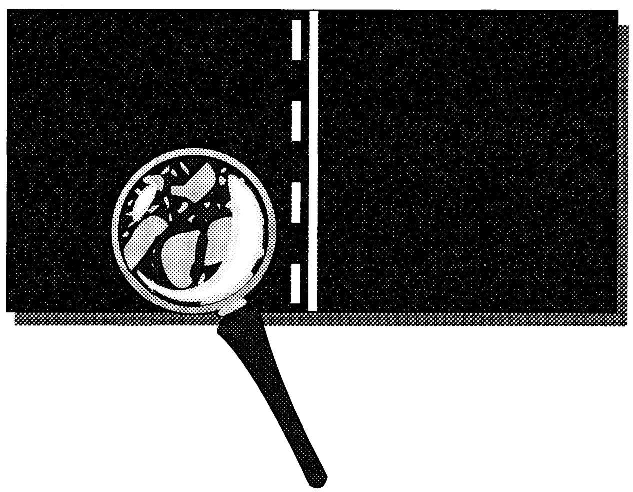
TECHNICAL
ASSISTANCE REPORT

FOLLOW-UP FIELD INVESTIGATION OF THE EFFECTIVENESS OF ANTISTRIPPING ADDITIVES IN VIRGINIA



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Standard Title Page - Report on State Project

Report No.	Report Date	No. Pages	Type Report:	Project No.:
VTRC 97-TAR6	January 1997	19	Technical Assistance	9398-010-940
			Period Covered: January 1996-January 1997	Contract No.:

Title and Subtitle

Technical Assistance: Follow-up Investigation of Antistripping Additive Effectiveness in Virginia

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Key Words

Asphalt
Chemical additives
Hydrated lime
TSR
Pavement voids

Sponsoring Agencies' Name and Addresses

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Supplementary Notes

Abstract

A previous field study of 12 pavements revealed considerable stripping in the surface layers of mixtures placed in 1991-92. Most of the mixes containing chemical additives showed visual stripping, but the ones containing hydrated lime did not show significant stripping.

This study was a broad field survey with cores taken from each of the nine VDOT districts. The purpose was to get a better estimate of stripping in Virginia than that of the earlier study. Significant visual stripping was detected in many sites, which verified the findings of the earlier study. However, in this study, hydrated lime performed no better than chemical additives. The SM-2A 50-blow mixes with slightly more asphalt performed no better than the SM-2B or SM-2C 75-blow mixes. Pavement voids at many sites were too high for good durability, and the compaction and mix design specifications should be examined. The degree of stripping damage in underlying layers could influence performance at many sites.

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Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the
Virginia Department of Transportation and
the University of Virginia)

Charlottesville, Virginia

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ABSTRACT

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INTRODUCTION

Moisture-induced stripping of asphalt from aggregate has affected the durability of flexible pavements for many years. Many studies have investigated various facets of stripping and improvements have been made in testing and prevention, but problems may still exist. Several techniques have been used to deter or prevent stripping. One of the best solutions is to build a pavement that is impermeable, thereby excluding the causative factor, water. Proper mix design and construction are very important. However, since the construction of impermeable pavement is difficult, additives are often put into the mix during construction to improve its resistance to stripping. Two basic types of antistripping agents are chemical liquids that are added to the asphalt cement and finely ground solids, such as hydrated lime and portland cement, that are used to coat the aggregate surface.

VDOT has required antistripping additives in various types of mixes for several decades in an attempt to prevent stripping. They have gone through several phases or changes dealing with antistripping additives. Chemical additives were used initially, but when stripping was observed, experimentation began with another type of additive, hydrated lime. The performance of test sections containing hydrated lime were so favorable that VDOT's specification was changed to require hydrated lime or a chemical additive that produced a tensile strength ratio (TSR) equal to or greater than that of the same mix with hydrated lime.[1-2] It was believed that chemical additive suppliers improved their product to meet the specification. To test this hypothesis and examine the expected performance of mixes containing chemical additives, sections of pavement overlay were sampled over two construction seasons during construction, tested, and cored 3 to 4 years later to determine the amount of stripping. Unexpectedly, considerable stripping was observed in the cores from eight of the nine projects containing chemical additives, but the three containing hydrated lime had much less stripping.[3] VTRC's Asphalt Advisory Committee recommended that a broader survey be done to verify the accuracy of the findings.

PURPOSE AND SCOPE

The purpose of this investigation was to obtain a better estimate of stripping in Virginia than that obtained in an earlier limited study. Cores were drilled in each of VDOT's nine highway districts and evaluated visually. An attempt was made to include as many variables as possible, such as aggregate type and contractors.

EXPERIMENTAL PLAN

A plan was devised by VTRC and VDOT's Materials Division to core and evaluate pavements placed in 1991, the same general time pavements were constructed in the previous study. Because of the time lag between studies, the pavements in the latter study were 1 to 2 years older. Each of VDOT's nine districts was asked to locate 10 surface mixes, but some districts were unable to locate 10 meeting the requirements. A total of 74 sites were sampled. Both SM-2C (75-blow design with AC-30 asphalt cement) and SM-2A (50-blow design with AC-20) mixes were tested to determine whether the higher asphalt content of the SM-2A mixes resulted in improved performance. Some SM-2B (75-blow design with AC-20) mixes were also included. Nineteen SM-2A, 11 SM-2B, and 44 SM-2C mixes were sampled. Eight of the SM-2A, 5 of the SM-2B, and 15 of the SM-2C mixes contained hydrated lime, and the remaining mixes contained chemical additives. Six brands of chemical additives were used.

A majority of the mixes contained granite as all or part of the coarse aggregate. Other primary aggregates were traprock, quartzite, and gravel. Ninety-five percent of the mixes contained natural sand as a fine aggregate with other primary fine aggregates being granite, limestone, and traprock.

The sampling plan shown in Figure 1 was used to take the cores. Twenty cores were taken at each site, 10 for the stripping evaluation and 10 for voids determination. Concern had been expressed that mixes may have a high void content, which would probably affect durability and possibly stripping susceptibility. An equal number of cores were taken from the right wheel path and between wheel paths in the outside traffic lane to determine the effect of traffic on performance. District personnel were responsible for obtaining the cores, transporting them to the laboratory, and running the density tests. The degree of stripping was estimated visually on each stripping core.

Two cores per site were drilled full depth to inspect and evaluate the underlying layers. This information provided a rough estimate of the extent of stripping in underlying asphalt, which could have a major effect on pavement performance.

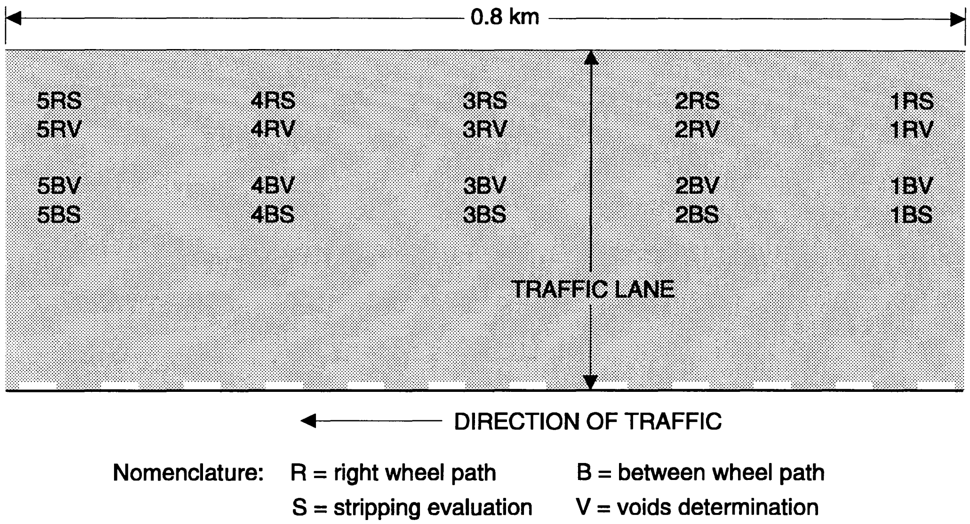

Figure 1. Stripping Evaluation Coring Plan

SAMPLING, TESTING, AND EVALUATION

Sampling

The cores were taken at five locations approximately equidistant apart in an 0.8-km length of pavement. This length was selected so that traffic control signs would have to be set up only one time at each site. The coring personnel were instructed to select the 0.8-km section within an area with average performance for the mix being sampled, and they were cautioned to avoid sampling only good or bad areas. Immediately after coring, the stripping cores were wrapped in plastic and secured with tape to prevent the escape of moisture and possible healing of any stripping that may have been present. Cores were protected from sunlight and extreme heat that might promote drying or deformation. The cores were taken from March through June 1996. The previous winter had been severe, with heavy snowfall accumulations, and pavements sampled early may not have been allowed to heal as much as pavements sampled later in the spring.

Testing and Evaluation

Each stripping core was transported to the lab and split apart using an indirect tensile testing device no later than 24 hours after coring. The split halves were covered to prevent contamination by dirt. When all sites had been cored and split, the author was contacted. He went to the lab and showed two other district lab personnel how to evaluate the cores. He and the two lab personnel then evaluated them Examples of stripping were illustrated by showing photos of previous cores where stripping had been estimated by the author. Each person evaluated each core independently for stripping in both the coarse (+2.36 mm) and fine (-2.36 mm) aggregates. Each person was instructed to estimate the amount of the split surface that was coarse aggregate and the percentage of that area that had stripped. A similar estimate was made for the fine aggregate.

The surface mix of the 10 density (voids) cores was separated from the other layers by sawing or chiseling in preparation for the specific gravity determination. The specific gravity test was performed according to VTM 6 (Appendix). Several cores were heated and combined after the specific gravity test to provide sufficient material for theoretical maximum specific gravity tests (AASHTO T-209).[4]

RESULTS

Stripping

The first question dealt with the general level of stripping in Virginia. The previous study had found that the level of severity was significant in 8 of 12 projects for the coarse aggregates and 6 of 12 for the fine aggregates. The previous study had five levels of severity: very slight, slight, moderate, moderately severe, and severe. The follow-up study used four similar levels, which are defined in Table 1. The author believes that the same percentage of stripping is more critical in the fine aggregate matrix than in the coarse aggregate. This is why each level of severity for fine aggregate was arbitrarily assigned a smaller percentage of stripping for each severity level.

Table 1. Definitions of Stripping Severity Levels

Severity	Coarse Aggregate % Stripped	Fine Aggregate % Stripped
Slight	0-14	0-9
Moderate	15-29	10-24
Moderately-Severe	30-49	25-39
Severe	≥ 50	≥ 40

As described previously, the cores were taken from both the wheel paths and between the wheel paths to determine whether stripping was influenced by water being forced into the pavement surface by traffic. The average stripping for each district listed in Table 2 shows very little apparent difference between the stripping in the two locations. The *t* test at an alpha risk of 0.05 was also used to determine whether the average stripping differed between the two types of cores. There was no significant difference for either coarse or fine aggregate in any of the types of mixes with regard to this variable. This would tend to indicate that traffic did not have a great effect on the stripping observed in the cores. Thus, the remainder of this report discusses stripping only in the wheel path for simplicity.

Table 2. Average Stripping in Right-Wheel Path and Between-Wheel Path

District	% Stripped			
	+ #8 Aggregate		- #8 Aggregate	
	RWP	BWP	RWP	BWP
Bristol	22	22	13	11
Salem	31	32	21	19
Lynchburg	24	21	17	16
Richmond	49	44	41	37
Suffolk	31	19	16	11
Fredericksburg	27	22	25	22
Culpeper	42	38	29	24
Staunton	23	23	6	5
Northern Va.	23	21	18	17

Figures 2 and 3 for coarse and fine aggregate, respectively, illustrate that the stripping was significant at many sites. Approximately 80 percent of the sites had stripping that was at least moderate (>15% stripped) for the coarse aggregate or fine aggregates. About 50 percent of the sites had at least moderately severe stripping (>30%) for the coarse aggregate and about 30 percent had such stripping (>25%) for the fine aggregate. Five to 10 percent of the sites had severe stripping. Therefore, the amount of stripping statewide appears to be significant.

Figures 4 and 5 illustrate the stripping for the coarse and fine aggregates for each district. The Richmond and Culpeper districts had the highest levels. The Staunton and Bristol districts had the lowest stripping severity levels for the fine aggregate, possibly because of the use of limestone fines in some of their mixes. Eighty and 40 percent of the mixes in the Bristol and Staunton districts, respectively, contained limestone fines. Also, hydrated lime was used in 70 percent of the mixes sampled in these two districts. Thirty percent of the mixes in the Salem District also contained limestone fines but did not show the same resistance to stripping.

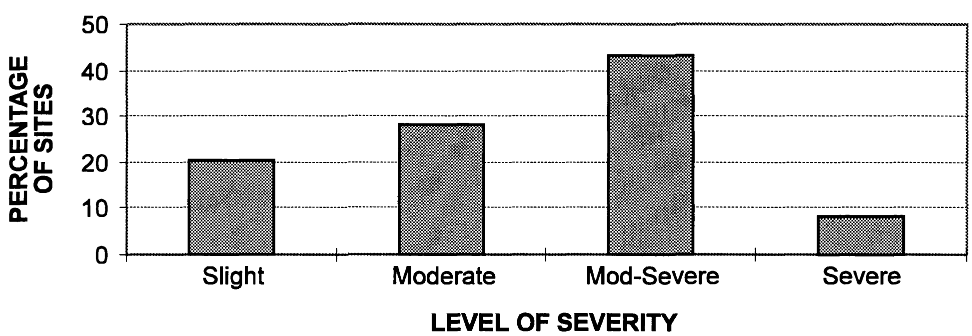

Figure 2. Severity of Coarse Aggregate Stripping in Virginia

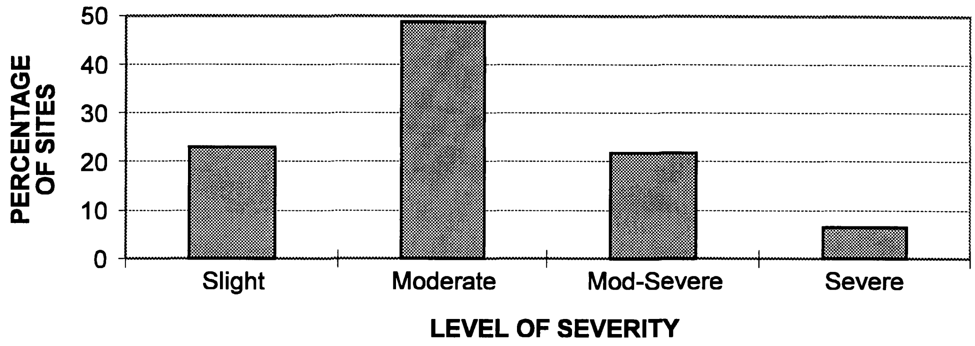

Figure 3. Severity of Fine Aggregate Stripping in Virginia

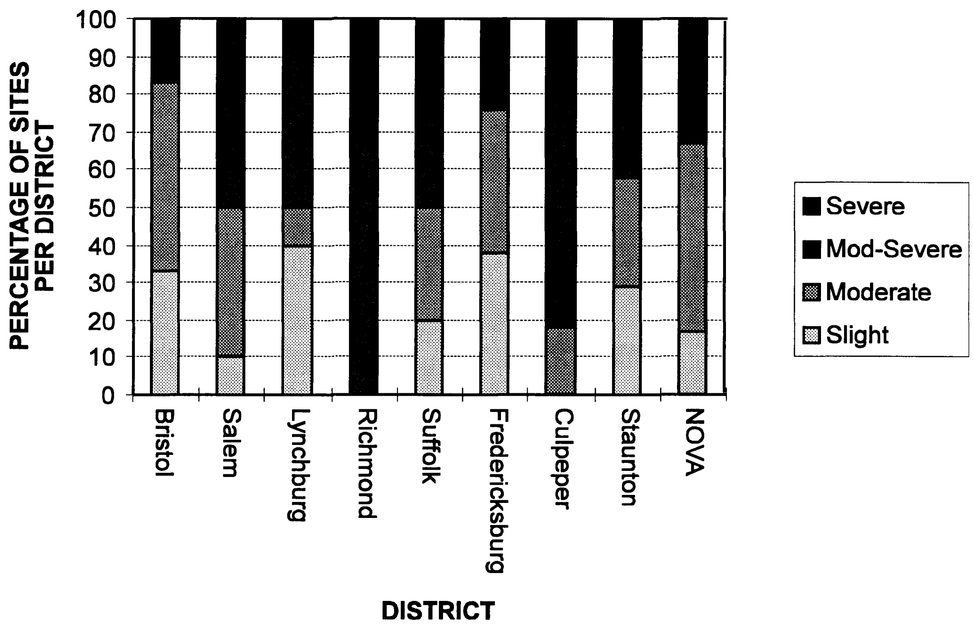

Figure 4. Severity of Stripping on Coarse Aggregate

Table 3 lists the average site ranges for stripping in each district. It is obvious that stripping varied quite a bit within a district from site to site. For instance, the Fredericksburg District had a site with a low average of only 6 percent but another site with a high average of 61 percent for coarse aggregate. Also, at some sites, the amount of stripping between cores varied widely. It was not unusual for one or two sites per district to have stripping that differed as much as 60 to 70 percent between individual cores. The most logical factors that could have affected this variation were the absence or presence of additive and construction variables such as uniformity of compaction and mix segregation.

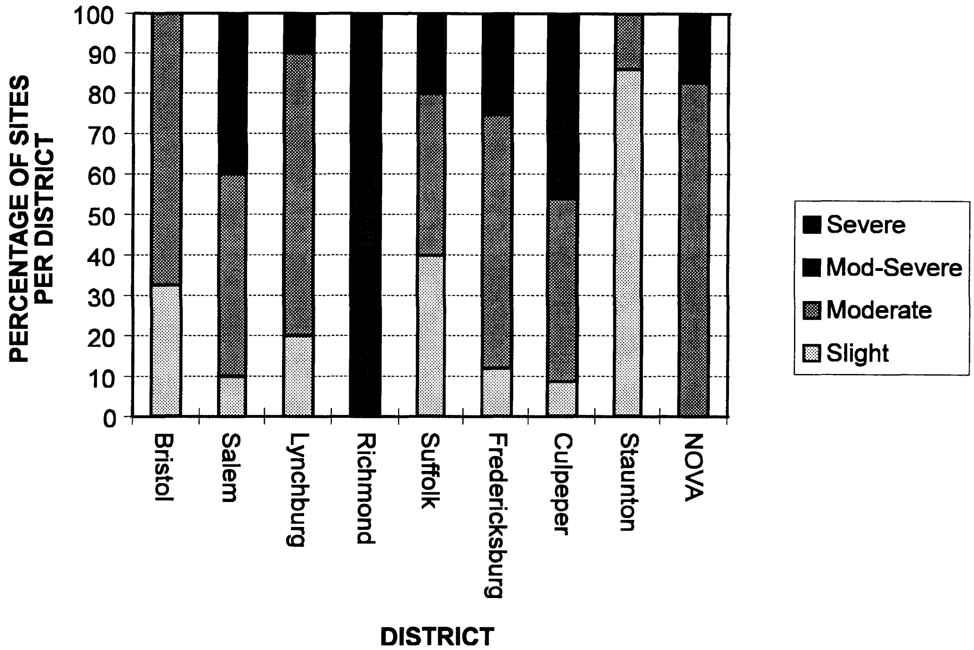

Figure 5. Severity of Stripping on Fine Aggregate

Table 3. Stripping in Right Wheel Path

District	**+ #8 Aggregate**		**- #8 Aggregate**	
	Average of All Sites	**Range Site to Site**	**Average of all Sites**	**Range Site to Site**
Bristol	22	11-52	13	5-22
Salem	31	13-50	21	8-39
Lynchburg	24	9-47	17	8-35
Richmond	49	39-67	41	32-64
Suffolk	31	11-50	16	4-34
Fredericksburg	27	6-61	25	8-53
Culpeper	42	32-51	29	20-41
Staunton	23	11-37	6	2-13
Northern Virginia	23	12-34	18	10-26

Next, an analysis of variance using an alpha risk of 0.05 was performed to determine whether the average stripping illustrated in Figures 6 and 7 for coarse and fine aggregates, respectively, was different for the three mix types. It was not different among mix types for either coarse or fine aggregate. One would probably expect the SM-2A mix with higher asphalt content to be more resistant to stripping than the 75-blow B and C mixes. However, when the

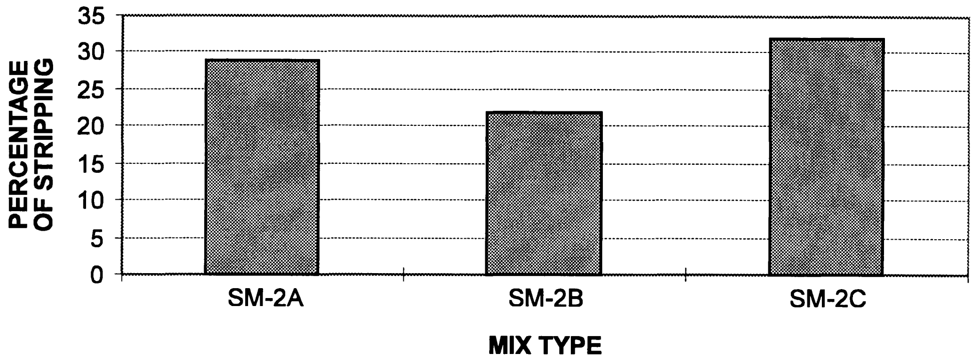

Figure 6. Average Stripping in Coarse Aggregate

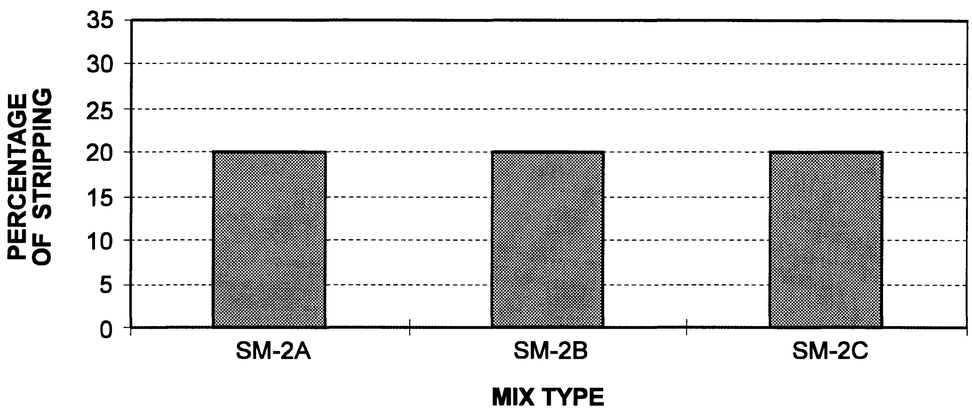

Figure 7. Average Stripping in Fine Aggregate

typical asphalt film thickness of the mixes is calculated and compared, the average film thickness of the A mixes is only about 1 micron more than the average film thickness of the B and C mixes. Therefore, it was not surprising that the stripping was not different for the distinct mix types.

Another point of the investigation was to determine whether the hydrated lime was more effective than chemical additive, as was indicated in the earlier study. The comparison of the amount of stripping of the coarse and fine aggregates for the two treatments for each mix type is illustrated in Figures 8 and 9. The *t* test at an alpha risk of 0.05 indicated no differences between average stripping values for chemical and hydrated lime treatments except for the SM-2A coarse aggregate and SM-2B fine aggregate. A closer examination of the sites revealed that three SM-2A mixes using hydrated lime contained the same aggregate, which tended to bias the results. The stripping in all of these mixes was high. There were only six SM-2B mixes with chemical additives and five SM-2B mixes with hydrated lime, which may have been insufficient for a valid statistical comparison. The important point is that the results do not agree with the results of the earlier study where hydrated lime appeared to perform better than chemical additives.

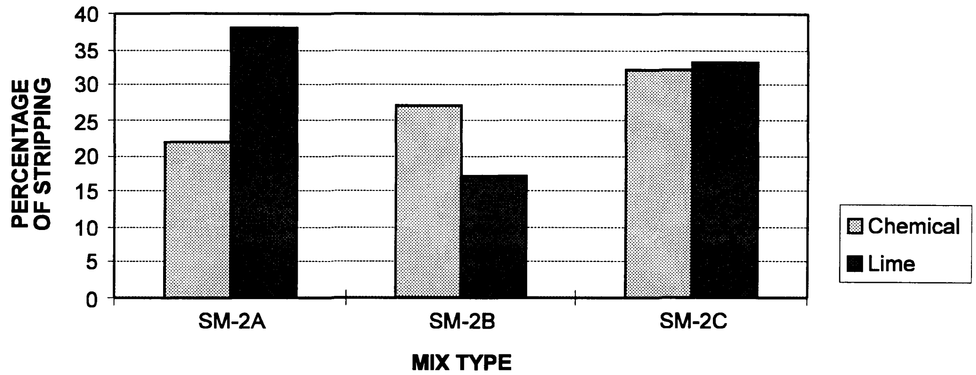

Figure 8. Average Stripping in Coarse Aggregate

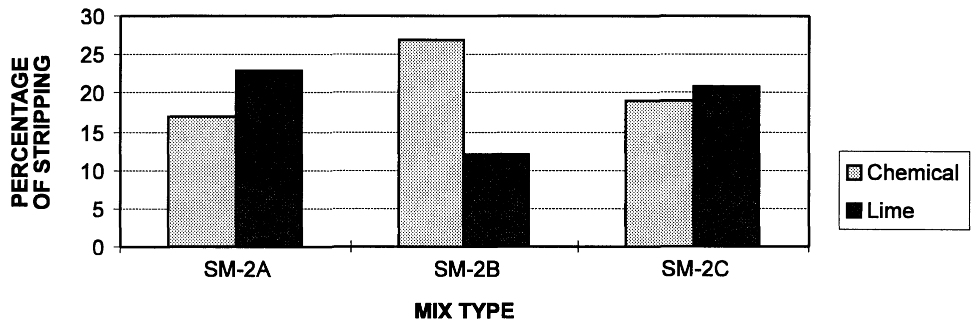

Figure 9. Average Stripping in Fine Aggregate

Voids

Table 4 lists the average voids in total mix (VTM) after approximately 5 years of service. There was no correlation between average voids and stripping . In other words, the districts with higher voids did not necessarily have higher stripping. A similar correlation for each individual site for specific mixes also revealed no correlation. There were probably too many other variables that affected stripping, and the effect of air voids alone was not large enough to detect. If other factors could be held constant, air voids might show an effect.

It was obvious that some sites had void levels much too high for reasonable durability. Most districts had at least one site that averaged as high as 10 to 11 percent after 5 years of service. Even if the pavement did not allow surface water to enter and cause stripping, the excessive voids would promote oxidation and decrease durability. A study in Washington found that "each percent increase in air voids (over a base air void level of 7 percent) results in about a 10 percent loss in pavement life (or about 1 year less)."[5]

Table 4. Percent Voids in Each District

District	Right Wheel Path		Between Wheel Path	
	Average	Range	Average	Range
Bristol	7.8	4.5-10.3	8.8	7.3-10.8
Salem	5.9	4.5-9.1	7.9	6.0-10.9
Lynchburg	6.0	2.5-8.2	7.7	5.8-9.3
Richmond	5.3	2.7-6.8	6.5	2.4-8.7
Suffolk	5.4	3.4-8.4	7.6	5.8-9.8
Fredericksburg	6.8	4.2-8.4	9.0	7.3-10.6
Culpeper	6.0	3.8-7.7	8.1	6.2-9.7
Staunton	7.1	6.0-10.1	7.5	5.6-10.8
Northern Virginia	7.4	5.8-9.2	7.8	5.9-9.8

Stripping of Underlying Layers

Table 5 lists the average stripping for each district for the coarse and fine aggregate in the underlying layers. The Suffolk and Culpeper districts appear to have more stripping than the other districts. The high water table in the coastal area of the Suffolk District could cause more stripping in the underlying layers, but there is no apparent reason for more stripping in the Culpeper District.

Table 5. Average Percentage Stripping of Underlying Layers in Right Wheel Path

District	+ #8 Aggregate	- #8 Aggregate
Bristol	37	11
Salem	24	21
Lynchburg	23	23
Richmond	34	28
Suffolk	52	20
Fredericksburg	25	27
Culpeper	50	32
Staunton	17	4
Northern Virginia	36	25

Pavement Performance

Each district was asked to describe the condition of each site as poor, fair, good, or excellent. These conditions were then averaged by a numbering system to obtain an average for each district. Condition data were available for only six districts, and the results are listed in Table 6. Five of the six districts rated their pavements as fair-good, and one as poor-fair. Since factors other than stripping cause pavement distress, a direct correlation between pavement condition

Table 6. Average Pavement Condition

District	Condition
Bristol	Fair - Good
Salem	
Lynchburg	Fair - Good
Richmond	Fair - Good
Suffolk	
Fredericksburg	
Culpeper	Poor - Fair
Staunton	Fair - Good
Northern Virginia	Fair - Good

and the observed stripping was not possible. When the stripping is catastrophic and distress is significant, a direct assignment of stripping to the observed distress is possible, but no extreme cases of stripping were detected in this sampling. The degree of stripping observed would probably shorten pavement life by causing premature cracking.

DISCUSSION

The results of the earlier study were confirmed. Stripping was significant in cores representing all types of SM-2 mixes. One would expect this degree of stripping to result in reduced service life. The mixes treated with hydrated lime did not strip less than mixes with chemical additives as observed in the earlier study.

The SM-2A mixes did not strip less than the drier SM-2B and SM-2C mixes. The proposed reason is that the film thickness was only about 1 micron greater for the SM-2A mixes and was probably not different enough to cause a significant difference in stripping.

Stripping was probably extensive enough in the underlying layers to cause shortened pavement life. There was some difference in the degree of stripping between districts, which may have been caused by environment, materials (aggregates), and possibly mix design.

The pavement voids were higher than desirable for good performance. Some pavements averaged 8 to 10 percent voids after 5 years under traffic, which may have resulted in water penetration and was also undesirable from an oxidation-durability perspective. An attempt to correlate voids level with degree of stripping was unsuccessful, probably because so many other factors influenced the stripping.

Stripping has always been an elusive phenomenon. The incorporation of additives seems to help, but stripping still occurs for no explainable reasons. The evaluation of long-term effectiveness by testing is difficult. No test has been found that correctly predicts performance

100 percent of the time. Much work is still needed in this area. Suggestions to eliminate or minimize stripping are to thoroughly dry the aggregate before mixing with asphalt, provide good pavement drainage, achieve adequate compaction during construction, eliminate moisture-susceptible aggregates, and use the most effective antistripping additives available.[6]

It is believed that Virginia already regularly follows the first two suggestions. Compaction has been a concern. The air voids detected in this study on some sites were possibly high enough to allow water and air to enter the pavement surface and cause deterioration. Although voids low enough to cause rutting are dangerous, it is felt that lower voids than are typically being achieved would be beneficial from a durability perspective. The compaction and mix design specifications should be examined to determine whether lower voids are achievable and desirable. Another area that should be investigated is mix permeability. Relative permeability of various mixes should be measured, both in the lab and field if possible. The fourth suggestion to eliminate moisture-susceptible aggregates is impossible to implement, since stripping occurs with most aggregates produced in Virginia. The final suggestion concerning effective additives is being followed to the best of engineering ability, but, a test method to predict stripping is still needed in this area.

CONCLUSIONS

- Significant stripping was detected in many sites.
- There was no significant difference detected in stripping among SM-2 mix types.
- Hydrated lime showed no superiority over chemical antistripping additives.
- Pavement voids at many sites were too high to promote durability.
- Stripping damage in underlying layers was detected.

RECOMMENDATIONS

- Examine the VDOT compaction and mix design specifications to determine if lower air voids are achievable and desirable.
- Investigate the permeability of mixes used in Virginia in anticipation of using less permeable mixes.
- Improve the accuracy of predictive stripping tests.

ACKNOWLEDGMENTS

Thanks go to those who helped carry out this large field investigation. Robert Horan and his staff, especially Mike Bowyer and Mike Wells, were instrumental in planning the investigation, contacting the districts, finalizing the master list of sites, and performing tests on cores taken in the Fredericksburg, Northern Virginia, and Richmond districts. District personnel were especially cooperative in taking cores, performing necessary tests, providing site information, and participating in the visual stripping evaluation. The reviewers of the final report, R. D. Horan, C. S. Hughes, and M. M. Sprinkel, were very helpful.

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APPENDIX

Virginia Test Method for Field Determination of Bulk Specific Gravity of Compacted Asphalt Mixtures Using Saturated Surface Dry Specimens

Designation: VTM-6

1. Scope

    1.1 This method of test covers the field determination of bulk specific gravity of compacted asphalt mixtures.

    1.2 The bulk specific gravity of the compacted asphalt mixtures may be used in calculating the unit of mass of the mixture.

    1.3 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Test Specimens

    2.1 Test specimens are from any course of asphalt pavements.

    2.2 Size of specimen shall be as specified in VTM-22.

3. Apparatus

    3.1 Balance: A 2000 gram balance with an accuracy of 1.0 gram. The balance shall be equipped with suitable suspension apparatus and holder to permit weighing the specimen while suspended from the center of scale pan of balance. (Note 1).

    Note 1: The holder shall be immersed in water to a depth sufficient to cover it and the test sample during weighing. Wire suspending the holder should be the smallest practical size to minimize any possible effects of a variable immersed length.

    3.2 Water Bath: For immersing the specimen in water while suspended under the balance.

    3.3 Water used in water bath shall meet the requirements for water used with cement or lime in the *Road and Bridge Specifications.*

4. Procedure

4.1 Mass of dry specimen in air - Weigh the specimen in air. Designate this mass as "A".

4.2 Mass of specimen in water - Immerse the specimen in water bath for one minute and determine the weight. Designate this mass as "C".

4.3 Mass of saturated surface dry specimen in air - Surface dry the specimen by blotting all sides quickly with a towel and then weigh in air. Designate this mass as "B".

Note 2: Specimens removed by a process that does not use water will require no further drying.

Note 3: Wet specimens removed by coring shall be dried to a constant mass at 125 $\pm$ 5 °F until further drying does not alter the mass 0.1 percent. Samples saturated with water shall initially be dried overnight at 125 $\pm$5 °F and then weighed at two-hour intervals until constant weight is obtained.

Note 4: If desired, the sequence of testing operations may be changed to expedite the test results. For example, first the immersed mass © can be taken, then the surface dry mass (B), and finally the dry mass (A). When the sequence of testing operations is changed, the method outlined in VTM-49 may be used to dry specimens to a constant mass.

5. Calculation

5.1 Calculate the bulk specific gravity of the specimen as follows: (Report the value up to value up to two decimal places.)

Bulk Specific Gravity = A/(B-C)

Where: A = mass, in grams, of sample in air.
B = mass, in grams, of surface dry specimen in air.
C = mass, in grams, of sample in water.

File No. 2.4.66

February 7, 1997

MEMORANDUM

TO: Mr. R. D. Horan
Assistant Materials Engineer

SUBJECT: Technical Assistance Report: Follow-up Field Investigation of the Effectiveness of Antistripping Additives in Virginia (Project No. 9398-010-940)

Attached is the report by G. W. Maupin, Jr., on the field evaluation of stripping that was recommended by the Asphalt Research Advisory Committee. Unfortunately, the results seem to verify the earlier limited survey results that stripping was significant in our asphalt surface mixes produced in 1991-92. Hydrated lime did not have an advantage over chemical additives as indicated in the earlier study.

The lack of a difference in stripping between mix types with different asphalt content (SM-2A and SM-2C) was somewhat surprising. However, estimates revealed only slight differences in asphalt film thickness. It is believed that the new Superpave mixes will be less susceptible to stripping because of much greater asphalt film thickness.

The voids measurements indicated excessive voids for good durability in many instances; therefore, we believe it would be wise to examine VDOT's compaction and mix design specifications for possible modification. Other areas that could be beneficial to investigate are permeability of mixes and toughening of the stripping test used to approve mix designs. Bill will be glad to discuss the recommendation and possible areas of study with you.

Gary R. Allen
Director

Attachment

cc: Mr. P. R. Kolakowski
cc/att. Mr. A. Mergenmeier
Mr. R. J. Betsold
Mr. L. Triandafilou
District Materials Engineers
Asphalt Research Advisory Committee
Mr. M. M. Sprinkel
Mr. G. W. Maupin, Jr.
Mr. W. E. Kelsh
Ms. C. D. Goodman