FINAL REPORT

STRIPPING POTENTIAL OF BITUMINOUS CONCRETE

by

G. W. Maupin, Jr.
Research Engineer

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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

Charlottesville, Virginia

November 1978
VHTRC 79-R27

BITUMINOUS RESEARCH ADVISORY COMMITTEE

MR. R. L. ALWOOD, Chairman, District Materials Engineer, VDH&T

MR. A. D. BARNHART, District Materials Engineer, VDH&T

MR. P. F. CECCHINI, District Engineer, VDH&T

MR. J. L. CORLEY, Assistant District Engineer, VDH&T

MR. W. A. DENNISON, District Materials Engineer, VDH&T

MR. C. E. ECHOLS, Asst. Prof. of Civil Engineering, U. Va.

MR. R. V. FIELDING, Materials Engineer, VDH&T

MR. C. S. HUGHES III, Senior Research Scientist, VH&TRC

MR. A. B. JOHNSON, Assistant Construction Engineer, VDH&T

MR. J. T. LOVE, Materials Engineer, Materials Division, VDH&T

MR. H. E. MARSHALL, District Engineer, FHWA

MR. C. G. MCALLISTER, Chief Chemist, Materials Division, VDH&T

MR. R. S. THOMAS, Bituminous Engineer — Maintenance Div., VDH&T

MR. R. D. WALKER, Chairman, Dept. of Civil Engineering, VPI & SU

MR. R. P. WINGFIELD, Assistant Maintenance Engineer, VDH&T

ABSTRACT

Laboratory data were gathered with a newly developed stripping test in anticipation that the test would be adopted for use by the Department. In addition to providing experience in the performance of the test and interpretation of test results, the investigation was designed to give a determination of whether there were significant differences in the brand of asphalt cements and antistripping additives used as reflected by their influence on the bond between the asphalt and aggregate in the mixtures tested. The results of tests on mixes containing aggregates from eight sources, three asphalt cements, and two antistripping additives in various combinations indicated a significant difference for the additives but none for the asphalts. Results of a supplementary investigation indicated that the test method might be modified so that it can be performed with equipment already available within the district materials laboratories.

FINAL REPORT

STRIPPING POTENTIAL OF BITUMINOUS CONCRETE

by

G. W. Maupin, Jr.
Research Engineer

INTRODUCTION

Several years ago stripping failures in some asphaltic concrete surface mixes prompted a requirement that all such mixes contain an antistripping additive. Although asphaltic concrete has been considered to have a low permeability, examinations of more recent pavement failures revealed water and stripping in this type material used in the base and intermediate layers. Failures of this type have been observed on major roads such as Routes 11, 29, 460, I-64, I-81, and I-85. In recognition of this finding that stripping is also a problem in base and intermediate layers, the Department has specified that an antistripping additive be used for all asphaltic concrete except that containing carbonate type aggregate.

With a view to eliminating the requirement for use of an additive in every mix, an investigation was undertaken to further evaluate the test for determining the susceptibility of asphaltic concrete to stripping that was developed under NCHRP Project 4-8(3) 13.(1) Because this test method had given encouraging preliminary results on field installations placed by the Department and six other agencies under the NCHRP project, it was decided to gather necessary additional information in preparation for possible implementation of the test by the Department.

PURPOSE AND SCOPE

The primary purpose of the study was to gain familiarity with the new method by testing several asphaltic concrete mixes believed to yield poor performance because of stripping. Although not planned originally, a very limited attempt was made to determine the effect of the type of asphalt cement and type of antistripping additive on the bond between the asphalt and aggregate in a general way. It was realized that the scope of the study would limit the generalization of any conclusions on the effect of asphalt cement

Table 3

Asphalt Cements and Antistripping Additives Contained in Various Mixes

Mix	Aggregate	Phase 1	Phase 2	Phase 3
1	Crushed Gravel	Exxon		
2	Quartzite	Exxon		
3	Crushed Gravel	Exxon	Shell & Chevron	Shell Kling Beta LV & ACRA 500
4	Granite	Exxon	Shell & Chevron	Chevron Kling Beta LV & ACRA 500
5	Granite	Exxon		
6	Diabase	Exxon		
7	Granite	Exxon	Shell & Chevron	Shell Kling Beta LV & ACRA 500
8	Granite	Exxon		

Specimen Preparation

The aggregates were combined according to the mix design gradations obtained from the district materials engineers. For each mix, the aggregate and asphalt were heated in an oven, the former to 149°C (300°F) and the latter to 135°C (275°F), and then mixed in a laboratory mixer for approximately 2 minutes. The procedure suggested by Lottman in the field evaluation phase of NCHRP Project 4-8(3)/1 was used in preparing, preconditioning, and testing the specimens.(3) The mixture was cooled at room temperature for 2.5 hours and placed in a forced air oven at 60°C (140°F) for 15 hours for curing. The mixture was removed from the oven and placed in an oven at 121°C (250°F) for 2 hours prior to compaction.

Compaction was performed according to section 3.5 of ASTM D 1559-76, "Standard Test Method for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus." The compactive effort was 50 blows per side, except for mixes 2, 5, and 8, which required only 30, 30, and 25 blows, respectively, to yield a void content representative of field conditions.

Because it had been verified by Lottman that voids have a significant influence on the degree of stripping in a mix, it was important for the lab mixes to contain void contents similar to those produced in field mixes. One of the mixes known to have a stripping history was initially compacted at a low void content and the test results indicated no stripping. Specimens were recompacted at a higher void content and the tests indicated a significant amount of stripping.

Permeable voids (voids saturated with water under vacuum) for the NCHRP project were determined by the procedure given in reference 3.

Preconditioning

Preconditioning is designed to simulate the damage sustained by a pavement due to the environment and traffic. The two types of preconditioning were (1) vacuum saturation, and (2) vacuum saturation plus freezing at -18°C (0°F) for 15 hours and thawing in a 60°C (140°F) water bath for 24 hours (hereafter referred to as freeze-thaw).

Vacuum saturation is achieved by applying a vacuum of about 100 mm (4 in.) of mercury for 30 minutes to the submerged specimens and then allowing them to remain submerged an additional 30 minutes.

Vacuum saturation preconditioning simulates short-term damage and freeze-thaw preconditioning simulates long-term damage that may occur over several years.

Testing

The specimens to be tested dry were wrapped in aluminum foil and coated with wax to ensure watertightness, and then placed in a 12°C (54°F) water bath 3 hours prior to testing. The preconditioned specimens were placed unwrapped into the water bath 3 hours prior to testing. The indirect tensile test was performed by loading the specimen in a diametral direction (Figure 1) at a vertical deformation rate of 1.6 mm/min. (0.065 in./min.) with a hydraulic, closed-loop test system. The indirect tensile strength, S_t, was computed as:

$$S_t = \frac{S}{1.75 \times 10^6} \quad \frac{P}{t},$$

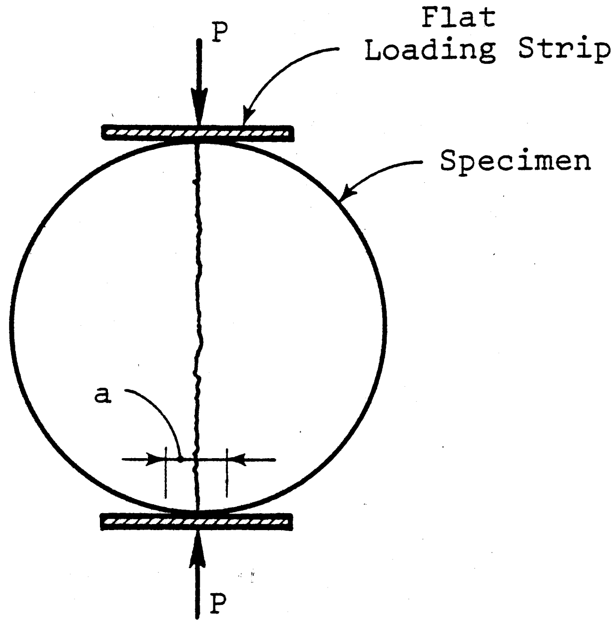


Figure 1. The indirect tensile test.

where

P = maximum compressive load on specimen, N (lb.);

t = thickness of sample, m (in.); and

S = maximum tensile stress, Pa, produced in a 102 mm (4 in.) diameter solid cylinder by a load of P - 4,448 N (10,000 lb.) per 25.4 mm (1 in.) thickness. (Value S must be adjusted for flattening, a, of specimen by graphic solution.)

After testing the specimens were split and examined visually for stripping.

Resilient modulus tests were performed on each specimen to identify any discrepancies in the indirect tensile test results. The specimens initially were placed in a 22°C (72°F) water bath for 2 hours as described above; the resilient modulus test was performed; the specimens were placed in the 12°C (54°F) water bath for 3 hours; and another resilient modulus test was performed. After the resilient modulus test at 12°C (54°F) the specimens were tested immediately in indirect tension as previously described.

RESULTS

Phase 1

In phase 1, the stripping test was performed on eight mixes using the Exxon AC-20 asphalt cement.

The tensile strength ratio (TSR), which is the ratio of the preconditioned strength to the dry strength, is used to predict stripping. A TSR of 1.0 indicates that a mix does not have a stripping potential, while a TSR less than 1.0 indicates that it does. On the basis of experience a TSR less than 0.7 is considered unsatisfactory. None of the mixes showed significant damage from the vacuum saturation preconditioning (see Table 4). Six of the eight yielded a TSR of less than 0.7 under the freeze-thaw preconditioning, which indicated they would undergo a significant stripping over a long term.

Table 4

Indirect Tensile Tests — Phase 1

Mix No.	Voids Total Mix, %	Average Indirect Tensile Strength, MPa			Average Tensile Strength Ratio	
		Dry	Vac. Sat.	Freeze-Thaw	Vac. Sat. /Dry	Freeze-Thaw /Dry
1	6.3	0.63	0.64	0.29	1.01	0.46
2	5.4	0.39	0.39	0.20	1.02	0.52
3a	3.4	0.62	0.69	0.72	1.11	1.17
4a	4.7	0.61	0.62	0.32	1.02	0.52
5	6.1	0.36	0.34	0.28	0.94	0.77
6	8.0	0.42	0.43	0.23	1.02	0.56
7a*	6.8	0.41	0.42		1.02	
	6.8	0.53		0.23		0.44
8	7.0	0.44	0.46	0.28	1.03	0.62

Note: 1 MPa = 145 psi.

*Two sets of specimens were required because of testing malfunction.

Three mixes were selected for further investigation in phases 2 and 3. These mixes, nos. 3a, 4a, and 7a, had high, median, and low TSR values, respectively. It was impossible to test more than three mixes in phases 2 and 3 because of the excessive number of specimens and tests that would have been required.

Phase 2

Phase 2 involved testing mixes 3b, 4b, and 7b, which were the same as 3a, 4a, and 7a, except that Shell and Chevron cement asphalts were substituted for the Exxon, to determine if the brand of asphalt cement affected the TSR.

The test results for phase 2 are listed in Table 5. There was no damage to the specimens preconditioned by vacuum saturation as measured by the TSR. The magnitudes of the TSR values for the mixes with different asphalt cements were similar for the freeze-thaw preconditioned specimens.

Table 5

Indirect Tensile Tests — Phase 2

Mix No.	Asphalt	Voids Total Mix, %	Average Indirect Tensile Strength, MPa			Average Tensile Strength Ratio	
			Dry	Vac. Sat.	Freeze-Thaw	Vac.Sat./Dry	Freeze/Dry
3b	Exxon*	3.4	0.62	0.69	0.72	1.11	1.17
	Shell	3.4	0.75	0.77	0.61	1.03	0.81
	Chevron	3.9	0.65	0.70	0.65	1.09	1.00
4b	Exxon*	4.7	0.61	0.62	0.32	1.02	0.52
	Shell	6.0	0.79	0.79	0.37	0.99	0.47
	Chevron	5.3	0.65	0.68	0.27	1.05	0.41
7b	Exxon*	6.8	0.41	0.42		1.02	
		6.8	0.53		0.23		0.44
	Shell	7.4	0.70	0.71	0.19	1.01	0.26
	Chevron	6.9	0.61	0.61	0.21	0.99	0.35

Note: 1 MPa = 145 psi.

*Test results from Phase 1.

An analysis of variance indicated that the asphalt cement did not have a significant effect on the TSR of the freeze-thaw specimens at a 95% confidence level. The import of this result is that after a mix has been tested, it will not have to be retested when a different asphalt cement is used. The limited number of asphalt cements tested should be considered if this conclusions is used to develop an acceptance test procedure. Also these results should not be used to classify asphalt cements for performance.

Phase 3

Phase 3 involved testing mixes 3c, 4c, and 7c, which were the same as 3b, 4b, and 7b, with the addition of antistripping agents. The test results are listed in Table 6.

There was no damage to the specimens preconditioned by vacuum saturation as measured by the TSR. Both of the antistripping additives caused an increase of the TSR over those for the mixes with no additive, and an analysis of variance indicated that the increase was significant. There was also a significant difference between the performance of the two antistripping additives. Therefore, if an aggregate or mix is tested and found to require an additive, it probably would have to be tested with each additive that is used. Particular additives may have to be required for particular aggregates.

Visual Examination of Split Specimens

After the indirect tensile tests were performed the specimens were split and examined visually for stripping damage. Generally the visible stripping is indicative of the relative TSR, especially for the same mix with different void contents, additives, etc.

Figure 2 shows the effect of two antistripping additives on the stripping potential of mix 7c. The correlation of TSR to visible stripping is evident. Additive Beta LV performed better than additive ACRA 500 according to the TSR values and the amounts of visible stripping.

Figure 3 shows the effects of the two antistripping additives to be the same for mix 4c according to the TSR values and the appearance of the test specimens.

Table 6

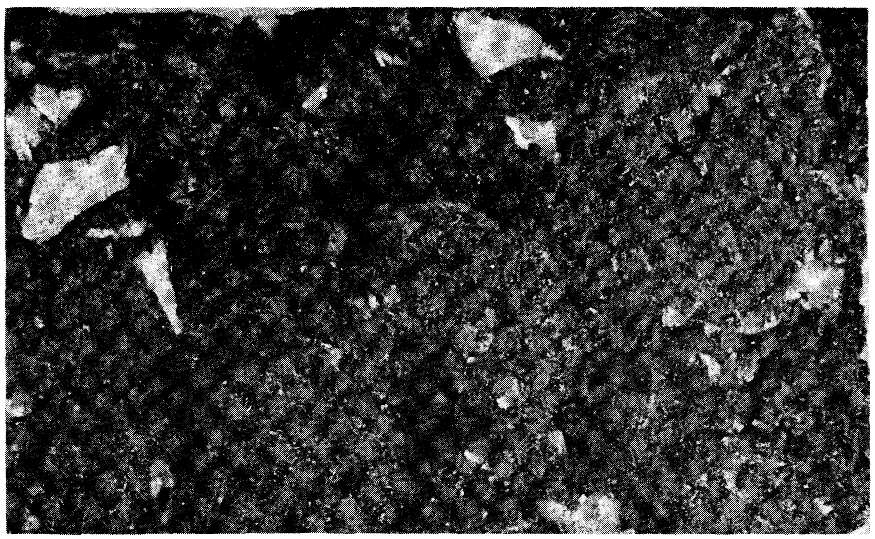
Indirect Tensile Tests — Phase 3

Mix No.	Additive	Voids Total Mix, %	Average Indirect Tensile Strength			Average Tensile Strength Ratio	
			Dry	Vac.Sat.	Freeze-Thaw	Vac. Sat. /Dry	Freeze-Thaw /Dry
3c Shell, Crushed Gravel	ACRA 500	4.5	0.77	0.77	0.74	1.00	0.96
	Kling Beta LV	4.5	0.78	0.79	0.75	1.02	0.96
	No Additive	3.4	0.75	0.77	0.61	1.03	0.81
4c Chevron, Vulcan Granite	ACRA 500	7.0	0.63	0.67	0.59	1.05	0.92
	Kling Beta LV	7.0	0.63	0.64	0.56	1.01	0.88
	No Additive	5.3	0.65	0.68	0.27	1.05	0.41
7c Shell, Trego Granite	ACRA 500	6.7	0.68	0.69	0.45	1.02	0.66
	Kling Beta LV	6.7	0.74	0.74	0.65	1.02	0.90
	No Additive	7.4	0.71	0.71	0.19	1.01	0.26

Note: 1 MPa = 145 psi.

Dry

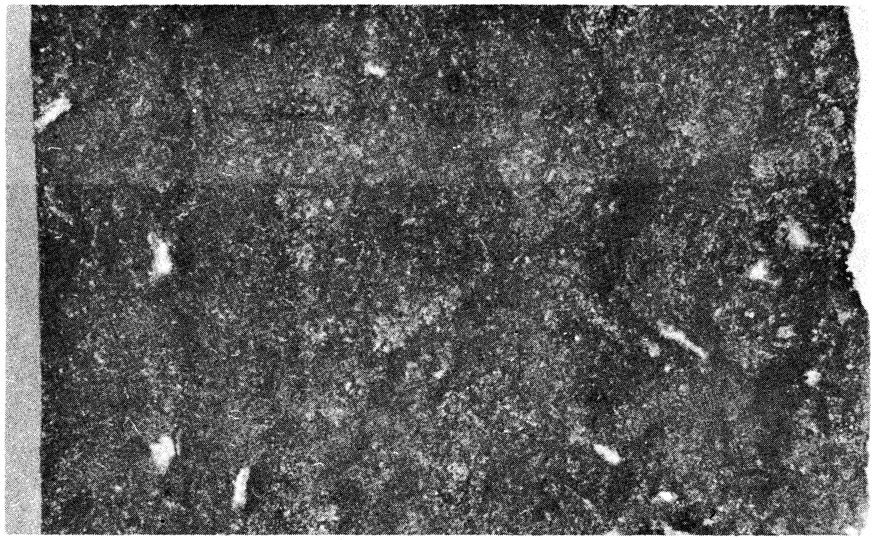
Freeze-thaw (no additive)
TSR = 0.26



Freeze-thaw (Kling Beta LV)
TSR = 0.90

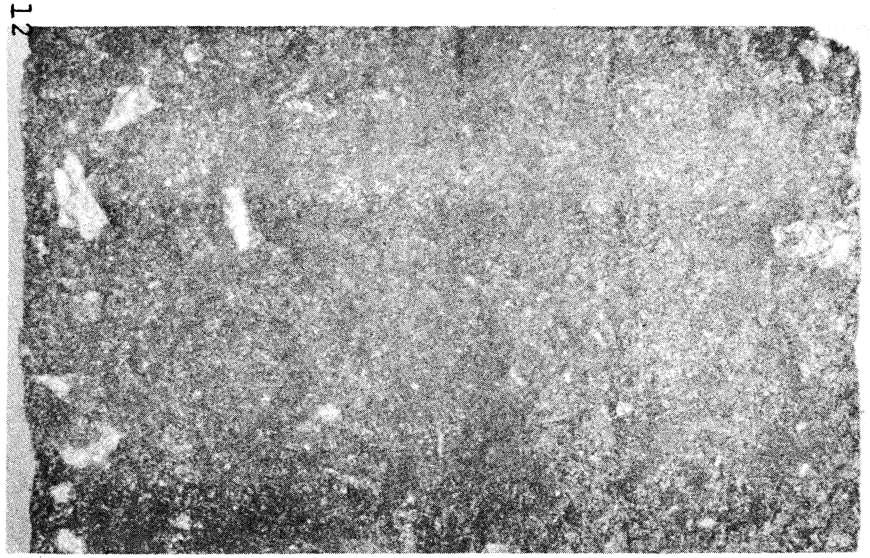
Freeze-thaw (ACRA 500)
TSR = 0.66

Figure 2. Visible stripping of Mix 7c with Shell asphalt cement.

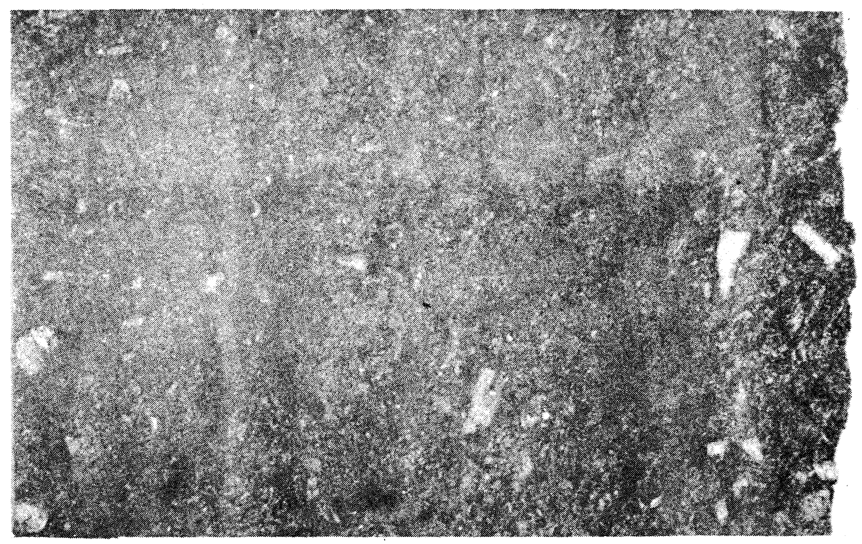


Dry

Freeze-thaw (no additive)
TSR = 0.41



Freeze-thaw (Kling Beta LV)
TSR = 0.88



Freeze-thaw (ACRA-500)
TSR = 0.92

Figure 3. Visible stripping of Mix 4c with Chevron asphalt cement.

Modification of Test Method

The materials labs that normally would be performing the stripping test do not have equipment to test at a deformation rate of 1.6 mm/min. (0.065 in./min.) and 12°C (54°F). Therefore, implementation of the test would be facilitated if it could be modified so that the existing equipment could be used.

To investigate this possibility, the mixes tested in phase 1 were retested at a deformation load rate of 51 mm/min. (2 in./min.) and test temperature of 25°C (77°F). The Marshall stability testing device and a 25°C (77°F) water bath used for penetration tests on asphalt cement, which are usually available in materials labs, were used in the performance of the test.

The results of both test methods are compared in Table 7. A correlation between the two methods was obtained in the form

$$Y = 0.927\ X + 0.008 \qquad R = 0.976,$$

where

Y = TSR by 51 mm/min. (2 in./min.) deformation rate and 25°C (77°F) test temperature;

X = TSR by 1.6 mm/min. (0.065 in./min.) deformation rate and 12°C (54°F) test temperature; and

R = coefficient of correlation.

The t test indicates that there is no significant difference in the test methods at a 95% confidence level. The methods are equivalent with respect to their ability to predict stripping.

Table 7

Tensile Strength Ratios by Two Test Methods

	Original 1.6 mm/min., 12°C (.065 in./min., 54°F)		Modified 51 mm/min., 25°C (2 in./min., 77°F)	
Mix No.	Voids Total Mix, %	Tensile Strength Ratio	Voids Total Mix, %	Tensile Strength Ratio
1	6.3	0.46	6.9	0.52
2	5.4	0.52	5.4	0.45
3a	3.4	1.17	4.7	1.12
4a	4.7	0.52	5.5	0.51
5	6.1	0.77	6.6	0.72
6	8.0	0.56	7.3	0.52
7a	6.9	0.44	6.6	0.41
8	7.0	0.62	7.5	0.52

CONCLUSIONS

1. None of the mixes showed significant stripping after only the vacuum saturation preconditioning; therefore, with these mixes, pavement damage would not occur in a short period of time, or the vacuum saturation preconditioning does not predict the short-term performance of the mixes.

2. Six of the eight mixes showed significant stripping after the freeze-thaw preconditioning; therefore, for these six mixes, pavement damage would probably occur over a long period.

3. From the results of tests with the three asphalt cements used, it is concluded that the type of asphalt cement used does not significantly affect the tensile strength ratio.

4. On one mix there was a significant difference between the performances of the two antistripping additives used.

5. A test method developed under NCHRP Project 4-8(3)/1 can be modified so it can be performed with equipment now available in most materials labs.

6. The magnitude of stripping can be detected by visual examination of specimens.

RECOMMENDATIONS

1. Variability data should be collected on the modified test method using a 2 in./min. deformation rate and 77°F test temperature.

2. After variability data have been collected, the test method should be implemented to determine the need for antistripping additives in asphaltic mixes containing noncarbonate aggregates.

REFERENCES

1. Lottman, R. P., Final Report — Predicting Moisture-Induced Damage to Asphaltic Concrete, University of Idaho, February 28, 1974.

2. Road and Bridge Specifications, Virginia Department of Highways and Transportation, Commonwealth of Virginia, January 1, 1978.

3. Lottman, Robert P., Working Plan and Guidelines to Participating States for NCHRP Research Project 4-8(3)/1, University of Idaho, June 10, 1975.