RECYCLING OF WATER-SUSCEPTIBLE PAVEMENTS

by

G. W. Maupin, Jr.
Research Scientist

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

In Cooperation with the U. S. Department of Transportation
Federal Highway Administration

Charlottesville, Virginia

May 1980
VHTRC 80-R45

2662

BITUMINOUS RESEARCH ADVISORY COMMITTEE

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

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

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

J. L. CORLEY, Assistant District Engineer — Construction, VDH&T

W. R. DAVIDSON, Assistant Maintenance Engineer, VDH&T

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

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

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

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

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

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

H. E. MARSHALL, District Engineer, FHWA

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

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

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

SUMMARY

Several bituminous concrete interstate pavements that experienced failures suspected to have been caused by stripping were investigated. On two projects, the degree of deterioration, potential serviceability, and possible remedial measures were studied. Cores were taken to determine the degree of stripping and tensile strength, and dynaflect tests were performed.

An emulsion mix design was developed for stripped bituminous concrete removed from another project with the expectation that it could be used as a surface mix on a highway with a low traffic volume. While this expectation was not realized, it was concluded that the material is suitable for use in a base mix.

A maintenance resurfacing on a fourth project that experienced stripping failure is being monitored and the performance is being evaluated.

2661

RECYCLING OF WATER-SUSCEPTIBLE PAVEMENTS

by

G. W. Maupin, Jr.
Research Scientist

PURPOSE AND SCOPE

Pavement failures caused by water entering the asphaltic concrete have been evident for several years. The failure mechanism, known as "stripping", can affect the pavement layers to various degrees. For example, stripping might occur in the surface, binder, or base mix, or in various combinations of these layers at the same time. A detailed field investigation is necessary to determine the extent and location of the stripping.

The purpose of the investigation reported here was to examine the deterioration caused by stripping in several sections of interstate pavement to gain information that could be used to develop rehabilitative measures for extending the life of the pavements.

The strength and predicted serviceability were determined on several sections by taking deflection measurements, and cores were taken to determine the extent and location of stripping. Recycling was considered on one section where the removal of material was necessary.

PAVEMENT SECTIONS INVESTIGATED

The sections of pavement investigated had exhibited various degrees of distress in the spring of 1978. Preliminary observations at that time revealed stripping damage; however, no extensive examinations of the pavements were made prior to the present investigation. The sections are described under the following subheads.

I-64 in Goochland County

A section approximately 10.5 miles (16.9 km) long between Routes 605 and 522 in Goochland County that was completed in 1968 showed initial distress in the form of cracks. Later, potholes developed.

A trench cut across the westbound traffic lane in the spring of 1978 revealed stripping throughout the full depth of asphaltic concrete.

The cracks were sealed prior to the application of a slurry seal treatment in 1978; yet, potholes continued to appear in the spring of 1979.

I-85 in Brunswick County

Cracking occurred in varying degrees of severity along a 20-mile (32-km) section of I-85 in Brunswick County from the Dinwiddie County line to the Meherrin River. This pavement was completed in 1970. Cores taken from one of the most deteriorated areas revealed extensive stripping through the full depth of the asphaltic layers. This area was repaired with a slurry seal treatment in 1978, which seemed to alleviate the deterioration.

I-81 in Washington and Smyth Counties

Several sections of asphaltic concrete pavement on I-81 developed severe cracking and potholes. A preliminary investigation revealed stripping of the original surface mix, which had been overlaid, but no damage was found in the underlying bituminous concrete, which was made with limestone aggregates. The damaged layers consisted of an approximately 80 lb/yd.^{2} (43 kg/m^2) original surface course constructed in 1967 and a 100 lb/yd.^{2} (54 kg/m^2) overlay placed in 1976.

I-81 in Botetourt County

Approximately 11 miles (18 km) of I-81 from the Rockbridge County line south to Route 11, which was constructed during 1960 to 1965, exhibited distress in 1978. The stripping was attributed to the use of a quartzite aggregate that has since been banned from use in interstate pavements.

TESTING

The most extensive testing program was conducted on sections of I-64 and I-85. In 1979, 34 cores were removed from Route I-64 and 30 cores from I-85. The cores were separated into the individual pavement layers for indirect tensile testing; however, the surface layer of S-5 mix was too thin for this purpose. One-half of the cores were tested in a dry condition and one-half after vacuum saturation with water. The results indicated the overall strength of the asphalt and the strength loss caused by moisture. Also, a visual determination of the stripping was made.

Viscosity and penetration measurements were made according to ASTM D2170 and ASTM D5, respectively, on asphalt cement recovered from cores by the Abson recovery procedure, ASTM D1856.

The strengths of the pavement systems were computed from the results of dynaflect measurements. The results of these measurements were also used to predict the remaining service life of the pavement.

Pavement strengths were determined in terms of thickness equivalencies, in which the equivalency value of a full-depth layer of asphalt is equal to 1.0. The maximum deflection, shape of the deflection basin (spreadability), and the general evaluation chart(1) shown in Figure 1 were used to compute the thickness equivalencies. In this calculation the maximum deflection is defined as the equivalent Benkelman beam deflection and the spreadability is defined as

$$S = \frac{d_{max} + d_1 + d_2 + d_3 + d_4}{5d_{max}} \times 100,$$

where d_{max} is the deflection under the center of the applied load, and d_1, d_2, d_3, and d_4 are the deflections at 1, 2, 3, and 4 ft. (30 cm, 61 cm, 91 cm, and 122 cm) from the center of the applied load.

RESULTS

I-64 in Goochland County

The pavement structure on this section consists of 6 in. (15 cm) of stabilized soil cement, 8.0 in. (20 cm) of #21-A crushed subbase material, 7.5 in. (19 cm) of B-3 bituminous concrete base, 1.2 in. (3.0 cm) of I-2 bituminous concrete, and 0.9 in. (2.3 cm) of S-5 bituminous concrete surface. The aggregate was from a quarry used only for the construction of the interstate pavement. Although the aggregate had a high mica content, it passed all of the Virginia specifications for quality and soundness.

The pavement developed cracks in 1978 and potholes in 1979. The cracks were sealed with a cutback and a slurry seal treatment was applied in 1978 in an attempt to seal the surface and stop the stripping of the bituminous concrete that appeared to be the primary cause of failure.

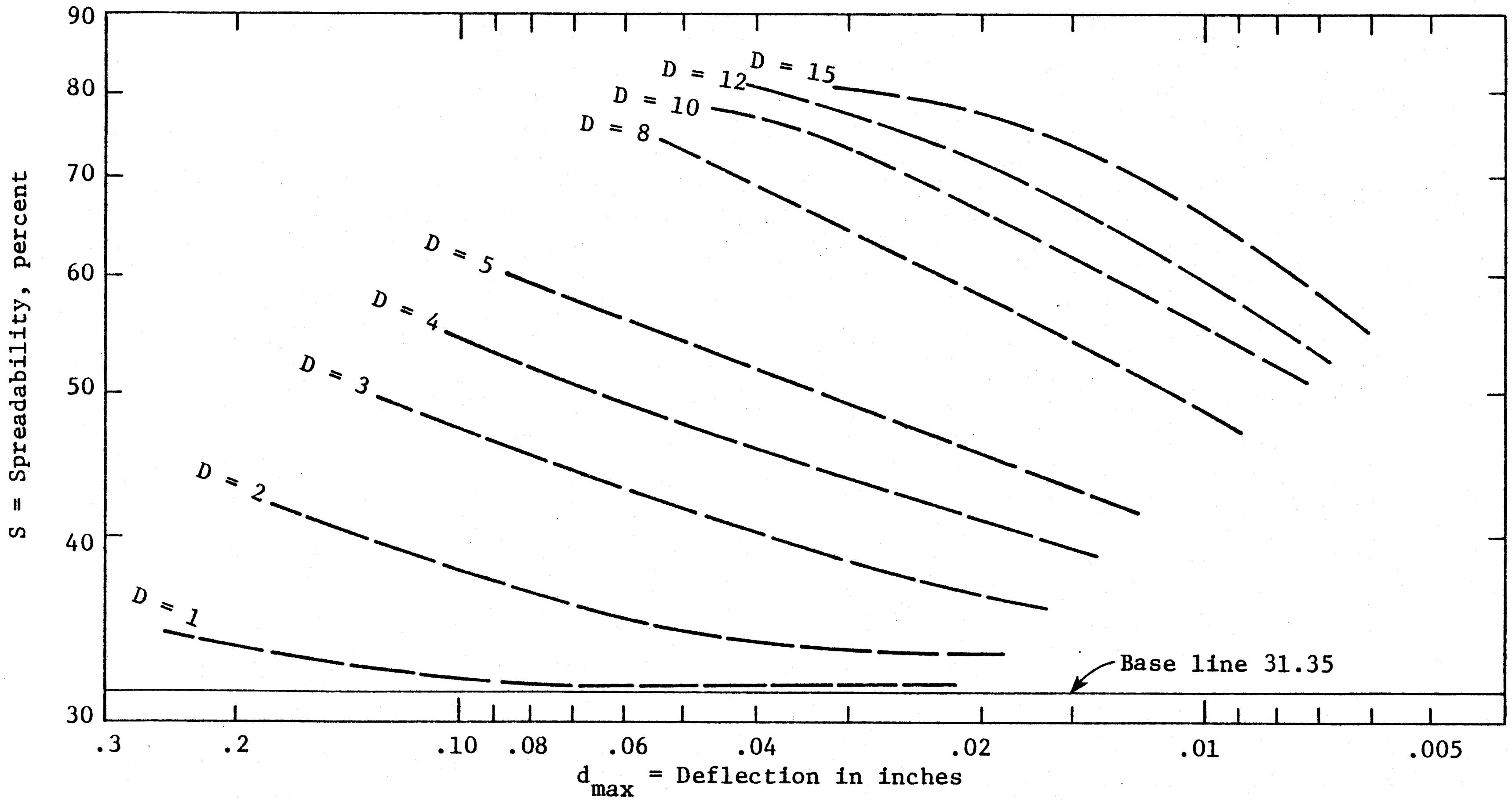

Figure 1. Chart used in determining thickness equivalency. (From reference 1).

Cores were taken and dynaflect tests performed approximately every mile in the eastbound and westbound traffic lanes and every 2 miles (3 km) in the passing lanes in June 1979. Dynaflect tests were performed within 150 ft. (46 m) of the area cored.

Core Analysis

After they were separated into individual layers, one-half of the cores were dried and the other half were vacuum saturated with water. The cores were tested in indirect tension at a vertical deformation rate of 2 in. (5.1 cm) per minute and a temperature of 72°F (22°C). As noted previously the mix in the surface course was not tested in indirect tension because of its insufficient thickness. Penetration and viscosity tests were performed on asphalt cement recovered from several cores to obtain an indication of the brittleness of the pavement.

Table 1 lists the indirect tensile strengths of the I-2 and B-3 layers. It is noted that the strength of the layers from the eastbound traffic lane (EBTL) was less than that of the layers from the WBTL, especially for the I-2 mix. The traffic counts were approximately equal in both directions, so the differences in strength were not traffic-related. Construction records also indicate that material sources did not change during the project. The strengths for the passing lanes were considerably greater than those for the traffic lanes. This difference probably resulted from the higher traffic volume carried by the latter.

Table 1

Indirect Tensile Strengths, in psi, Cores from I-64

Mix	Test Condition	Lane		
		WBTL	EBTL	PL
I-2	Dry	90	67	134
	Vac. Sat.	57	32	120
	Percent of Dry Strength	63	48	90
B-3	Dry	91	85	180
	Vac. Sat.	50	39	100
	Percent of Dry Strength	55	46	56

1 psi = 6,890 Pa

There was a 37% to 54% reduction in the strength of the asphaltic concrete from the traffic lanes when the material was vacuum saturated. These results indicate a significant reduction of pavement strength in late winter and early spring, when the pavement is wet.

The properties of asphalt recovered from cores were determined and are listed in Table 2. These results, except those for the B-3 cores, indicated severe oxidation. The penetrations for the asphalt from the S-5 and I-2 mixes averaged approximately 20 mm, and both tests on the B-3 material gave a value of 40 mm.

Table 2

Properties of Recovered Asphalt, I-64

Mix	Penetration, mm	Viscosity 140°F (60°C), poises	Viscosity 275°F (135°C), cSt
B-3	40	8,800 - 11,400	740 - 940
I-2	21 - 23	49,000 - 66,000	1,840 - 2,120
S-5	17 - 24	29,000 - 73,000	1,580 - 2,550

Dynaflect Tests

The total pavement strength (thickness equivalency) was determined from dynaflect test results. The dynaflect tests were performed in June 1979; therefore, the pavement should have been relatively dry. Table 3 lists the thickness equivalency values. The measured thickness equivalencies were from 5 in. (13 cm) to 7 in. (18 cm) less than that needed for the present traffic volume, especially in the traffic lanes. These results can be interpreted to indicate that the pavement will not stand up under the present traffic volume for the design life and there will be additional premature failures.

Table 3

Thickness Equivalency, in., I-64

Lane	Design	Needed for Current Traffic	Measured Average	Measured Range
EBTL	14.7	14	6.5	5.0 - 7.5
WBTL	14.7	14	9.0	8.0 - 10.5
EBPL	14.7	11	8.0	6.5 - 8.5
WBPL	14.7	11	9.0	8.0 - 11.0

1 in. = 2.54 cm

I-85 in Brunswick County

The pavement structure on this section of I-85 consists of 6 in. (15 cm) of soil cement, 6 in. (15 cm) of cement treated stone, and 9-10 in. (23-25 cm) of asphaltic concrete. The granitic aggregate used in the mixes was supplied from both a permanent and a temporary quarry.

The pavement developed minor cracking and some severe cracking in 1978. One of the worst sections was slurry sealed in 1978. This section has shown no further distress and the original cracks are hardly detectable.

Tests were performed on five 2-mile (3-km) sections spaced throughout the 20-mile (32-km) length because of traffic control restraints. Cores were obtained in both the traffic and passing lanes of each section and dynaflect tests were performed in proximity to the core locations.

Core Analysis

Table 4 lists the dry and saturated indirect tensile strengths of the I-2 and B-3 layers. The strength of the layers in the saturated condition was only approximately 30%-50% of the dry strength; therefore, the structural integrity of the pavement could be greatly reduced in the spring, if water penetrates the pavement and drying conditions are poor. The excellent performance of the slurry sealed section probably can be attributed to the prevention of water entering the pavement surface. The properties of the recovered asphalt, shown in Table 5, indicate severe oxidation, especially for the I-2 and S-5 mixes. The asphalt is prone to cracking and failure because of the brittleness.

Table 4

Indirect Tensile Strength, in psi, Cores from I-85

		Section				
Mix	Test Condition	1	2	3	4	5
I-2	Dry	86	84	85	—	93
	Vac. Sat.	34	46	34	—	27
	Percent of Dry Strength	40	55	40	—	29
B-3	Dry	62	89	77	92	81
	Vac. Sat.	33	55	32	36	44
	Percent of Dry Strength	53	62	42	39	54

1 psi = 6,890 Pa

Table 5

Properties of Recovered Asphalt, I-85

Mix	Penetration, mm	Viscosity 140°F (60°C), poises	Viscosity 275°F (135° C), cSt
B-3	20 - 45	5,300 - 38,000	820 - 1,280
I-2	19 - 21	40,000 - 50,000	1,400 - 1,570
S-5	15 - 21	70,000 - 84,000	1,670 - 2,180

Dynaflect Tests

The thickness equivalencies for the five sections tested are listed in Table 6. The measured thickness equivalencies of sections 1 through 3 were approximately equal to that necessary for the current traffic load; those for sections 4 and 5 were slightly less. Because of excellent drying conditions prior to testing, the values probably reflect a damp rather than a saturated condition.

Table 6

Thickness Index, in., I-85

Section	Design	Needed for Current Traffic	Measured Average	Measured Range
1	17.9	17.5	16	12 - 18
2	18.4	17.5	18	15 - 20
3	18.4	17.5	17	15 - 18
4	17.4	17.5	14	10 - 17
5	17.9	17.5	13	10 - 17

1 in. = 2.54 cm

I-81 in Washington, Smyth, and Wythe Counties

The original structural sections of these pavements on I-81 consisted of 6 in. (15 cm) of crushed stone; 7.5 in. (19 cm) of H-3(1) bituminous base; 1.2 in. (3.0 cm) of H-2 intermediate mix;

0.7 in. (2 cm) of I-3 surface mix and a layer of select material with a minimum CBR of 30 that varied from 10 to 12 in. (25-30 cm) among the different pavements. All of the pavements tested were covered with approximately 1.5 in. (3.8 cm) of maintenance resurfacing (S-5).

Pavement distress appeared in the form of cracks and potholes in the spring of 1978. An inspection revealed that damage was confined to the original surface and overlay. The failure resulted from severe stripping in the original surface course. The maintenance resurfacings applied to these sections were of two types: an S-5 non-polishing mix and a sprinkle mix.(2) Permeability tests revealed that the sprinkle mix was very permeable and allowed water to reach the original surface mix. The original surface contained a quartzite aggregate that is not presently allowed for use in interstate pavements because of its stripping history.

Utilization of Removed Pavement

In 1979, approximately 18 miles (29 km) of the pavement was removed by cold-milling approximately 1.5 to 2.0 in. (3.8 to 5.1 cm) deep, and a surface mix was applied to the freshly milled surface. The removed material was stockpiled for possible future utilization as base material or recycling material for a low-traffic-volume highway.

An emulsion mix designed for use of 100% milled material resulted in values of 1.0% for moisture and 3.0% for CSS-1h emulsion.

Schmidt, Santucci, and Coyne discovered that portland cement increases the early strength of emulsion mixes and prevents a strength loss when the mix is saturated with water.(3) Consequently, 1.3% portland cement, along with 3.0 CSS-1h emulsion and 1.0% moisture, was used in two sets of specimens made with the material removed from the pavement. After a 72-hour curing period, stability tests were performed on one set, while the second set was soaked for 96 hours and tested. A comparison of the test results for specimens with cement and the results from control specimens without cement indicated that the former underwent no loss of strength while the latter sustained a 30% loss. For the specimens with cement, there was no increase in early strength as reported by Schmidt et al.

The removed pavement contained approximately 6% asphalt cement, which was the original input value. There are two contrasting views about the addition of emulsion to pavement material that contains the designed amount of asphalt. The two views are:

1. The addition of emulsion is necessary for adhesion, but might result in a mix with excess asphalt.

2. The original asphalt performs as aggregate and when emulsion is added to promote adhesion, the mix will not contain too much asphalt.

The placement of several small test sections would probably allow a determination of whether the material could be used as a recycled surface mix with or without the addition of emulsion. Without emulsion, it could probably be used successfully as a base material.

I-81 in Botetourt County

The section of pavement in Botetourt County had a layer of asphaltic concrete that contained an aggregate that has been banned from use in interstate pavements because of stripping problems associated with it. No tests were performed because a 2.5 in. (6.4 cm) maintenance resurfacing had already been scheduled on several of the worst areas to determine the suitability of this type of repair. Some of the area covered had severe pavement distress such as potholes; therefore, the success of the resurfacing should be evident in two to three years. The resurfacing has been in service one year and the general performance is good. The locations of the failed areas in the resurfaced sections were recorded photographically and will be compared to areas that may fail later.

If the resurfacing fails, an evaluation should be made and other repair procedures should be investigated. Possible alternatives are (1) the removal of the damaged pavement and replacement with new or recycled asphaltic concrete, and (2) sealing the pavement surface with a waterproof membrane or slurry seal.

SUMMARY OF RESULTS

I-64 in Goochland County

1. The entire depth of bituminous concrete had experienced considerable stripping.

2. Core strength tests indicated that —

   a. the strength of the EBL was less than that of the WBL;

   b. the strength of the traffic lanes was less than that of the passing lanes; and

   c. there was a significant loss in strength caused by vacuum saturation.

3. The thickness equivalency, which indicates pavement strength, was approximately 50% of that needed for the present traffic volume. It is possible that the low strength may be attributable in part to the use in this pavement of the sandwiched layer system in which an unstablized layer is sandwiched between two stablized layers. Some unreported measurements on other pavements with a sandwich structure indicate that the pavement strength is sometimes weaker than the calculated design strength.

4. The thickness equivalency of the EBL was less than that of the WBL.

I-85 in Brunswick County

1. Some stripping was evident from cores through the full depth of bituminous concrete.

2. The results of strength tests on cores indicated that a 50% to 70% loss in strength was caused by vacuum saturation.

3. A slurry seal treatment appeared to have prevented the entrance of water and further deterioration.

4. On three test sections the measured thickness equivalency was approximately equal to that required and for the two remaining sections it was only slightly less than that needed.

I-81 in Washington, Smyth, and Wythe Counties

1. The use of removed bituminous concrete in an emulsion surface mix would not be satisfactory because of the risk of obtaining a pavement with excess asphalt.

2. The removed material could probably be used in a base mix with or without the addition of emulsion.

I-81 in Botetourt County

1. The performance of a 2.5 in. (6.4 cm) maintenance resurfacing is being evaluated.

RECOMMENDATIONS

While in the planning of the study recycling was considered to be a prime rehabilitation possibility, it was removed from consideration except for the I-81 project in Washington, Smythe, and Wythe Counties. Consequently, the only recommendation for recycling relates to this project. In regard to the other pavements investigated, the asphaltic concrete of I-64 was so water-susceptible that recycling was considered highly impractical. The condition of I-85 did not warrant removal of the pavement; and operations personnel had already decided to try a resurfacing of I-81 in Botetourt before tests could be performed.

1. The structural strength of the I-64 pavement should be increased and the surface should be sealed to prevent the entry of water.

   As a result of the above recommendation, several experimental sections will be installed in 1980. The sections will be covered with a fabric sealer and varying thicknesses of hot mix. The treatments are: (1) 1.4 in. (3.5 cm) of hot mix; (2) 2.2 in. (5.5 cm) of hot mix; and (3) 1.4 in. (3.5 cm) of hot mix over a fabric sealer. The primary purpose of the fabric is to prevent water from entering the water-susceptible asphaltic concrete. A comparison of the performance of treatments 1 and 3 should indicate whether the fabric is beneficial. Treatment 2 will be included because its cost is approximately equal to that of treatment 3, and the added thickness might be more beneficial than a fabric sealer.

2. The surface of the I-85 pavement should be sealed, possibly with a slurry seal. This recommendation has been implemented and a slurry seal was applied July 1980.

3. The bituminous concrete removed from the I-81 pavements can be used as a base material.

ACKNOWLEDGEMENTS

The author thanks A. D. Newman, S. L. Hite, and W. A. Dennison for assisting in the necessary field testing, and R. M. Cleek, Jr. and B. S. Byrd for providing traffic control. Appreciation is expressed to G. V. Leake and L. E. Wood, Jr. who conscientiously performed the field and laboratory tests, respectively.

The author also thanks J. H. Dillard for his support and C. S. Hughes III and K. H. McGhee for their professional advice on the conduct of the investigation and interpretation of results.

The investigation was financed with HPR funds administered by the Federal Highway Administration.

2678

REFERENCES

1. Vaswani, N. K., "Pavement Design and Performance Study — Phase B: Deflection Study — Interim Report No. 3, Virginia Highway Research Council, February 1971.

2. Dillard, J. H., and G. W. Maupin, Jr., "Use of Sprinkle Treatment to Provide Skid Resistant Pavements", Proceedings, Association of Asphalt Paving Technologists, Vol. 40, 1971.

3. Schmidt, R. J., L. E. Santucci, and L. D. Coyne, "Performance Characteristics of Cement-Modified Asphalt Emulsion Mixes", Proceedings, Association of Asphalt Paving Technologists, Vol.42, 1973.

2680