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16. Abstract

Several chemical antistripping additives were used in field installations and compared to a similar installation using hydrated lime. The performance of the installations was monitored periodically, and material that was sampled during construction was tested in the laboratory. The cores of mixes with less visual stripping showed a gradual increase in strength and stiffness with time, whereas mixes with considerable stripping showed little, if any, increase. Two additives influenced the viscosity of the asphalt significantly, thereby requiring the lowering of the required mixing and compaction temperatures.

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SI CONVERSION FACTORS

To Convert From	To	Multiply By
Length:		
in	cm	2.54
in	m	0.025 4
ft	m	0.304 8
yd	m	0.914 4
mi	km	1 . 609 344
Area:		
in^2	cm^2	6.451 600 E+00
ft^2	m^2	9.290 304 E-02
yd^2	m^2	8.361 274 E-01
mi^2	Hectares	2.589 988 E+02
acre (a)	Hectares	4.046 856 E-01
Volume:		
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pt	m^3	4.731 765 E-04
qt	m^3	9.463 529 E-04
gal	m^3	3.785 412 E-03
in^3	m^3	1.638 706 E-05
ft^3	m^3	2.831 685 E-02
yd^3	m^3	7.645 549 E-01

NOTE: $1m^3$ = 1,000 L

To Convert From	To	Multiply By
Volume per Unit Time:		
ft^3/min	m^3/sec	4.719 474 E-04
ft^3/s	m^3/sec	2.831 685 E-02
in^3/min	m^3/sec	2.731 177 E-07
yd^3/min	m^3/sec	1.274 258 E-02
gal/min	m^3/sec	6.309 020 E-05
Mass:		
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dwt	kg	1.555 174 E-03
lb	kg	4.535 924 E-01
ton (2000 lb)	kg	9.071 847 E+02
Mass per Unit Volume:		
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lb/in^3	kg/m^3	2.767 990 E+04
lb/ft^3	kg/m^3	1.601 846 E+01
lb/yd^3	kg/m^3	5.932 764 E-01
Velocity: (Includes Speed)		
ft/s	m/s	3.048 000 E-01
mi/h	m/s	4.470 400 E-01
knot	m/s	5.144 444 E-01
mi/h	km/h	1.609 344 E+00
Force Per Unit Area:		
lbf/in^2 or psi	Pa	6.894 757 E+03
lbf/ft^2	Pa	4.788 026 E+01
Viscosity:		
cS_t	m^2/s	1.000 000 E-06
P	Pa·s	1.000 000 E-01

Temperature: (°F-32) 5/9 = °C

FINAL REPORT

EVALUATION OF ANTISTRIPPING ADDITIVES

G. W. Maupin, Jr.
Research Scientist

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

Virginia Transportation Research Council
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ABSTRACT

Several chemical antistripping additives were used in field installations and compared to a similar installation using hydrated lime. The performance of the installations was monitored periodically, and material that was sampled during construction was tested in the laboratory. The cores of mixes with less visual stripping showed a gradual increase in strength and stiffness with time, whereas mixes with considerable stripping showed little, if any, increase. Two additives influenced the viscosity of the asphalt significantly, thereby requiring the lowering of the required mixing and compaction temperatures.

FINAL REPORT

EVALUATION OF ANTISTRIPPING ADDITIVES

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INTRODUCTION

Many states use antistripping additives in an attempt to prevent or alleviate the damage of asphalt concrete by moisture. Approximately one-third of additive users responding to a national questionnaire in 1981 indicated that sometimes additives were ineffective (1). In recent years, additive producers have attempted to improve their product and to persuade transportation departments to install test sections using the improved additives.

PURPOSE AND SCOPE

The purpose of this investigation was to evaluate three "improved" antistripping additives and compare their effectiveness against that of hydrated lime. The performance of field test sections was monitored, and materials sampled during construction were tested in the laboratory.

MATERIALS

Mix Design

The contractor, APAC-Virginia, Inc., designed the S-5 mix, and it was approved by the Virginia Department of Transportation (Table 1).

Additives

Three chemical additives and hydrated lime were used in the test mixes (Table 2). A control mix with no additive was used for comparison. Also a test section with the contractor's conventional S-5 mix, which contained recycled asphalt pavement (RAP) with 1.0 percent ACRA-2000, was included in the evaluation even though it had not been planned (see Table 3 for the job mix design).

Table 1

S-5 Mix Design

Sieve	% Passing
1/2	100
#4	58 ± 4
#30	20 ± 3
#200	4.4 ± 1
A.C.	5.7 ± 0.3

60% No. 8 crushed stone - Vulcan Materials, South Boston
25% No. 10 crushed stone - Vulcan Materials, South Boston
15% No. 10 washed crushed stone - Vulcan Materials, South Boston

Table 2

Additives

Additive	% of Asphalt Cement	Source
ACRA-2000	1.0	Tomah Products
BA-2000	0.5	Carstab Corp.
Kling Beta 2550 HM	1.0	Scan Road, Inc.
Hydrated Lime	1.0*	USG Industries, Inc.

*1% by weight of total mix

Table 3

S-5 RAP Mix Design

Sieve	% Passing
1/2	100
#4	62 ± 4
#30	21 ± 3
#200	4.4 ± 1
A.C.	5.7 ± 0.3

50% No. 8 crushed stone	- Vulcan Materials, South Boston
20% No. 10 (washed)	- Vulcan Materials, South Boston
15% No. 10 (unwashed)	- Vulcan Materials, South Boston
15% RAP	- APAC-Virginia, Inc.

TEST SECTIONS

The test sections were constructed in the westbound traffic lane on an 8-mi stretch of Route 58 in Halifax County (Figure 1) from August 4 through 23, 1986. Stability-flexibility additives, which were used in adjacent test sections, are covered in a separate study (2). The weather was excellent: clear to partly cloudy with temperatures ranging from 70°F to 90°F.

Prior to paving, 2 to 5 in of defective stripped pavement was milled, removed, and replaced with B-3 base mix. The Department elected to split the 1.5-in-thick experimental surface mix into a 0.5-in "scratch" layer and a 1.0-in surface layer in an attempt to obtain a smooth riding surface. No density tests were performed on the "scratch" layer, which was not rolled. The general paving plan was to pave a test section in the traffic lane each morning, and "square up" the adjoining passing lane in the afternoon with the conventional recycled asphalt pavement (RAP) mix.

A 2.5-ton batch plant with automatic plant controls located adjacent to Vulcan Materials Quarry at South Boston was used to produce the mix. The mixing times were 2 seconds dry and 30 seconds wet, except that the hydrated lime mix required a slightly longer dry mix time to introduce the hydrated lime into the pugmill. The temperature of the mixes immediately after mixing ranged from 280°F to 290°F.

The hydrated lime was dumped from paper bags by hand into an opening in the pugmill. The dry mixing time was controlled manually by the plant operator to ensure that all of the hydrated lime was in the pugmill before the asphalt was introduced.

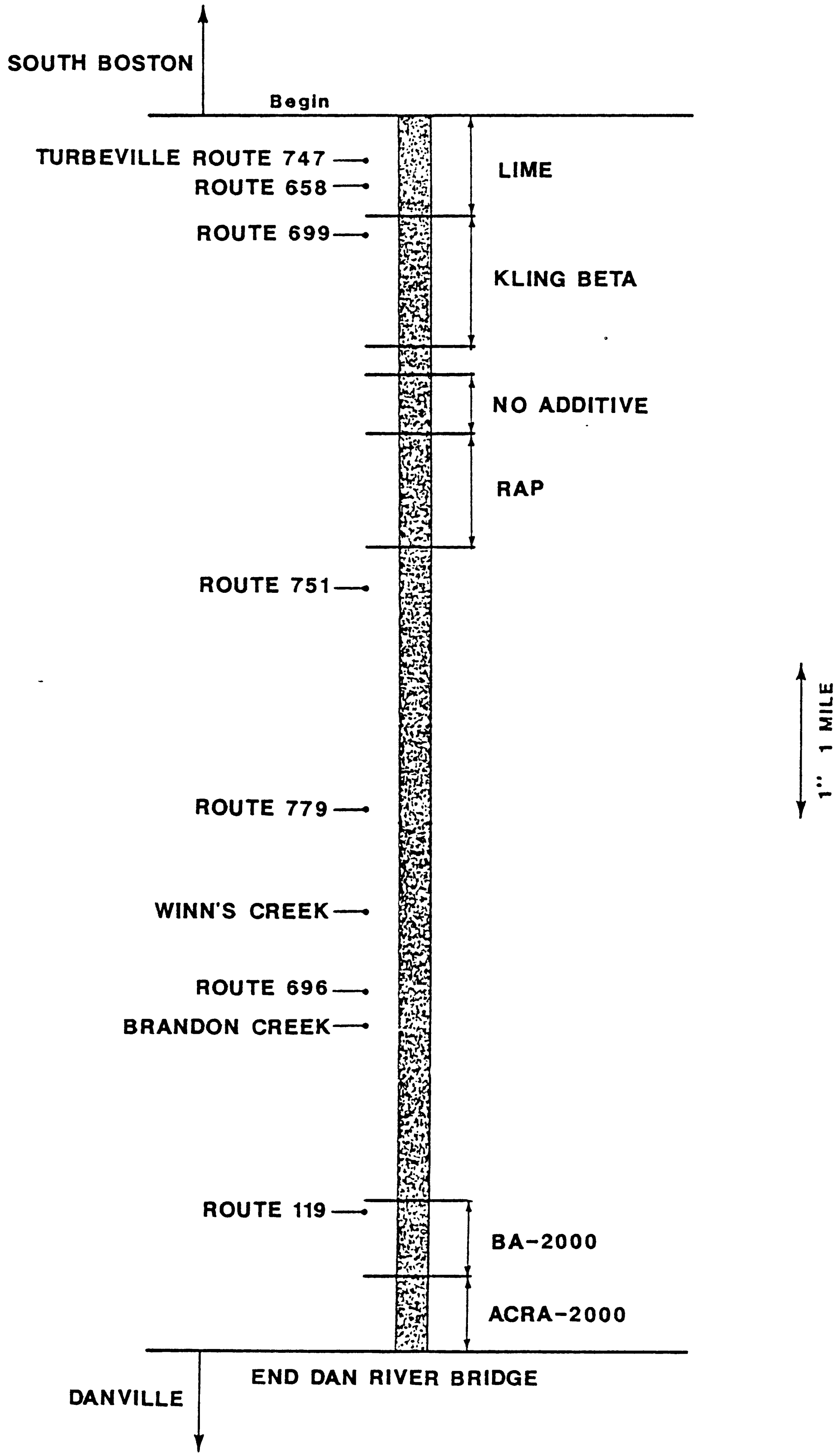

Figure 1. Test sections.

The chemical additives were pumped directly into the asphalt line prior to entering the pugmill. Because of the possibility that each additive would flow at a different rate, the pump was calibrated for each one.

The Kling Beta 2550 HM and ACRA-2000 additives were pumped directly from 50-gal containers with no problems; however, the BA-2000 was too viscous to be pumped properly. After placing several truck-loads of mix with less than the required amount of BA-2000, the additive manufacturer requested that a new batch of additive be obtained with the required viscosity and that it be used at a later date. The BA-2000 with a changed viscosity was used successfully approximately two weeks later. Also, the density of the initial test section containing ACRA-2000 was less than desirable; therefore, a second test section was placed approximately two weeks later.

TESTS

Asphalt

Samples of the virgin asphalts and additives were obtained at the plant during construction of the test sections. Additives were blended with the asphalts at the specified concentrations in the laboratory for testing. Penetration and ductility tests were performed according to ASTM test methods D-5 and D-113 (3) respectively. The tests were performed at 39.2°F, 50°F, 60°F, and 77°F on samples of asphalt containing chemical additive from the test sections with chemical additive and on samples containing no additive from the test sections with hydrated lime and no additive. Viscosity tests at 140°F and 275°F were conducted according to ASTM test methods D2171 and D2170 (3), respectively. Also, viscosity, penetration, and ductility tests were performed on various samples of residue from the thin-film oven test (TFOT) (ASTM D1754-87) (3).

Density

Density tests (ASTM D2726) (3) were performed on cores removed from the test sections approximately every six months. A moisture correction, which was determined by drying several additional cores, was used to adjust the core density for moisture content. Typical moisture contents ranged from 1.0 to 1.5 percent.

Stripping Tests

The modified Lottman test (Virginia Test Method, VTM-62) (4), which was in effect in 1986, was used by Froehling and Robertson, Inc. (F&R) to estimate moisture damage before construction and during construction. The procedure basically consisted of performing indirect tensile tests at a 2 in/min loading rate at 77°F. The ratio of the strength of two sets of specimens--one unconditioned and one conditioned by saturation, freezing, and thawing in a 140°F water bath--yields a tensile strength ratio (TSR), which was used to predict potential stripping. A similar test developed under the National Cooperative Highway Research Program (Project 10-17) (1) was used by the author to test mixes sampled during construction and cores obtained two weeks after construction. This test controls the degree of saturation, whereas the test described previously does not.

The third type of stripping test used was a boil test (VTM-13) (4), which requires a 10-minute boiling time. To pass, a sample must display no stripping.

Indirect Tensile Test

Cores were drilled (using water as a coolant), wrapped in plastic wrap, transported to the laboratory, separated from underlying layers, and tested for density and indirect tensile strength. The indirect tensile tests were performed at a deformation rate of 2 in/min at 72°F. A special effort was made to prevent moisture from escaping and to prevent the mix from healing before testing.

Visual Observation of Cores and Pavement Surface

The degree of stripping on the broken surface of the tested cores was estimated on a scale of 0 to 5--0 indicating no stripping, and 5 indicating very severe stripping.

The pavement surface was examined during each coring operation for any distress.

DISCUSSION OF RESULTS

Asphalt

The asphalt properties with and without additive are presented in Table 4. All values conform to the AASHTO specification for viscosity-graded asphalt cement (M226 - Table 2) as specified (5). The viscosity at 140°F decreased approximately 400 poises because of the addition of Kling Beta 2550 HM and ACRA-2000, and although the asphalt containing the ACRA-2000 passed the minimum allowable limit of 1600 poises, it was borderline. The lowering of viscosity by the addition of these additives should require lowering the mixing and compaction temperatures by 10°F to 15°F; however, this adjustment was not made.

The only property besides viscosity at 140°F that was affected significantly was the ductility at 77°F for the TFOT residue of the Kling Beta 2550 HM blend. The ductility of the TFOT residue was 77 cm compared to 150+ cm for the other additives.

Table 4

Asphalt Cement Properties

Identification		Penetration (0.1 mm)				Ductility (cm)				Viscosity	
Test Section	Asphalt	39.2°F	50°F	60°F	77°F	39.2°F	50°F	60°F	77°F	140°F Poises	275°F Cs
No Additive	No Additive	7	14	22	63	0	11	150+		2210	400
	TFOT Residue				43				150+	4650	540
Hyd. Lime	No Additive	8	17	26	75	1	30	150+		2190	420
	TFOT Residue				48				150+	4480	570
Kling Beta	No Additive				63				150+	2120	380
	With Additive	9	14	24	73	0	16	150+		1740	360
	*TFOT Residue				47				73	3760	480
BA-2000	No Additive				67				150+	2050	390
	With Additive	7	13	24	68	4	11	150+		2030	380
	*TFOT Residue				47				150+	3820	500
ACRA-2000	No Additive				68				150+	2050	400
	With Additive	9	15	26	67	4	14	150+		1600	350
	*TFOT Residue				46				150+	3430	480
RAP (ACRA-2000)	No Additive				65				150+	2210	400
	With Additive	5	14	25	60	4	14	150+		1700	350
	TFOT Residue				45				150+	3600	470

*Performed on asphalt with additive

Density

The pavement voids determined from periodic cores had decreased approximately 2 percent after 31 months of traffic (see Figure 2), which is typical at these void and traffic levels. Because of the variability of measurements, there were no significant differences detected between densification of the various mixes.

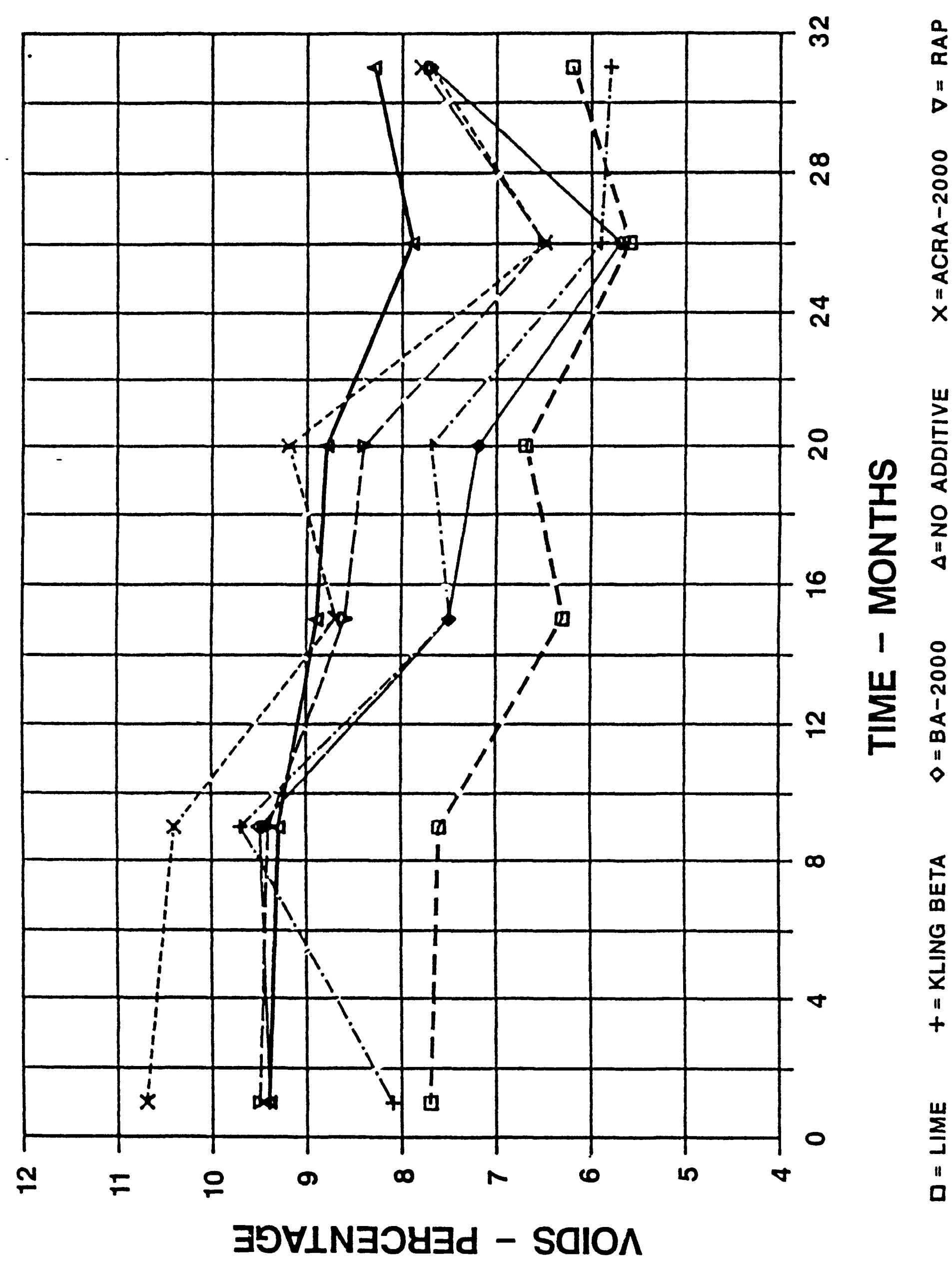

Figure 2. Pavement voids v. time.

Stripping Tests

TSR values for production samples determined by F&R using VTM-62 and the Research Council using the test from NCHRP project 10-17 are relatively close, even though the test methods are slightly different (see Table 5). If 0.75 was the minimum acceptable value, the F&R test would have passed, and the Research Council test would have failed for the mix without any additive. The comparison of TSRs on production samples and cores by the Research Council yielded good agreement. The boil test (VTM-13) performed by the Research Council failed when the mixes with no additive and hydrated lime were used, whereas all boil tests run by F&R passed. The mix with no additive should be expected to fail VTM-13, and even though hydrated lime may yield satisfactory TSR values and be effective, it will not always pass the boil test. It is recognized that the subjective evaluation of the boil test produces poor reproducibility between labs, and this was the case in this study.

It can be expected from TSR results of boil tests performed by the Research Council that stripping will occur in the pavement with no additive. None of the other mixes should be susceptible to excessive stripping.

Table 5

Stripping Test Results

	Froehling & Robertson, Inc.			Research Council		
Section I. D.	VTM-62 (design)	VTM-62 (production)	VTM-13 (production)	10-17 (production)	10-17 (cores)	VTM-13 (production)
No additive	-	0.81	Pass	0.67	0.65	Fail - 70**
Hydrated Lime	-	0.87	Pass	0.96	0.96	Fail - 98**
Kling Beta 2550 HM	0.96	0.96	Pass	0.98	0.94	Pass
BA-2000	0.90*	0.88	Pass	0.93	0.89	Pass
ACRA-2000	0.99	0.88	Pass	0.92	1.08	Pass
RAP (ACRA-2000)	-	-	-	0.87	0.79	-

*1% BA-2000 by weight of asphalt
**Percent coated

Indirect Tensile Tests

The pavements with low visual stripping (rating less than 3, see Table 6) demonstrated a gradual increase of strength with time through 26 months (Figure 3). The pavements with considerable stripping (rating greater than 3) produced no overall gain in strength; also, the strength appeared to be cyclic: low values in the spring and high values in the fall (Figure 4). The cyclic behavior may have been caused by weakening because of stripping when the pavement was wet in the winter followed by strengthening resulting from drying in the summer. This cyclic trend of strength loss and recovery shows the susceptibility of these mixes to stripping.

Table 6

Visible Stripping in Cores at 31 Months

ACRA 2000	0.8
Hydrated lime	1.2
Kling Beta 2550 HM	2.3*
BA-2000	3.3
RAP (ACRA-2000)	3.5
No additive	4.2

(0 = no stripping; 5 = severe stripping)
*Individual values = 4.0, 1.5, 1.5

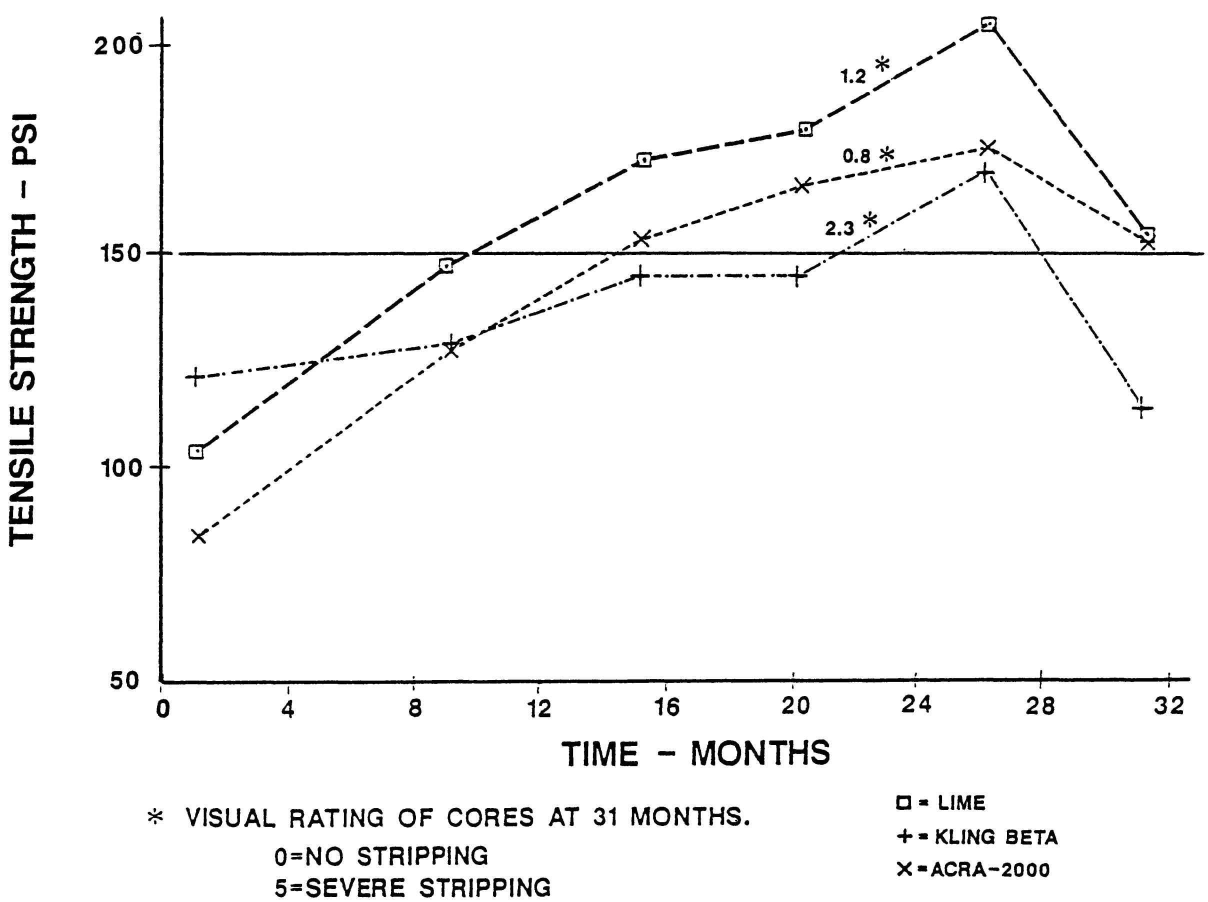

Figure 3. Tensile strength v. time.

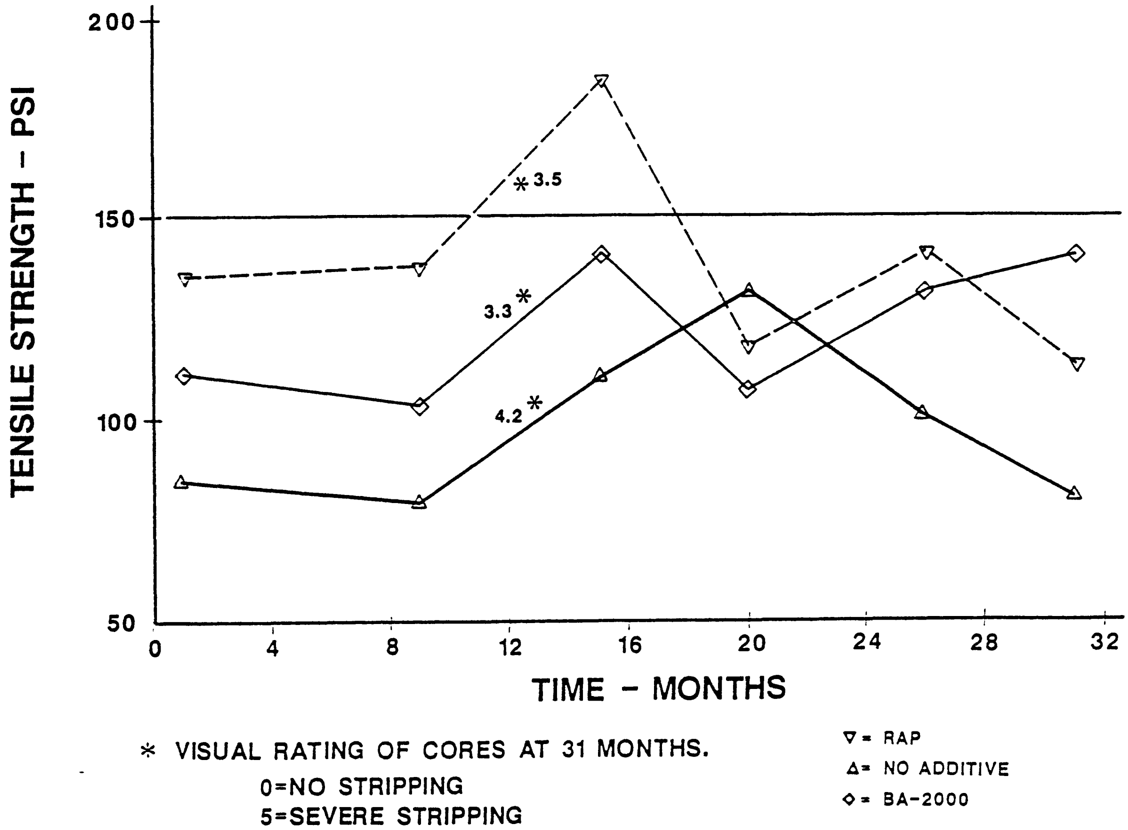

Figure 4. Tensile strength v. time.

Resilient Modulus Tests

The general trends of resilient modulus results are similar to the indirect tensile test results, which were discussed previously (Figures 5 and 6). The pavements with less stripping (rating less than 3) exhibit a higher increase in modulus and less cyclic behavior than the pavements with considerable stripping (rating greater than 3).

Observation of Cores and Pavement

Table 6 lists the visual stripping ratings of broken cores taken from the test sections at 31 months. One of the three cores evaluated from the Kling Beta section had considerable stripping, whereas the other two cores did not. Since previous cores had shown insignificant stripping, it is believed that this isolated incident of significant stripping probably was caused by additive being inadvertently omitted from a small quantity of plant mix. The three sections with ACRA, Kling Beta, and lime have approximately the same amount of stripping. Although the RAP section also used ACRA, it apparently was not as effective with the recycled material. Since the RAP was partially coated with asphalt, it was impossible to obtain a uniform mixing and coating of the RAP with new asphalt containing ACRA.

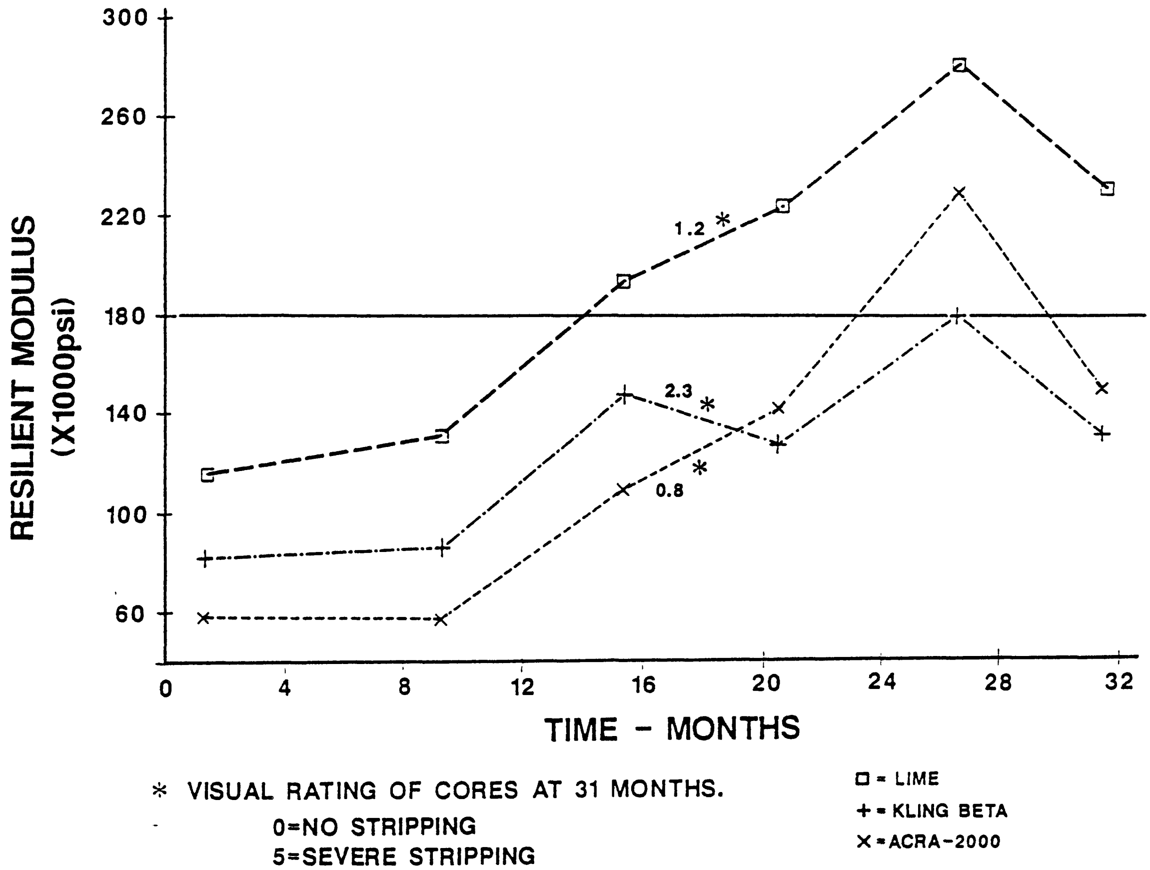

Figure 5. Resilient modulus v. time.

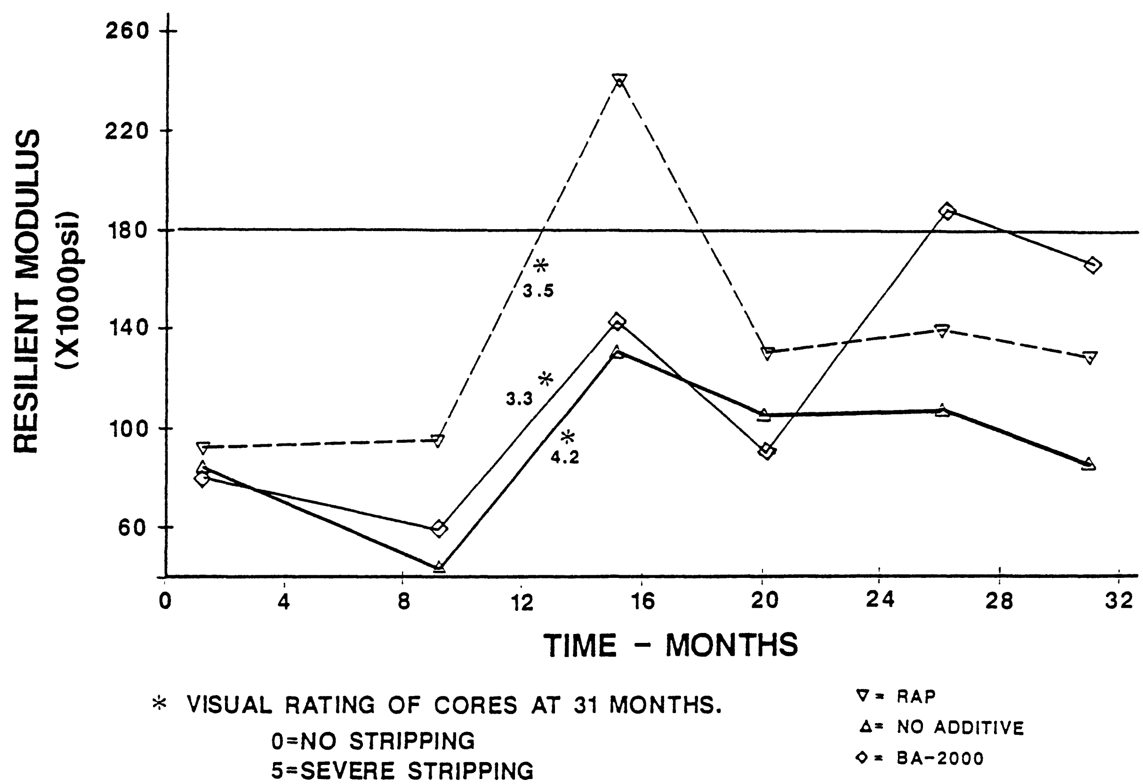

Figure 6. Resilient modulus v. time.

The only pavement distresses were longitudinal and transverse cracks in a 200- to 300-ft length of the Kling Beta section. The location was not the same as that with the stripped core; thus, these cracks probably were reflection cracks unassociated with the quality of the overlay.

CONCLUSIONS

1. The sections with Kling Beta, ACRA, and lime have much less stripping than the other test sections.

2. The mixes with less visual stripping showed a gradual increase of strength and stiffness with time, whereas the mixes with considerable stripping showed little, if any, overall gain.

3. The susceptibility of mixes to stripping is evidenced by the cyclic development of and loss of strength and stiffness with time.

4. Two additives influenced the viscosity of the asphalt significantly; consequently, the recommended mixing and compaction temperatures were changed by 10°F to 15°F.

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