FINAL REPORT

DESIGN AND CONSTRUCTION OF A NEW ASPHALT DRAINAGE LAYER

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Virginia Transportation Research Council
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DISCLAIMER

ABSTRACT

Because of the importance of having a good drainage mechanism built into a pavement structure to prevent premature failure, the Virginia Department of Transportation (VDOT) has used drainage layers under portland cement concrete and asphalt concrete since the early 1990s. Unfortunately, these mixes have been rather difficult to place and durability has been a possible issue of concern. The purpose of this study was to design an improved asphalt drainage layer that eliminated the deficiencies of previous drainage layers for one of the VDOT districts.

A 50-50 blend of No. 68 and No. 8 aggregates was chosen based on laboratory testing, and the mix was installed in a newly constructed flexible pavement with good results. The mix was easy to place and contained thick asphalt films that should contribute to a long service life. Based upon this success, a specification was drafted and the mix was used in an additional project in the fall of 2003.

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INTRODUCTION

Drainage has been a major issue in pavement structures since roads began to be constructed to carry people and goods. Wet conditions weaken the subgrade and supporting layers and can cause deterioration of the asphalt and portland cement concrete layers. Emphasis has recently been placed on providing drainage systems that will remove any water that enters through the pavement surface. There needs to be a uniform drainage layer that has sufficient means to transport the water from the drainage layer and pavement structure to the edge of the pavement shoulder. NCHRP Project 1-34, through a review of previous studies, examination of in-service sections, and estimation by mechanistic-empirical models, found that drainage systems generally improve performance when installed properly.[1] The Virginia Department of Transportation (VDOT) has used open-graded drainage layers that may be stabilized with portland cement or asphalt under asphalt and concrete pavements since the early 1990s. The design ranges for the three open-graded asphalt mixtures are provided in Table 1.

Reported problems with the mixtures described in Table 1 are difficulty of construction, decreased durability, decreased stability, and increased roughness that transfer to the upper layers during paving. The mixtures generally have been difficult to place and smooth surfaces difficult to obtain because of the large aggregate. If the surface of the drainage layers is rough, achieving smoothness on successive layers is difficult. Durability suffers because of the low asphalt contents necessary to prevent the asphalt from draining off the aggregate after mixing and during transport to the job site.

Table 1. Design Ranges for Three VDOT Open-Graded Drainage Mixtures (% Passing Sieve)

Sieve, mm	Type I	Type II	Type III
37.5	100	100	100
25.0	95 ± 5	96 ± 4	97.5 ± 2.5
12.5	43 ± 9	54 ± 14	70 ± 8
4.75	0-10	25 ± 6	0-25
2.36	0-5	20 ± 4	0-8
0.075	0-5	0-5	0-5
% AC	2.0 ± 0.5	3.0 ± 0.5	2.5 ± 0.5

PURPOSE AND SCOPE

The purpose of this project was to design an improved asphalt drainage layer. After the laboratory design process was conducted, the selected drainage layer was placed on a construction project in the Virginia Department of Transportation's Lynchburg District.

METHODOLOGY

Mixtures and Materials

An attempt was made to select aggregates and develop mixture properties that corrected the problems encountered with the drainage layers in VDOT's Lynchburg District. Mixtures using smaller nominal size aggregate were designed to correct problems with construction and to help achieve smoother layers. An effort was made to incorporate as much asphalt binder as possible to produce thick asphalt films and alleviate problems with durability. The asphalt content was increased by lowering the mixing temperature to prevent asphalt drainage during construction. The author's experience with VDOT's open-graded friction courses (OGFC) in the 1970s indicated that binder drainage could be minimized by lowering the mixing temperature. .

Four mixtures were tested, as described in Table 2. Blue Ridge Stone Corp. in Lynchburg, Virginia, supplied the aggregate, which was coarse granite. The asphalt binder used was a PG 70-22.

Table 2. Mixture Proportions and Gradations for Laboratory Design

Variable	Mixture 1	Mixture 2	Mixture 3	Mixture 4
Aggregate Size, % Aggregate				
No. 57			100	
No. 68		50		100
No. 8	100	50		
Sieve, mm, % Passing				
37.5			100	
25.0		100	98	100
12.5	100	80	32	60
4.75	30	21	2	11
2.36	4	4	1	3
0.075	2.1	1.9	1.1	1.7

Laboratory Design Testing

Laboratory design testing was performed at a range of asphalt contents. After initial visual observations of the different mixtures at 3 percent asphalt content, the author thought the most promising mixture would be Mixture 2, but Mixture 1 was also a possibility. Mixture 2 was a 50-50 blend of No. 68 and No. 8 aggregates and would have more aggregate contact points than one of the other single-size mixtures. Therefore, it should be more stable. Mixture 1 was similar to the mixture used in the 1970s for the OGFC as a thin surface layer, but there was some concern that this mixture might lack adequate stability. Most of the testing was performed using Mixture 2, with some testing with Mixture 1. The selected design mixture and asphalt content for field use complied with the draindown and permeability test maximum criteria values of 0.3 percent and 1,000 ft per day, respectively. Mixture 4 was used only for visual comparison because its gradation was somewhat similar to that of one of the open-graded drainage layers already in the specifications.

Design tests performed during the study included gyratory volumetrics, asphalt draindown, and permeability. Stability tests using the Marshall procedure were also performed; however, the results are not presented because of the lack of relevance.

Gyratory Tests

Gyratory specimens were made in accordance with AASHTO T 312[2] using 65 revolutions. The volumetric information, especially the air-void contents, was used to estimate the properties of the pavement that was to be placed.

Asphalt Draindown Tests

The tendency of hot asphalt binder to drain during construction was checked with a VDOT draindown test (VTM-100).[3] The test is used to check stone matrix asphalt (SMA), which has a similar coarse aggregate structure but is filled with an asphalt-filler mastic. The test consists of determining the amount of asphalt binder that drains as the loose mixture is placed in a wire basket in a heated oven for 1 hour. The draindown tests were performed at 250 °F and 275 °F. This range of temperature was selected because prior experience with OGFC indicated this to be the approximate temperature at which excessive draindown would commence.

Permeability Test

The permeability test was performed in accordance with to VTM-84,[4] which is a constant head test for open-graded drainage layer material. The amount of water passing through the specimen in a specified time interval under a 140-mm head was measured, and the permeability was computed. The maximum permeability allowed for VDOT's open-graded drainage layers is 1,000 ft/day[5] and was the criterion used to evaluate the mixtures in this study.

LABORATORY RESULTS

Gyratory Volumetrics

The author thought that approximately 15 to 25 percent air voids would produce a mixture that would drain well because of his prior experience with OGFC. The air-void content in the gyratory specimens at various asphalt contents is shown in Figure 1 and was approximately 20 percent. Each data point is the average of tests on three specimens. There was not much difference between the results for different mixtures where comparisons were possible. There was a general trend for the air-void content to decrease with increasing asphalt content, as would be expected. A mixture with such an air-void content would be expected to allow the passage of water freely.

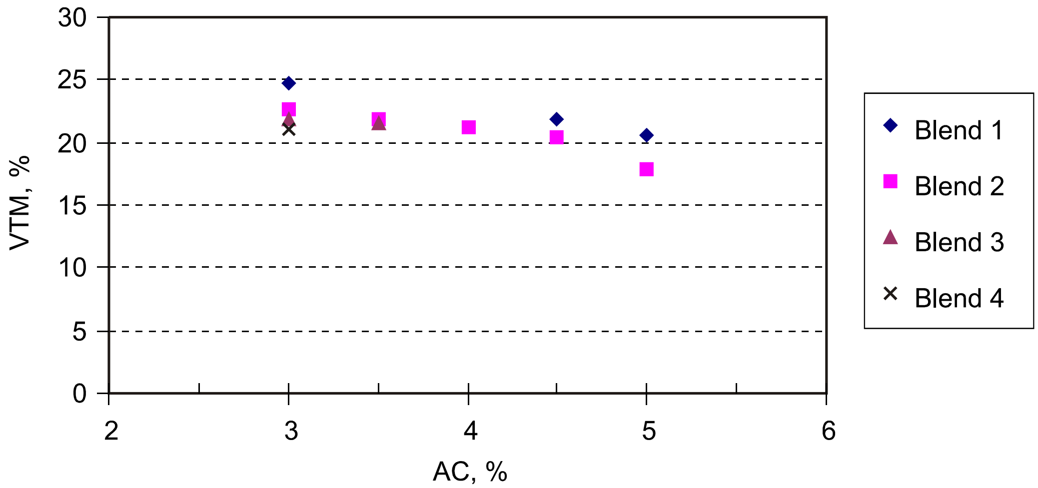

Figure 1. Voids of Gyratory Specimens.

Asphalt Draindown

Since the mixtures tested in this study contained only coarse aggregate, the drainage was composed mostly of asphalt binder. Figure 2 shows the draindown at 250 °F and 275 °F where each data point is the average of six tests. The maximum draindown permitted in the SMA mixture is 0.3 percent. If that criterion is used, the maximum mixture temperature must remain below 250 °F to prevent draindown and permit an asphalt content above 4 percent.

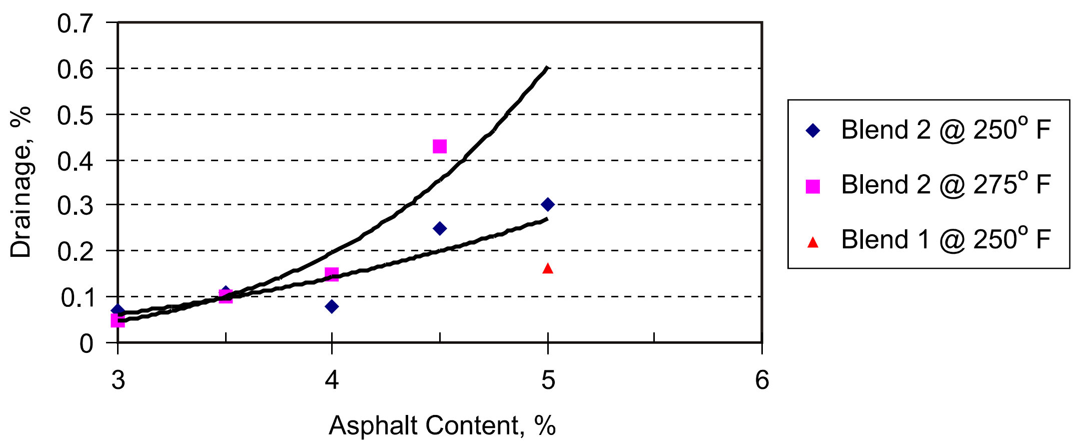

Figure 2. Asphalt Drainage Results for Laboratory Mixtures.

Permeability

The results of the permeability tests are shown in Figure 3. Mixture 2 maintained permeability above 1,000 ft/day for asphalt contents less than 4.5 percent. The permeability for Mixture 1 was only slightly less than 1,000 ft/day at 4.5 percent asphalt. The permeability of

Mixture 3, at an asphalt content of 3.0 percent, which was comparable to that of one of the drainage layers used in the Lynchburg District, was above 2,000 ft/day.

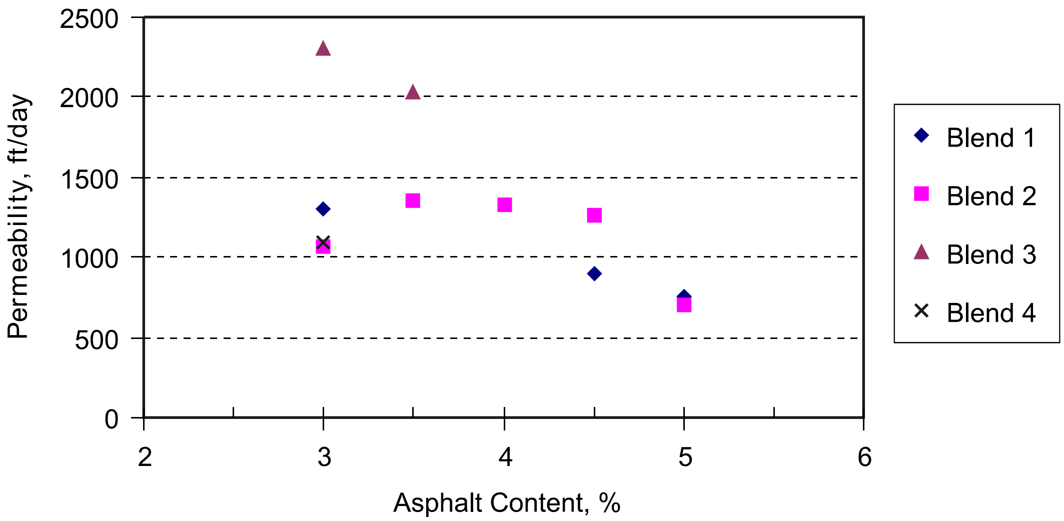

Figure 3. Permeability Results for Laboratory Mixtures.

FIELD SECTION OBSERVATION AND TESTING

Mixture 2, the 50-50 blend of No. 8 and No. 68 aggregates, was selected for a construction job on the Route 210 Connector near Lynchburg. The author thought that the 50-50 blend provided a mixture that met draindown and permeability criteria and might be more stable with regard to supporting construction traffic and the pavement structure than the other mixtures containing only one size of aggregate. The mixture was placed in September 2003 by Lawhorne Brothers, Inc. The structural cross section consisted of 6 in of cement-treated subgrade, 5 in of cement-treated crushed stone, a 2-in asphalt drainage layer, 5 in of a BM-37.5 asphalt base mixture, 2 in of an IM-19.0 asphalt intermediate mixture, and 1.6 in of an SM-12.5D asphalt surface mixture. The drainage layer butted against a longitudinal underdrain at the edge of the lane to remove any water. The job mix for the drainage layer is described in Table 3, which also lists an analysis of a sample taken during construction. The field sample was slightly finer than that specified in the job mix design.

The mixture was produced at a lower than normal temperature to prevent draindown of the asphalt binder during hauling and handling. The target mixing temperature was 265 °F, and the mixture arrived at the job at approximately 250 °F. Figure 4 shows that the mixture was not sticking in the truck bed after it was dumped in the paver, which would have occurred with excessive draindown. The mixture had to cool to approximately 150 °F as measured on the pavement surface before it would support a roller to set the aggregate together. A minimum number of passes (2 or 3) were applied since achieving maximum density was not an issue. Once it was rolled and allowed to cool to ambient temperature, the mixture supported construction traffic without any difficulty.

Table 3. Job Mix and Gradation of Field Sample

Materials		
50%	No. 8 aggregate	Blue Ridge Stone Corp., Lynchburg, Va.
50%	No. 68 aggregate	Blue Ridge Stone Corp., Lynchburg, Va.
0.5%	Hydrated lime	APG Lime Corp., Ripplemead, Va.
4.0%	PG 70-22 asphalt	Associated Asphalt, Roanoke, Va.

Gradation		
Sieve, mm	*Job Mix*	*Field Sample*
25.0	100	
19.0	96	100.0
12.5	82	88.0
4.75		24.0
2.36	7	6.4
0.075	2.5	3.6
% AC	4.0	3.8

Figure 4. Asphalt Not Sticking in Trucks.

Air voids and permeability values for cores taken during a day's production on September 12, 2003, are listed in Table 4. They were very close to the values obtained for the specimens compacted in the laboratory at 4.0 percent asphalt content and shown in Figure 1 and Figure 3, respectively. These results indicate that there was good agreement between the laboratory design and in-place mixture properties. Figure 5 illustrates that the mixture drained water readily.

Table 4. Air Voids and Permeability of Road Cores

Site	Air Voids	Permeability (ft/day)
1	21	1,240
2	20	1,150
3	21	1,600
4	24	870
5	22	1,070
6	23	990

Figure 5. Water Draining Through Drainage Layer.

After some discussion, the Lynchburg District arranged to have one day's production of Mixture 3, which contained only No. 8 aggregate and had a 4.0 percent asphalt content. If the aggregates gave satisfactory performance, the mixture would give the designers and contractors another option. The contractor placed the mixture in the spring of 2004 but did not notify the district office, so no samples were collected and the construction was not observed by personnel from the Virginia Transportation Research Council.

CONCLUSIONS

The mixture with 50 percent No. 8 and 50 percent No. 68 aggregates and a 4.0 percent asphalt content (Mixture 2 in this study) was designed and placed successfully on the Route 210 connector near Lynchburg. It was easily constructed and received good reviews from the contractor and VDOT personnel. Upon completion, VDOT developed a specification (see the Appendix) that was used in the placement of additional mixture on Route 288, which also received good comments. The drainage layer on Route 288 was used to support a continuously reinforced concrete pavement. The only problem noticed was that the particular reinforcing steel chair used had a single-point support and tended to support the steel at variable depths because of the rough surface texture of the drainage layer. A chair with a broader foot should have been used.

RECOMMENDATIONS

1. VDOT should use the drainage layer specification written as a result of this study (see the Appendix).

2. VDOT should use chairs with a broad foot to support reinforcement placed above the drainage layer.

ACKNOWLEDGMENTS

The author thanks Don French, Lynchburg District Engineer, and his staff for their cooperation. The cooperation of the contractor, Lawhorne Brothers, Inc., is also greatly appreciated. VTRC personnel supervised by Troy Deeds are commended for their diligence in testing the materials and observing some of the construction. Trenton Clark, Pavement Program Manager, was especially instrumental in taking the initiative to develop the specification used for Route 288. Thanks also go to Mike Dudley, a former VTRC employee, who was active in the initial phase of planning for the study.

REFERENCES

1. Harrigan, E.T. Performance of Pavement Subsurface Drainage. *Research Results Digest Number 268.* Transportation Research Board, Washington, D.C., November 2002.

2. American Association of State Highway and Transportation Officials. Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Super pave Gyratory Compactor. In *Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Part 2B.* Washington, D.C., 2003.

3. Virginia Department of Transportation. Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures, VTM-100. In *Virginia Test Methods Manual.* Richmond, 2000.

4. Virginia Department of Transportation. Determining the Coefficient of Permeability of Open-Graded Drainage Layer Material, VTM-84. In *Virginia Test Methods Manual.* Richmond, 2000.

5. Virginia Department of Transportation. *Road and Bridge Specifications.* Richmond, 2002.

APPENDIX

313—ASPHALT STABILIZED OPEN-GRADED MATERIAL

313.01—Description.

This work shall consist of furnishing and placing a course of stabilized open-graded material on a prepared subbase or subgrade in accordance with the requirements of the Specifications and in reasonably close conformity with the lines and grades shown on the plans or established by the Engineer.

Asphalt cement stabilized open-graded material shall conform to the requirements of Section 211 of the Specifications except as noted herein.

313.02—Materials.

Asphalt cement stabilized open-graded material shall conform to the following requirements:

Coarse aggregate shall be Grade A crushed stone conforming to the requirements of Section 203 of the Specifications and shall conform to the soundness requirements of surface course stone.

Fine aggregate shall conform to the requirements of the Section 202 of the Specifications. and shall conform to the requirements of aggregate for use in concrete subject to abrasion.

Asphalt cement shall be PG 70-22.

Reclaimed asphalt pavement shall not be used as component material. unless approved by the Engineer.

313.03—Proportioning.

The Contractor shall submit or shall have his source of supply submit, for the Engineer's approval, a mix design or job-mix formula for each mixture according to the requirements of Section 211.03 for asphalt stabilized open-graded material.

Stabilized open-graded material shall be designed to have an in-place coefficient of permeability of at least 1000 feet per day, when tested in accordance with VTM-84.

The following design ranges shall be used for asphalt cement stabilized open-graded material:

Sieve	% Passing	
	Min	**Max**
1 inch	100	100
¾ inch	88	100
½ inch	70	90
No. 8	0	15
No. 200	0.5	4.5
A.C. Content 4.3 ± 0.3%		

Hydrated lime shall be used in all mixtures at the rate of at least 0.5 percent by weight of the total dry aggregate. Chemical additives may be used in addition to or in lieu of lime with approval of the Engineer based on previous approvals of chemicals used with the same aggregate in asphalt concrete mixes of other types as detailed in Section 211 of the Specifications.

The mix temperature shall be between 250 degrees F and 280 degrees F.

Design test data will not be required.

Draindown testing shall be in accordance with VTM-100 Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures. Draindown shall not exceed 0.3%.

313.04—Equipment.

Equipment used for the construction of the stabilized open-graded course shall be approved prior to the performance of such work. Any machine, combination of machines or equipment, which will place the material without undue segregation and produce the completed course in accordance with the specifications for moistening, mixing, placing and compacting will be approved.

313. 0504—Acceptance.

Acceptance for gradation and asphalt cement content of the asphalt cement stabilized open-graded material will be accordance with the requirements of the Section 211.08 of the Specifications.

Acceptance of aggregate coating in asphalt stabilized open-graded material shall be 100-percent surface coverage of the aggregate as verified by visual inspection by the Engineer.

313.0605—Placing limitations.

Stabilized open-graded material shall not be placed when weather or surface conditions are such that the material cannot be properly handled, finished or compacted. The surface upon which mixtures are to be placed shall be free of standing water at the time such materials are spread.

Asphalt cement stabilized open-graded material shall be spread only when the atmospheric temperature is above 40 degrees F, and the surface temperature upon which it is to be placed is no less than 35 degrees F.

Asphalt cement stabilized open-graded course shall not be cooled with water.

Vibratory rollers shall not be used on the asphalt stabilized open-graded course.

313.0706—Procedures.

Stabilized open-graded material shall not be placed until the surface upon which it is to be placed has been approved by the Engineer. Preparation shall include provision for surface drainage away from the material to prevent contamination from surface water in the event of rainfall.

The Contractor shall prevent contamination of the stabilized open-graded material. Material which, in the opinion of the Engineer, has been contaminated (surface clogged by dirt or other foreign material which impedes drainage) or damaged (loss of material stability) shall be removed and replaced promptly by the contractor at no additional expense to the Department.

The finished surface of the stabilized open-graded material shall be uniform and shall not vary at any point more than 0.5 inch above or below the grade shown on the plans or established by the Engineer.

Stabilized open-graded material with a surface higher than 0.5 inch above the grade established by the plans shall be removed and replaced with material, which complies with these specifications. If permitted by the Engineer, the high spots may be removed to within specified tolerance by any method that does not produce contaminating fines or damage the base to remain in place, except that grinding will not be permitted.

Hardened stabilized open-graded material with a surface lower than 0.5 inch below the grade established by the plans shall be removed and replaced with stabilized open-graded material which complies with these specifications or, if permitted by the Engineer, low areas may be filled with the next pavement course in the same operation in which the pavement is placed at no additional expense to the Department.

The Contractor shall not use the open-graded course as a haul road or storage area. Traffic will not be permitted on the open-graded course except for equipment required to place the next layer. Haul vehicles that are overweight or that have not had a legal load determination will not be permitted on the open-graded drainage course for any purpose.

Asphalt cement stabilized open-graded material shall be placed in one layer by approved equipment conforming to the requirements of Section 315.03 of the Specifications. Compaction shall begin when the internal mat temperature is approximately 150 degrees F to 200 degrees F. A static, steel, 2 wheel roller shall compact the material in 1 to 3 passes in an established pattern approved by the Engineer. An 8 to 10 ton roller is suggested. The mat shall be compacted sufficiently to support the placement of the next layer but not to the point that it is not free draining or that the aggregate is crushed. A light roller may be used to remove roller marks on the day after placement of the material at the direction of the Engineer.

Placement of the next higher pavement layer shall be suspended if any visible damage occurs to the stabilized open-graded material and construction of the next layer shall not proceed until directed by the Engineer.

313.0807—Measurement and Payment.

Asphalt cement stabilized open-graded material will be measured and paid for as stabilized open-graded material, in tons, complete-in-place. This price shall be full compensation for furnishing and placing asphalt material, aggregate, and lime or anti-stripping chemical admixture, removing and replacing unstable subgrade or subbase, preparing and shaping the subgrade or subbase, constructing and finishing shoulders and ditches, and disposal of unsuitable material.

Payment will be made under:

Pay Item	**Pay Unit**
Stabilized Open-Graded Material	Ton