOT and contractors on any future projects. The information includes materials, production and construction.

The specifications required the contractor to submit three trial blends for analysis, and although the contractor indicated this had been done, there was no supporting data available. The trial blends varied on all sieves; typically the percent passing the 75 μ m sieve is established and held constant (10 percent) with the blend altered to vary the 4.75 mm sieve at increments such as 20, 25, and 30 percent passing so that the range covers the specification tolerances.

The Voids in Coarse Aggregate (VCA) of dry-rodded samples for each gradation are performed and averaged to determine the amount of available voids in the materials after stone-on-stone contact is achieved. Samples are then prepared with a trial asphalt content near the estimated optimum asphalt content (generally about 6.0 percent for aggregates with a bulk specific gravity of 2.75). The VCA of the mix near optimum asphalt is compared to the average VCA of the dry-rodded samples. The VCA of the mixture should never exceed the VCA of the dry-rodded aggregate only, or it indicates that there is too much intermediate size aggregate; the larger aggregate are being pushed apart as a result, and the gradation should be coarsened on the 4.75 mm sieve.

The Contractor did not meet specification requirements for introducing mineral filler into the mixture. Specification Addendum No.2, page 8, states that the mineral filler “shall be added directly into the weigh hopper.” For this project the filler has been proportionately blended with the No. 4-dust aggregate component (evidently without WSDOT knowledge or approval). This limited the contractor’s ability to control the percent passing the 75 μ m sieve as evidenced by problems with surges of dust in the hot bins until the Contractor decided to run a one bin setup. Future specifications should stipulate that a separate silo and weighing or metering system be used for the mineral filler; be capable of accurately proportioning the required quantity into the mixture; and that it be interlocked with plant controls so that if the required amount of mineral filler is not introduced into the mix, the plant operations would be interrupted.

The Contractor's method of introducing fiber stabilizer meets the technical aspects of the specifications although the intent was not met. For this project fiber was prepackaged in 50 pound bags so that one half bag per 10,000 pound batch would yield a fiber dosage rate of 0.25 percent and the fiber was thrown into the pug mill by hand during the dry mixing cycle.

Specifications only indicate that a separate system for feeding the fiber is to be used. In this case the Contractor chose manual labor as the feed system. A more specific description of an adequate fiber supply system would be as follows:

Fiber Supply System: When fiber-stabilizing additives are required as an ingredient of the mixture, a separate feed system shall be utilized to accurately proportion the required quantity into the mixture in such a manner that uniform distribution will be obtained. The proportioning device shall be interlocked with the aggregate feed or weigh system so as to maintain the correct proportions for all rates of production and batch sizes. The proportion of fibers shall be controlled accurately to within plus or minus 10 percent of the amount of fibers required. Flow indicators or sensing devices for the fiber system shall be provided and interlocked with plant controls so that mixture production will be interrupted if introduction of the fiber fails.

The prepackaged fibers might be acceptable for a small tonnage test project such as this project was, but would not be acceptable for normal production. Prepackaged fiber limits the Contractor's ability to vary the dosage rate as needed to control drain-down.

Specifications require a fiber dosage rate of 0.2 to 0.4 percent of the total mix. The dosage rate for this project seems to be working much better at the 0.5 percent rate. While lower rates have worked well in other states where polymer-modified asphalt is also used, specifications should be modified to allow up to 0.5 percent if polymer modifiers are not used.

The aggregate materials used on this project seemed to be very consistent in that stockpile samples taken at the plant from different locations in the stockpile correlated closely with each other and with the gradations submitted at the time of mix design.

The asphalt content varied considerably from sample to sample with some test results about 1.5 percent lower in asphalt content than the amount targeted. This is also an indication of asphalt drain-down problems as asphalt drained onto and was absorbed by the cardboard sample box. It is likely that the asphalt cement that drained onto the cardboard box carried with it some of the mineral filler and resulted in a slightly lower percent passing the 75 μm sieve than was actually being put in, and affected Rice gravities and volumetric testing as well. I believe plant controls were more accurate than initial ignition oven results, and the desired amount of asphalt was being put into mix. Using metal sample cans apparently may help get more consistent results.

The mixing times were set at 15 seconds dry mix and 35 seconds wet mix. Stabilizing mineral fiber was added to the mixer after about 5 seconds into the dry mix cycle. This should be sufficient to adequately disperse the fiber with the aggregate prior to injecting the asphalt cement and should provide sufficient time to coat aggregate particles with asphalt binder.

The Contractor had trouble maintaining temperature especially upon startup of the plant. A provision should be included in the contract proposal that the mix be produced within a certain tolerance such as $\pm 25^{\circ}\text{F}$ of that specified on the mix design, or Job Mix Formula, or the mix would be rejected for use. Temperature probes were replaced at the drum discharge but problems may have still occurred due to inaccurate calibration. The probes were checked in boiling water, but were not verified at the operating temperatures of the asphalt plant.

The surface texture and appearance of the mix was satisfactory with the exception of several spots rich in AC due to drain-down. These spots were located between the wheel paths and were caused by running the conveyor of the MTV when the hopper is empty, and by insufficient fiber content to prevent drain-down in the truck. It was decided that the proportion of fiber stabilizer needed to be increased. After this was done on Wednesday, drain-down was essentially eliminated. There were some similar spots noticed Wednesday night, but these spots were primarily caused by truckers using fuel oil to clean out their truck beds (rather than an approved releasing agent) and from excessive tack build-up on the tires of the MTV which would drop off onto the surface just prior to the paver covering it up.

The specifications state that vibratory rollers may be used “on a limited basis.” No one is sure what the “limited basis” means and it needs to be clarified, or eliminated, on future contracts. My experience has been that vibratory rollers can be used just as in any conventional mix placement. For this project the Contractor needs to be more aggressive, particularly with the initial breakdown rolling, in order to improve density results.

There was some controversy between the Contractor and WSDOT concerning VMA calculations during the mix design. The Contractor was using the Effective Specific Gravity of the aggregate for his calculations while WSDOT was using the Bulk Specific Gravity of the aggregate for their calculations. The Contract Proposal should specify what method to use for VMA calculations, or reference a design procedure or publication that uses the desired procedure.

The minimum VMA of 18 percent specified in the Contract may be higher than needed. FHWA, NAPA, and Asphalt Institute publications recommend a VMA of 17 percent, and on this project it appears the VMA will run between 16 to 17 percent. To set a higher value in anticipation of typical VMA collapse during production may be unnecessary. If VMA drops below the minimum established, a field adjustment may be in order.

In conclusion, this test project has had numerous problems that are not uncharacteristic of any such project when something radically different is being researched. Both WSDOT and the Contractor have hit the SMA “learning curve” hard in the past week and have had to make some tough decisions in order to get the work underway. It seems that everyone involved in this project has made adjustments as needed to try to resolve those problems encountered and to make SMA work on this project.

It has been a learning experience for me as well. Since Georgia utilizes both polymer-modified asphalt and fiber stabilizers, we have not experienced the drain-down problems you have encountered. So we have all learned a few things during the past week and have all grown

somewhat from the experience. I believe the rest of your SMA project will be successful because of your hard work and commitment to make it happen.

I certainly want to thank all of you at WSDOT for inviting me to assist you in getting this project underway. Your hospitality has been most gracious and the scenery has been incredible. Thanks.

APPENDIX C

PROJECT BID TABULATION SHEETS

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION
 * * * BID TABULATION REPORT * * *

Item No.	Item Description	Units	Estimated Quantity	ENGINEERS ESTIMATE		LOW BIDDER	
				Unit Price	Total Amount	Unit Price	Total Amount
PREPARATION							
1	MOBILIZATION	L.S.			75,000.00		33,250.00
2	REMOVING CEMENT CONC. CURB AND GUTTER	m	27.00	32.60	880.20	8.00	216.00
3	REMOVING ASPHALT CONC. CURB	m	120.00	16.30	1,956.00	6.00	720.00
4	REMOVING TRAFFIC CURB	m	1200.00	16.30	19,560.00	6.75	8,100.00
5	REMOVING BEAM GUARDRAIL ANCHOR	Each	2.00	217.20	434.40	200.00	400.00
6	REMOVING BEAM GUARDRAIL	m	32.00	16.300	521.60	22.40	716.80
GRADING							
7	PAVEMENT REPAIR EXCAVATION INCL. HAUL	m2	300.00	27.20	8,160.00	15.00	4,500.00
LIQUID ASPHALT							
8	ASPHALT FOR TACK COAT	t	30.00	325.80	9,774.00	350.0	10,500.00
9	ANTI-STRIPPING ADDITIVE	Est			5,385.00		5,385.00
ASPHALT CONCRETE PAVEMENT							
10	CRACK SEALING	Est			3,500.00		3,500.00
11	PLANING BITUMINOUS PAVEMENT	m2	37,620.00	2.70	124,146.00	3.30	124,146.00
12	ASPHALT CONC. FOR PRELEVELING CL. G PG 64-22	t	150.00	54.30	8,145.00	59.00	8,850.00
13	ASPHALT CONC. FOR PAVEMENT REPAIR	t	150.00	54.30	8,145.00	80.00	12,000.00
14	ASPHALT CONC. PAVEMENT CL. STONE MATRIX PG 64-22	t	5,250.00	55.00	288,750.00	72.50	380,625
15	JOB MIX COMPLIANCE PRICE ADJUSTMENT	Calc			8,665.00		8,665.00
16	COMPACTION PRICE ADJUSTMENT	Calc			5,780.00		5,780.00
TRAFFIC							
17	CEMENT CONC. BARRIER CURB AND GUTTER	m	27.00	54.30	1,466.10	28.65	773.55
18	EXTRUDED CURB	m	120.00	32.60	3,912.00	11.00	1,320.00
19	TYPE C BLOCK TRAFFIC CURB	m	1,200.00	32.60	39,120.00	24.00	28,800.00
20	BEAM GUARDRAIL NON-FLARED TERMINAL	Each	2.00	2,715.00	5,430.00	2,200.00	4,400.00
21	RAISING EXISTING BEAM GUARDRAIL	m	116.00	21.70	2,517.20	22.40	2,598.40
22	REPAIR IMPACT ATTENUATOR	Est			5,000.00		5,000.00
23	TRUCK MOUNTED IMPACT ATTENUATOR	Each	2.00	5,430.00	10,860.00	1,500.00	3,000.00
24	OPERATION OF TRUCK MOUNTED IMPACT ATTENUATOR	Hr	200.00	54.30	10,860.00	31.00	6,200.00
25	PLASTIC GORE STRIPE	m	75.00	4.30	322.50	5.00	375.00
26	PLASTIC CROSSWALK STRIPE	m2	380.00	21.70	8,246.00	17.75	6,745.00
27	PLASTIC STOP BAR	m	200.00	10.90	2,180.00	10.40	2,080.00
28	PLASTIC TRAFFIC ARROW	Each	68.00	43.40	2,951.20	39.00	2,652.00
29	PLASTIC TRAFFIC LETTER	Each	16.00	32.60	521.60	28.00	448.00
30	RAISED PAVEMENT MARKER TYPE 1	Hund	144.70	190.00	27,493.00	145.00	20,981.50
31	RAISED PAVEMENT MARKER TYPE 2	Hund	17.50	325.80	5,701.50	170.00	2,975.00
32	TEMPORARY PAVEMENT MARKING	m	21,300.00	0.33	7,029.00	0.35	7,455.00
33	LOOP REPLACEMENT TYPE 2	Each	28.00	650.00	18,200.00	340.00	9,520.00
34	FORCE ACCOUNT ADJUST JUNCTION BOX	Est			1,200.00		1,200.00
35	FORCE ACCOUNT TRAFFIC LOOP CONDUIT REPAIR	Est			2,000.00		2,000.00
36	FORCE ACCOUNT LOOP TESTING	Est			2,000.00		2,000.00
37	TRAFFIC SAFETY DRUM	Each	300.00	54.30	16,900.00	50.00	15,000.00
38	SEQUENTIAL ARROW SIGN	Hr	350.00	6.50	2,275.00	7.50	2,625.00
39	TEMPORARY TRAFFIC CONTROL DEVICES	LS			8,175.00		6,100.00
40	TRAFFIC CONTROL LABOR	Hr	950.00	32.60	30,970.00	30.00	28,500.00
41	TRAFFIC CONTROL VEHICLE	Day	32.00	54.30	1,737.60	80.00	2,560.00
42	TRAFFIC CONTROL SUPERVISOR	Hr	320.00	38.00	12,160.00	35.00	11,200.00
43	CONSTRUCTION SIGNS CLASS A	m2	21.00	162.90	3,420.90	130.00	2,730.00
OTHER ITEMS							
44	ROADWAY SURVEYING	LS			4,200.00		5,000.00
45	ADJUST MONUMENT CASE AND COVER	Each	11.00	360.10	3,961.00	200.00	2,200.00
46	ADJUST MANHOLE	Each	35.00	360.10	12,603.50	400.00	14,000.00

Item No.	Item Description	Units	Estimated Quantity	ENGINEERS ESTIMATE		LOW BIDDER	
				Unit Price	Total Amount	Unit Price	Total Amount
OTHER ITEMS (continued)							
47	ADJUST CATCH BASIN	Each	4.00	360.10	1,440.40	400.00	1,600.00
48	ADJUST VALVE BOX	Each	49.00	350.00	17,150.00	200.00	9,800.00
49	ROADSIDE CLEANUP	Est			5,000.00		5,000.00
50	STREET SWEEPING	Hr	50.00	81.50	4,075.00	100.00	5,000.00
51	REIMBURSEMENT FOR THIRD PARTY DAMAGE	Est			5,000.00		5,000.00
52	CREDIT/DEBITS - MINOR CHANGES	Ca;c			-1.00		-1.00
CONTRACT TOTAL					\$831,697.80	\$834,191.25	

REFERENCES

1. “Designing and Constructing SMA Mixtures – State-of-the-Practice,” Quality Improvement Series 122, National Asphalt Paving Association.
2. “Stone Mastic Asphalt (SMA) Mixture Design”, FHWA-RD-92-006, Federal Highway Administration, Turner-Fairbank Highway Research Center, McLean Virginia, March 1992.
3. Dietz, Jason, M., “The Use and State of the Practice of Stone Matrix Asphalt”, February 1997.
4. Brown, E. R., Haddock, J. E., Mallick, R. B, and Bukowski, J., “Performance of Stone Matrix Asphalt (SMA) Mixtures in the United States”, paper prepared for 1997 Annual Meeting of the Association of Asphalt Paving Technologists, Salt Lake City, Utah, March 17-19, 1997.