Relationship Among Parameters Derived from High-Performance Liquid Chromatography, Physical Properties, and Pavement Performance in Texas

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The performance of asphalt cement in pavement mixes has aroused considerable interest and debate in the past few years. As a result of this, the Texas State Department of Highways and Public Transportation has sponsored studies to compare the performance of asphalt cement from different sources through a series of full-scale trials and associated laboratory studies. The laboratory studies include penetration and viscosity tests on the asphalt cement, from which temperature susceptibility parameters have been derived; mix parameters such as void content and resilient modulus; and state-of-the-art chromatography. The purpose of this paper is to make the results obtained to date available to other researchers and to draw some tentative conclusions about the interrelationship among the various tests that have been performed.

Pioneering work in relating chromatograms of asphalt fractions to the performance of pavements was sponsored by the Texas Highway Department [now the State Department of Highways and Public Transportation (SDHPT)] as early as 1963. The results of this study were reported to the Association of Asphalt Paving Technologists at their 1970 annual meeting and subsequently published in the proceedings *(1)*. This early research showed that the technique can be useful in studying the behavior of asphalt binders in highway pavements, though the authors did note on occasion that "there is really no satisfactory explanation for the results."

In 1981 the Texas SDHPT sponsored a study of the performance in pavements of asphalt cements from several sources. Test pavements were constructed in three different locations selected to represent different climatic zones within Texas. This study included high-performance liquid chromatography (HPLC) analysis of the asphalt cements as well as a program of measurements of the properties of the asphalt cements and the mechanical properties of the mixtures.

The purpose of this paper is to provide a preliminary analysis of the results. This analysis will be directed toward an assessment of the value of the HPLC technique for evaluating asphalt cements in comparison with physical tests. In addition, the experience gained from these studies will be used to make recommendations on how to proceed with this type of investigation in order to maximize the value of the information that can be obtained.

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It is expected that this will be the first of a series of reports from the Texas Transportation Institute because the SDHPT has continued their sponsorship of this research to gain the maximum benefit of a long-term evaluation of their pavements.

TEST SECTIONS

The three test sites are located at Dickens, Dumas, and Lufkin, Texas, as shown in Figure 1. The study included AC-10 and AC-20 asphalts, which had widely varying chemical and physical properties, from five different Texas sources. Sources are labeled A through E, though neither all grades nor all sources of asphalt cement were used at all sites. Table 1 gives the sources of asphalt cement and the places from which samples were taken. The coding system used for presenting results in the following tables is introduced in Table 1.

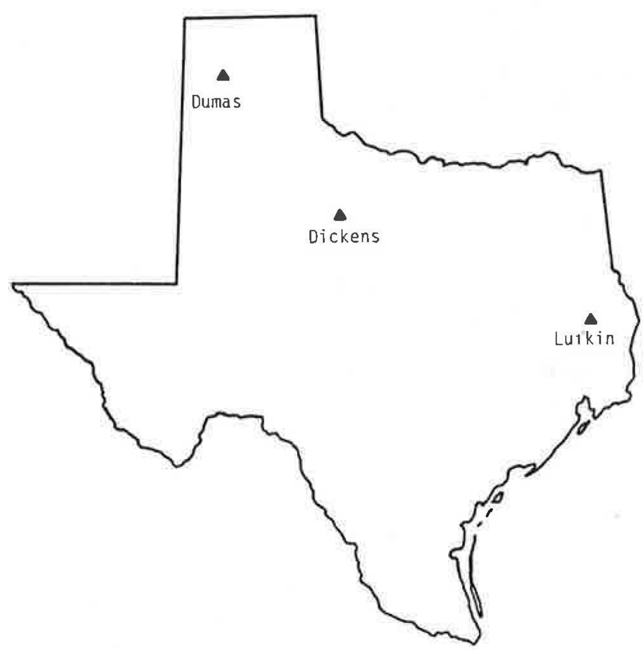

FIGURE 1 Location of asphalt cement test sections.

TABLE 1 SUMMARY OF SOURCES OF ASPHALT CEMENT

Asphalt Cement Source and Grade	Code Number							
					Recovered Material			
	New Asphalt from				Laboratory Compacted from		Cores from	
	Refinery[a]	Dickens	Dumas	Lufkin	Dumas	Lufkin	Dumas	Lufkin
A AC-10	1	11	17	–	30	–	38	–
A AC-20	2	12	18	24	–	36	–	40
B AC-10	3	–	19	25	31	–	–	–
B AC-20	4	13	–	–	–	–	–	41
C AC-10	5	–	20	–	32	–	39	–
C AC-20	6	14	–	26	–	–	–	42
D AC-10	7	–	21	27	33	–	–	43
D AC-20	8	–	–	28	–	37	–	44
E AC-10	9	15	22	–	34	–	–	–
E AC-20	10	16	23	29	35	–	–	45

[a]These samples were obtained directly from the refineries several weeks before construction of the pavements in Dickens and Dumas, Texas. Test pavements in Lufkin were installed about 1 year after those in Dickens and Dumas.

The aggregate used on all sites was locally available crushed rock that met Texas SDHPT specifications. The Dickens aggregate was of siliceous mineralogy and nonabsorptive. At Dumas and Lufkin, the aggregates were absorptive; the Dumas rock was a limestone and the Lufkin rock a combination of limestone and sandstone. At a given location, the same equipment was used to mix, place, and compact the test pavements in the conventional manner. Further details of the construction processes can be found elsewhere *(2)*.

PHYSICAL TESTS

Asphalt Cement

The following tests were performed on the asphalt cements:

- Penetration at 39.2°F and 77°F and viscosity at 77°F, 140°F, and 275°F on new asphalt cement and on that recovered from cores and
- Percentage loss, penetration at 77°F, and viscosity at 140°F on neat asphalt after exposure in the thin-film oven.

Mixes

The following tests were conducted, when possible, on samples compacted in the laboratory and recovered from the field:

- Bulk specific gravity and resilient modulus at −13°F, 33°F, 77°F, and 104°F and
- Indirect tension at 77°F, Rice specific gravity.

RESULTS OF ASPHALT CEMENT TESTS

The study has generated a considerable volume of data on conventional physical properties and of HPLC chromatographic data on the asphalt cements. Chromatograms were normalized by a computer program developed by the chemical engineers working with HPLC at the Texas Transportation Institute. The method normalizes the data by adjusting the areas of the individual chromatograms based on the area of one that is selected arbitrarily as a standard. For the purposes of interpretation, each chromatogram has been divided into three sections. These are referred to as "early," "intermediate," and "late" elution times rather than large, medium, and small molecular size. This was done because there is some doubt *(3)* about the reliability of calibration of HPLC data with respect to molecular size.

Results of the chromatographic study are presented as percentages of total area under the portions of the curves described as early, intermediate, and late fractions and are given in Table 2. This table also includes two parameters derived from physical tests. The penetration index *(PI)* *(4)* is determined from Equations 1 and 2:

$$PI = \frac{20 - 500A}{1 - 50A} \quad (1)$$

where

$$A = \frac{\text{Log } pen \text{ at } T_1 - \text{Log } pen \text{ at } T_2}{T_1 - T_2}, \quad (2)$$

$pen\ T_1$ = penetration at temperature T_1, and
$pen\ T_2$ = penetration at temperature T_2.

Viscosity-temperature susceptibility *(VTS)* *(5)* is determined from Equation 3 using viscosities at 140°F and 275°F:

$$VTS = \frac{\log \log (n_2) - \log \log (n_1)}{\text{Log } T_1 - \text{Log } T_2} \quad (3)$$

where

n_1 = viscosity at T_1 (poises),
n_2 = viscosity at T_2 (poises), and
T = temperature (degrees Kelvin).

Tables 3 and 4 give the results of the physical tests performed on the asphalt cements. Table 5 gives the results of mechanical tests on selected paving mixtures. Table 6 gives the results from the thin-film oven tests.

PAVEMENT PERFORMANCE

Dickens

The test pavements appeared to be satisfactory after construction. After 1 year in service, no major distress was evident, but the surface appeared dry and coarse. As a result of this, a fog seal was applied after 3 years. There were no visually discernible differences in performance between the asphalts from the different sources or of different grades.

Dumas

The pavement appeared to be satisfactory after construction. Within 2 months, the sections with Asphalts B and C had begun to ravel severely; in some cases, raveling reached the base. At the end of 1 year of service, the section with Asphalt C was replaced and the section with Asphalt B was partly replaced. No further deterioration was evident after 3 years.

Lufkin

The pavement appeared to be satisfactory after construction and showed no distress on inspection after 1 and 2 years of service.

TABLE 2 CHROMATOGRAPHIC AND TEMPERATURE SUSCEPTIBILITY DATA

Asphalt Source (code no.)	Percentage				
	Early	Intermediate	Late	*PI*	*VTS*
1	71.3	24.6	4.1	1.01	3.52
2	71.6	24.2	4.2	1.54	3.19
3	49.4	44.1	6.5	1.5	3.42
4	48.5	43.8	7.7	5.53	3.44
5	42.7	46.5	10.8	1.26	3.60
6	43.7	46.6	9.7	3.58	3.72
7	50.8	40.6	8.6	3.56	3.38
8	51.8	39.9	8.3	3.79	3.44
9	45.0	51.0	4.0	1.53	3.66
10	43.0	46.8	10.2	3.14	3.70
11	45.4	44.5	10.1	0.31	3.20
12	70.8	25.0	4.1	−0.53	3.08
13	54.3	39.6	6.1	4.39	3.47
14	44.7	47.4	7.9	0.43	3.70
15	41.1	49.7	9.2	1.44	3.70
16	42.1	49.4	8.5	0.59	3.68
17	71.7	24.2	4.1	0.22	3.07
18	73.5	23.6	2.9	2.85	3.16
19	51.6	41.2	7.2	3.22	3.28
20	41.0	50.1	8.9	1.32	3.58
21	49.9	44.8	5.3	3.07	3.41
22	41.0	49.8	9.2	1.81	3.64
23	42.1	48.8	9.1	0.93	3.76
24	65.5	29.7	4.8	1.88	3.26
25	57.4	36.6	6.1	–	3.27
26	43.3	49.0	7.7	−1.2	3.65
27	46.7	44.3	9.0	3.31	3.51
28	49.0	42.7	8.3	3.18	3.49
29	44.9	47.7	7.9	0.65	
30	74.7	24.1	1.2	2.68	3.23
31	51.8	41.5	6.7	8.17	3.46
32	48.4	44.5	7.1	0.26	3.69
33	53.0	39.6	7.4	5.28	3.51
34	45.3	45.8	8.9	2.44	3.71
35	45.5	45.2	9.3	3.21	3.90
36	35.7	50.8	13.5	3.13	3.27
37	53.3	39.2	7.5	−0.83	3.63
38	72.9	24.7	2.4	2.6	3.46
39	45.3	47.4	7.3	4.71	3.51
40	68.9	26.6	4.5	1.44	3.29
41	57.3	38.5	4.2	−0.48	
42	47.6	46.2	6.2	1.64	3.66
43	51.9	42.8	5.3	2.41	3.49
44	54.2	40.3	5.5	1.92	3.48
45	46.4	45.0	8.7	0.68	

DISCUSSION OF RESULTS

Differentiation Between Grades of Asphalt

Table 7 gives the ratio of the three components of the chromatograms for grades AC-10 and AC-20 from the refineries. For Asphalts A through D the ratio for the early and intermediate fractions is quite close to unity; the range is plus or minus 2 parts in 100. A larger variation is evident in the ratio of the late fractions for these asphalts; the range is from minus 16 to plus 11 parts in 100. However, the late fraction makes only a small contribution to the total area and occurs in the part of the curve that tails off and is difficult to define. To assess the precision of this variability, the results of two additional replicate tests on samples of Asphalt Cement A were analyzed. Comparison of the results of the three tests shows that, on the basis of the mean value, the variation in the early and intermediate fractions is plus and minus 1 part in 100. In the late fraction, it is plus 5 minus 9 parts in 100. In addition, the difference between grades for Asphalt Cements A through D is of the same order of

TABLE 3 PHYSICAL TEST RESULTS ON THE ASPHALT CEMENTS

		Rheological Properties									
		Directly from Refinery					As Delivered to Construction Site				
		Viscosity			Penetration		Viscosity			Penetration	
Asphalt Refinery & Grade	Location of Test Pavement	77	140	275	39.2	77	77	140	275	39.2	77
A AC-10	**	0.66	973	2.76	20	106					
	Dickens	-	-	-	-	-	1.35	1220	4.51	15	95
	Dumas	-	-	-	-	-	0.56	958	4.65	16	104
A AC-20	**	3.55	2240	6.42							
	Dickens	-	-	-	-	-	4.00	2180	7.15	8	65
	Dumas	-	-	-	-	-	1.90	2160	6.39	16	61
	Lufkin	-	-	-	-	-	1.80	1730	5.05	16	70
B AC-10	**	0.22	773	2.76	35	166					
	Dumas	-	-	-	-	-	0.36	961	3.63	39	133
	Lufkin	-	-	-	-	-	0.76	932	3.63	25	95
B AC-20	**	1.55	3010	5.33	26	64					
	Dickens	-	-	-	-	-	1.20	2520	4.64	27	77
C AC-10	**	0.66	1268	2.85	16	80					
	Dumas	-	-	-	-	-	0.83	1388	3.06	15	74
C AC-20	**	1.70	2180	3.22	18	58					
	Dickens	-	-	-	-	-	2.75	2580	3.55	7	43
	Lufkin	-	-	-	-	-	1.55	1810	3.19	6	64
D AC-10	**	0.50	930	3.18	35	113					
	Dumas	-	-	-	-	-	0.53	1030	3.21	30	105
	Lufkin	-	-	-	-	-	0.42	1040	2.88	33	111
D AC-20	**	1.11	1810	4.09	26	81					
	Dickens	-	-	-	-	-	2.50	2150	4.53	22	69
	Lufkin	-	-	-	-	-	0.96	1910	3.96	23	79
E AC-10	**	0.88	955	2.34	17	80					
	Dickens	-	-	-	-	-	1.15	1260	2.55	15	72
	Dumas	-	-	-	-	-	0.97	1038	2.48	16	71
E AC-20	**	2.25	1910	3.10	13	45					
	Dickens	-	-	-	-	-	1.90	1520	2.87	9	53
	Dumas	-	-	-	-	-	1.60	2350	3.17	10	54

* Viscosity at 77°F given in poise x 10^6
Viscosity at 140 and 275°F given in poise

** These data are representative of asphalts obtained directly from refineries, ie, not from a specific construction site.

magnitude or less than the difference between replicate samples of original AC-10 asphalt from Source A and so could be attributed to experimental error.

The elution time ratios between grades show larger differences for Asphalt E than for Asphalts A through D. The only fraction that is significant in relation to the replicate tests on Asphalt A is the late fraction.

It should be noted that the penetration and viscosity data (Tables 3 and 4) do not suggest that asphalts from Refinery E are significantly different from the others, but the tests on the residue from the thin-film oven (Table 6) show substantially larger loss, decrease in penetration, and increase in viscosity after testing than do tests on cement from other sources.

Differentiation Among Samples from the Refinery, New Material on Site, and Recovered Material

To date, the test program has provided chromatograms of asphalt cement from the refinery, new material delivered to site,

TABLE 4 PHYSICAL TEST RESULTS ON ASPHALT CEMENTS RECOVERED FROM LABORATORY MIXES AND CORES

		Recovered from Lab Mixes					Recovered from Cores				
		Viscosity			Penetration		Viscosity			Penetration	
Asphalt Refinery & Grade	Location of Test Pavement	77	140	275	39.2	77	77	140	275	39.2	77
A AC-10	**										
	Dickens	12.0	2000	5.93	21	62	17.0	12400	7.29	15	37
	Dumas	1.6	1723	5.24	20	75	2.0	2600	4.81	15	57
A AC-20	**										
	Dickens	18.4	9560	11.0	14	20	12.0	12300	11.8	5	25
	Dumas	3.4	2980	7.13	12	51	5.8	4470	8.41	10	41
	Lufkin	4.5	3780	7.45	15	52	3.55	3470	6.92	10	48
B AC-10	**										
	Dumas	0.56	1360	3.49	57	107	0.7	1450	3.59	30	90
	Lufkin	3.45	3600	5.46	22	57	3.70	3890	6.26	7	56
B AC-20	**										
	Dickens	7.0	11250	8.30	20	38	21.0	9790	5.67	3	17
C AC-10	**										
	Dumas	2.9	3000	3.86	7	45	2.06	2480	4.41	15	62
C AC-20	**										
	Dickens	16.0	8670	6.06	8	21	8.00	5520	8.08	8	32
	Lufkin	3.3	2939	4.40	9	48	3.80	2750	3.87	10	46
D AC-10	**										
	Dumas	1.5	1990	3.98	26	66	1.28	1930	4.04	26	71
	Lufkin	1.28	1870	3.90	19	73	1.20	2420	4.44	16	63
D AC-20	**										
	Dickens	1.40	11400	8.74	21	32	21.0	8670	5.79	2	20
	Lufkin	4.10	5940	5.77	5	45	3.80	2975	4.98	12	52
E AC-10	**										
	Dickens	1.30	4322	4.16	8	28	18.5	23100	9.70	10	21
	Dumas	2.00	1940	3.08	12	47	-	-	-	-	-
E AC-20	**						30.0	15500	7.45	0	18
	Dickens	14.0	4750	4.49	9	29	-	-	-	-	-
	Dumas	5.0	2374	3.42	12	41	14.5	8790	5.06	4	23

* Viscosity at 77°F given in poise x 10^6

Viscosity at 140 and 275°F given in poise

** These data are representative of asphalts obtained directly from refineries, ie, not from a specific construction site.

TABLE 5 RESULTS OF MECHANICAL TESTS ON ASPHALT PAVING MIXTURES

Source Code	Asphalt Content, %	Air Voids, %	Resilient Modulus, psi x 106			
			-13°F	33°F	77°F	104°F
30	6.2	5.5	1.81	1.36	0.318	0.072
31	5.3	8.5	2.02	1.66	0.285	0.080
32	5.7	10.7	2.21	1.35	0.416	0.122
33	5.7	7.5	1.79	1.26	0.318	0.099
34	5.8	6.1	1.87	1.68	0.519	0.141
35	5.6	8.6	1.93	1.39	0.561	0.148
36	5.0	7.4	1.52	1.16	0.422	0.074
38	6.0	6.2	1.60	0.958	0.151	0.033
39	5.4	15.4	1.32	0.918	0.195	0.039
40	5.6	2.6	2.50	1.28	0.254	0.072
42	5.2	3.0	2.58	1.43	0.204	0.045
43	5.7	4.2	2.41	1.64	0.499	0.141
44	4.9	2.2	2.24	1.26	0.165	0.040
45	5.4	3.2	2.60	1.84	0.509	0.082

TABLE 6 THIN-FILM OVEN TEST RESULTS ON AC-10 ASPHALTS FROM REFINERIES

	Asphalt Source				
	A	B	C	D	E
Test 1					
Loss (%)	0	0.04	0.03	0.13	0.37
Viscosity at 140°F (poises)	1280	1210	2539	2381	2436
Penetration at 77°F (dmm)	69	121	50	68	42
Test 2					
Loss (%)	0	0.04	0.05	0.08	0.15
Viscosity at 140°F (poises)	4681	5008	4017	3236	4285
Penetration at 77°F (dmm)	41	53	32	56	32

TABLE 7 COMPARISON OF CHROMATOGRAPHIC DATA ON AC-10 AND AC-20 ASPHALTS FROM EACH REFINERY SOURCE

Fraction	Ratio Between Fractions (AC-10/AC-20) of Asphalts from Source				
	A	B	C	D	E
Early	1.00	1.02	0.98	0.98	1.10
Intermediate	1.02	1.01	1.00	1.02	1.11
Late	0.98	0.84	1.11	1.04	0.31

TABLE 8 COMPARISON OF CHROMATOGRAPHIC DATA ON ASPHALT CEMENTS AT VARIOUS AGES

Source, Grade, and Site	New, On Site			Recovered from Laboratory Molded			Recovered from Field Cores		
	E	I	L	E	I	L	E	I	L
A AC-10, Dumas	1.01	0.98	1.00	1.05	0.98	0.02	1.02	1.00	0.59
A AC-20, Dumas	0.91	1.23	1.14	–	–	–	0.96	1.10	1.07
B AC-20, Lufkin	1.18	0.84	0.79	–	–	–	1.18	0.88	0.55
C AC-10, Dumas	0.96	1.08	0.82	1.13	0.96	0.66	1.06	1.11	0.68
C AC-20, Lufkin	0.99	1.05	0.79	–	–	–	1.09	0.99	0.64
D AC-10, Lufkin	0.92	1.09	1.05	–	–	–	1.02	1.05	0.62
D AC-20, Lufkin	0.95	1.07	1.00	1.03	0.98	0.66	1.05	1.01	0.66
E AC-20, Lufkin	1.08	1.02	0.60	–	–	–	1.13	0.96	0.66

NOTE: E = early, I = intermediate, L = late.

$$\text{Ratio} = \frac{\text{Area under given section of chromatogram for given asphalt obtained either during construction or recovered from mix}}{\text{Area under given section of chromatogram for given asphalt obtained directly from refinery at an earlier date}}$$

material recovered from samples compacted in the laboratory, and that recovered from cores. These data are given in Table 8 in the form of ratios of the areas under the early, intermediate, and late portions of the chromatograms. Virgin asphalts obtained from construction sites and asphalts recovered from laboratory-compacted samples and field cores are compared with asphalts obtained directly from the refineries. Unfortunately the majority of the data relates to the pavements at Lufkin where the field cores were removed after only 1 week of service.

As would be expected, the physical property data show an increase in viscosity and a decrease in penetration from the new material to the recovered material.

Data from the chromatograms show differences between the asphalt obtained from the refinery, new asphalt on site, laboratory-compacted asphalt, and field cores. In general, this difference is relatively small: the maximum change in the early fraction from new at refinery to recovered from field cores is 6 percent; for the intermediate fraction it is 5 percent (both for Asphalt A, AC-20 at Lufkin); and for the late fraction it is 3.1 percent (Asphalt D, AC-10 at Lufkin).

The changes show most clearly when the ratios of the fractions are examined as a function of the components of the refinery samples (Table 8). The maximum change from refinery to field is plus 18 parts and minus 4 parts in 100 for the early fraction. In both cases, this difference is matched or exceeded

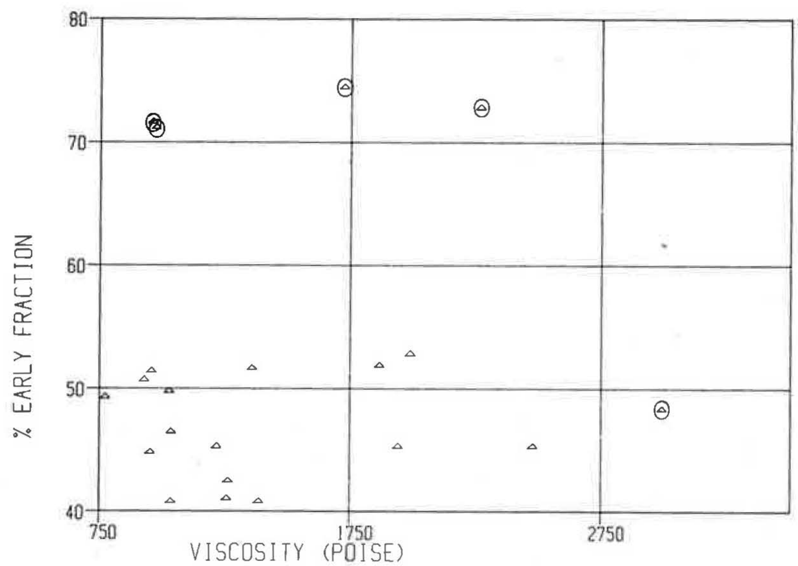

FIGURE 2 Early fraction as a function of viscosity.

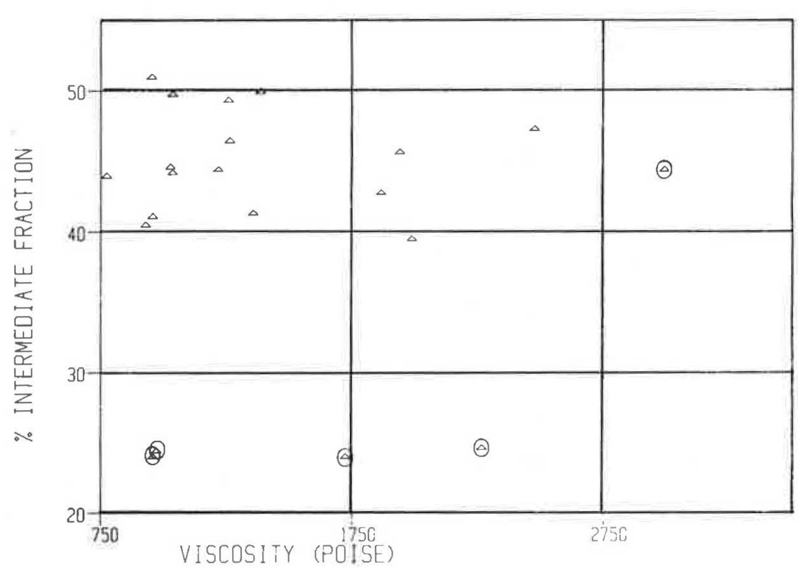

FIGURE 3 Intermediate fraction as a function of viscosity (AC-10 asphalts).

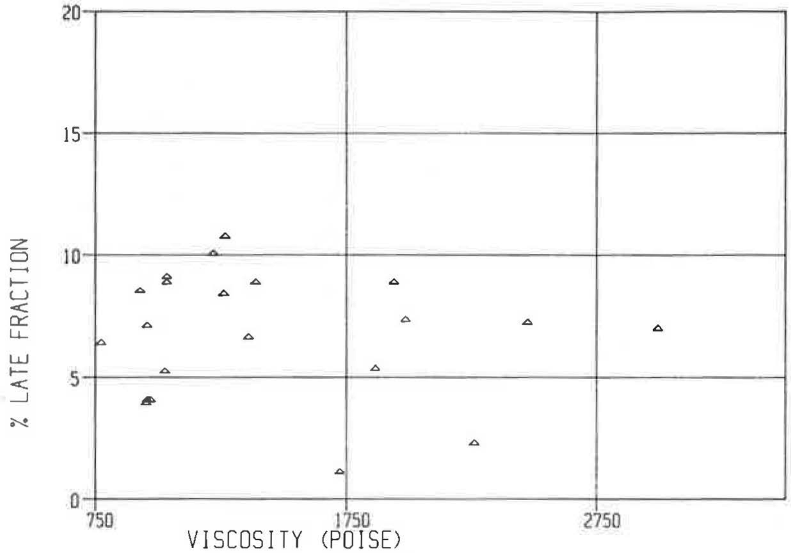

FIGURE 4 Late fraction as a function of viscosity.

by the difference between the new asphalt as delivered to site and that directly from the refinery. Ratios for the intermediate fraction range from plus 23 to minus 16 parts in 100. Once again, the greatest differences are between the virgin asphalt from the refinery and that delivered to the site.

The changes in the asphalts, as shown by ratios of areas for the late fractions, are much greater than for the other two fractions. In all cases but one (Asphalt A, AC-20, Lufkin), the late fraction has decreased from the refinery sample to the field sample. Also, in all cases but one, the changes from refinery to field for the late fractions are greater than the differences between the two new asphalts of different grades. In interpreting these data, it must be remembered that the actual changes in area are quite small; the greatest difference is a reduction from 7.7 percent of total to 4.5 percent of total, which yields a ratio of 0.58.

Relationship Between HPLC and Physical Properties

Figures 2–4 show the relationship among the early, intermediate, and late fractions determined from the chromatographs and viscosity measured at 140°F for the AC-10 asphalts. The data relating the chromatographic parameters to penetration have also been plotted, but, because they show a pattern similar to that of the viscosity data, they are not reproduced here. The three figures show that there is considerable scatter in the results. The data suggest that the quantity of material in each of the three sections of the chromatograph is independent of viscosity. There is, however, one interesting feature in Figures 2 and 3. In both of these figures, there are four points, which have been circled, detached from the main body of the data. These points are all for asphalt from Source A. It may be conjectured from this that there may be a family of lines that represents approximately constant quantity of either the early or the int rmediate fraction across the range of viscosity and that these lines may be unique to a particular source of asphalt cement. However, it should be noted that one point from the data on Asphalt A, also circled, lies within the body of the data, which represent all other sources, so the conjecture may be inappropriate. It is noteable that there is no separation of the points related to Asphalt A in Figure 4.

Figures 5–7 show the relationship between the parameters derived from the chromatograph and the *PI* for the AC-10 asphalts. These plots show that transforming penetration data to a temperature susceptibility parameter does not improve the relationship between physical tests and chromatographic data. Indeed, the general picture presented by the data is quite similar to that shown in Figures 2–4. Graphs of *VTS* are not reproduced in the interest of brevity and because they show the same pattern shown in Figures 5–7. Thus it would appear that there is no interrelationship between the standard rheological properties and the chromatographic plots for the AC-10 asphalts.

A similar analysis has been performed for the AC-20 asphalts. Figures 8–11 show a selection of these data. These figures show trends that closely resemble those observed for the AC-10 asphalts. If anything, the separation of the data into groups is more obvious than for the AC-10 asphalts, but again there are insufficient data to confirm the hypothesis that this suggests.

Relationship Between Parameters Derived from HPLC and Resilient Modulus

Figures 12–14 are plots of the area fractions from the chromatographs as a function of resilient modulus at 77°F. As was the case for penetration and viscosity, the chromatographic parameters and resilient modulus are not closely related. This is not surprising in view of the dependence of resilient modulus on the rheological properties of the asphalt cement.

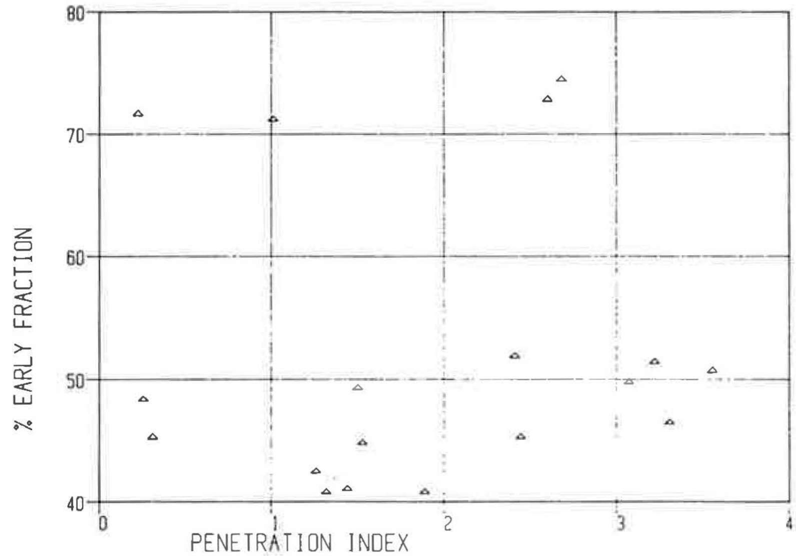

FIGURE 5 Early fraction as a function of *PI*.

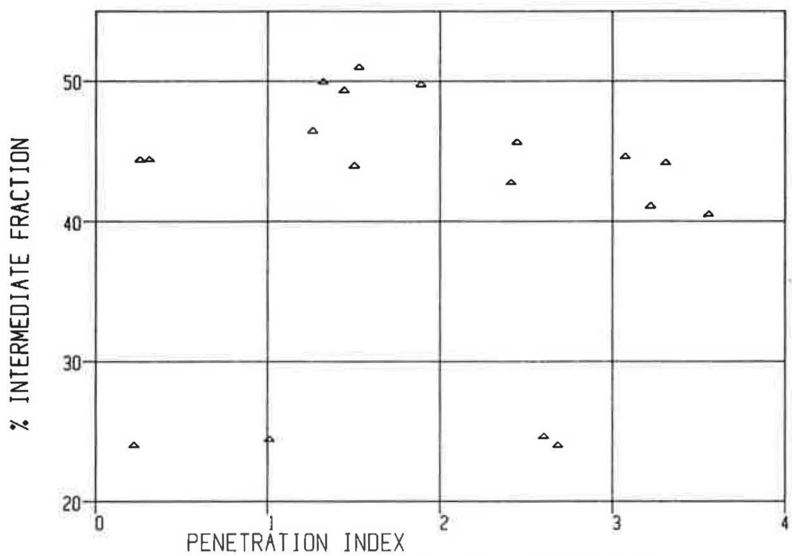

FIGURE 6 Intermediate fraction as a function of *PI* (AC-10 asphalts).

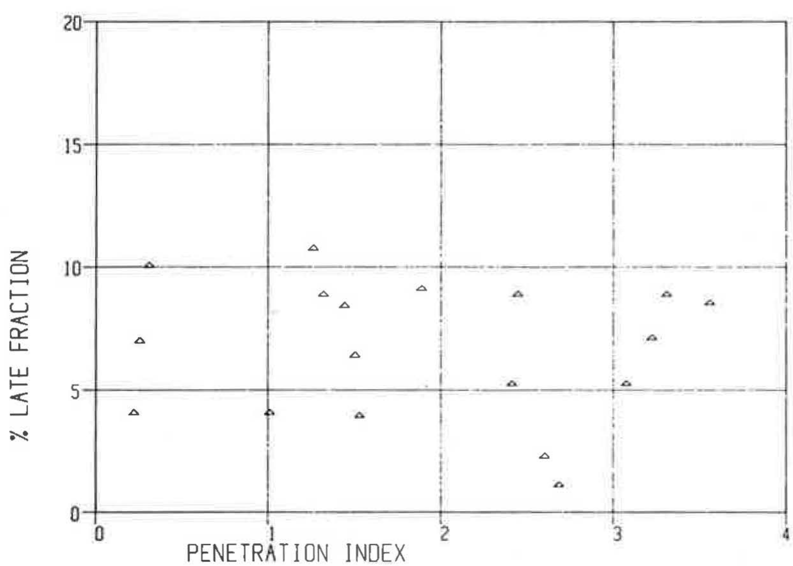

FIGURE 7 Late fraction as a function of *PI*.

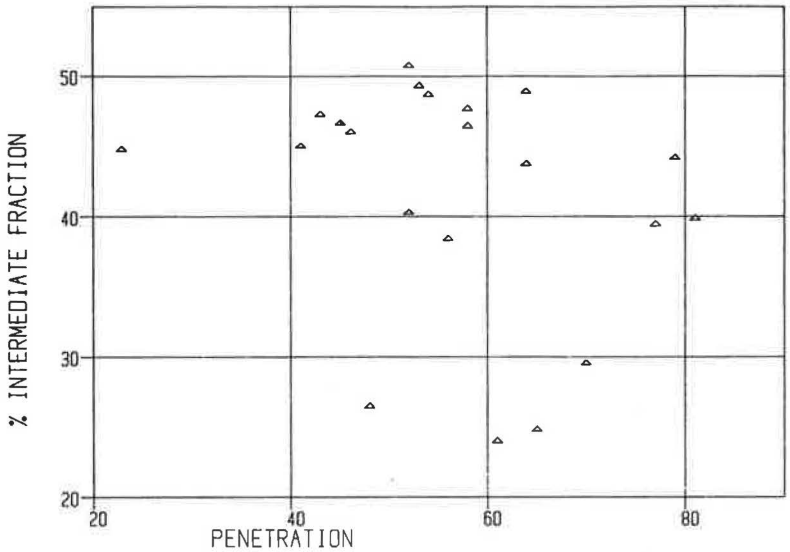

FIGURE 8 Intermediate fraction as a function of penetration.

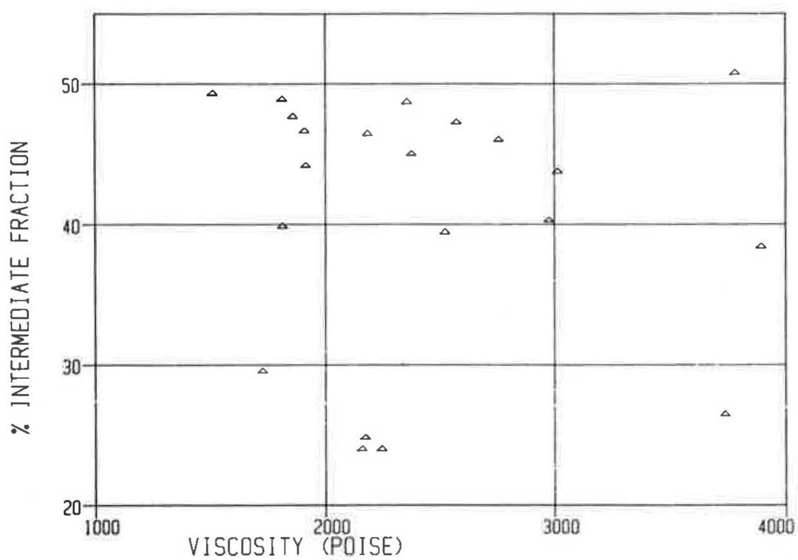

FIGURE 9 Intermediate fraction as a function of viscosity (AC-20 asphalts).

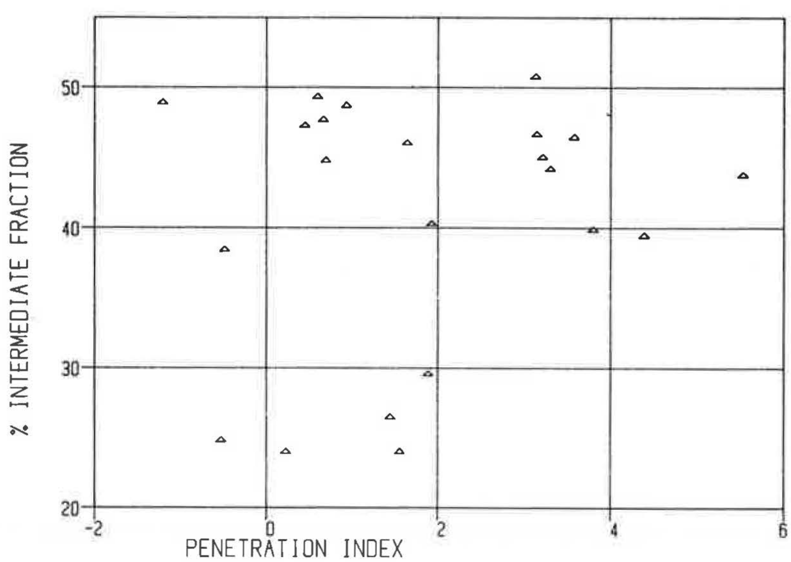

FIGURE 10 Intermediate fraction as a function of *PI* (AC-20 asphalts).

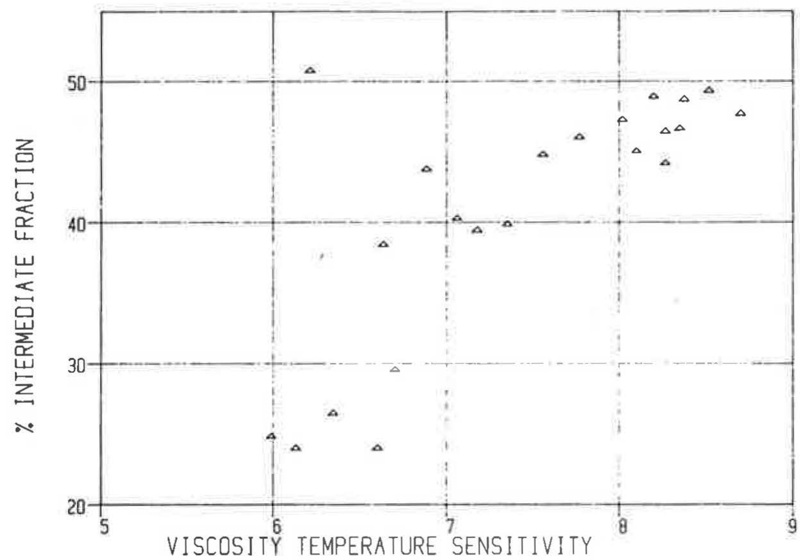

FIGURE 11 Intermediate fraction as a function of *VTS*.

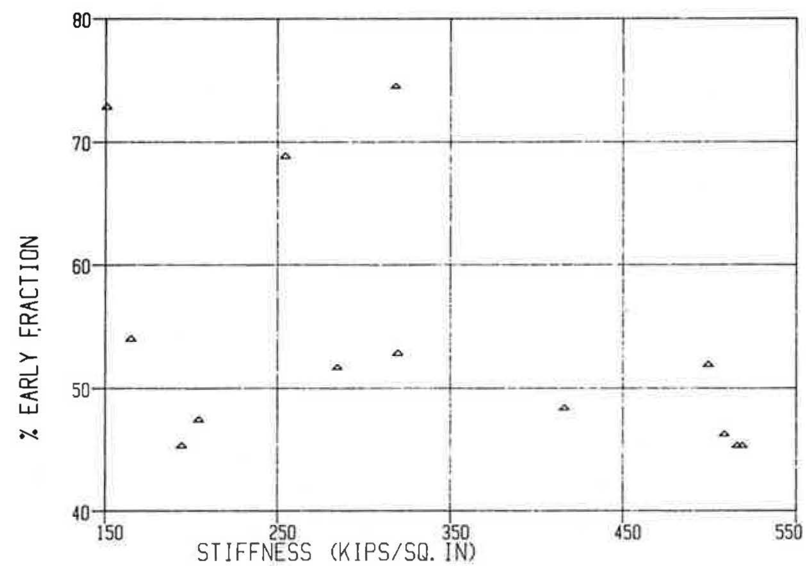

FIGURE 12 Early fraction as a function of stiffness.

Relationship Between Parameters Derived from HPLC and Pavement Performance

There are, to date, relatively few field data to use in an attempt to correlate the results of the chromatographic analysis with pavement performance at Dickens, Dumas, and Lufkin, Texas. The raveling observed in selected sections (containing Asphalts B and C) at the Dumas test site was most likely promoted by poor compaction of the mix. It should be pointed out, however, that all test sections were compacted to approximately equivalent air void contents and only two of them exhibited significant raveling. The raveling was reportedly due to extended periods of exposure to snow, ice, and moisture. One test section (Asphalt C) exhibited extremely severe raveling. If all other construction factors are reasonably constant, it may be possible to attribute the raveling to the character of the asphalts. The test sections at Dickens and Lufkin, which contain asphalts from the same refineries, showed no visible signs of distress after as much as 4 years. These inconsistencies in field performance and the limited quantity of data make it difficult to derive and support conclusions about asphalt quality. However, it is appropriate to comment on the potential of the chromatographic technique for predicting the performance of asphalt mixes. First, it must be remembered that the technique is applied to the asphalt cement alone; it does not provide information on the characteristics of the asphalt mix, and so it can only be of use in considering pavement distress that is related solely to the properties of the asphalt cement.

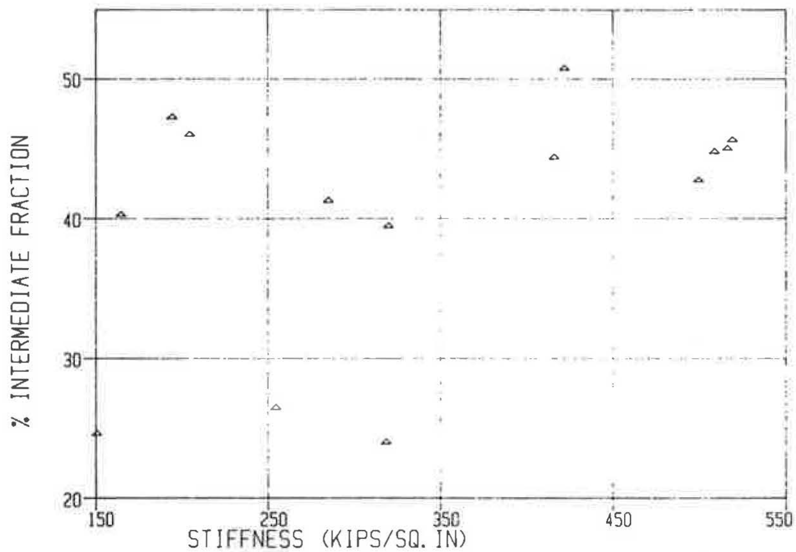

FIGURE 13 Intermediate fraction as a function of stiffness.

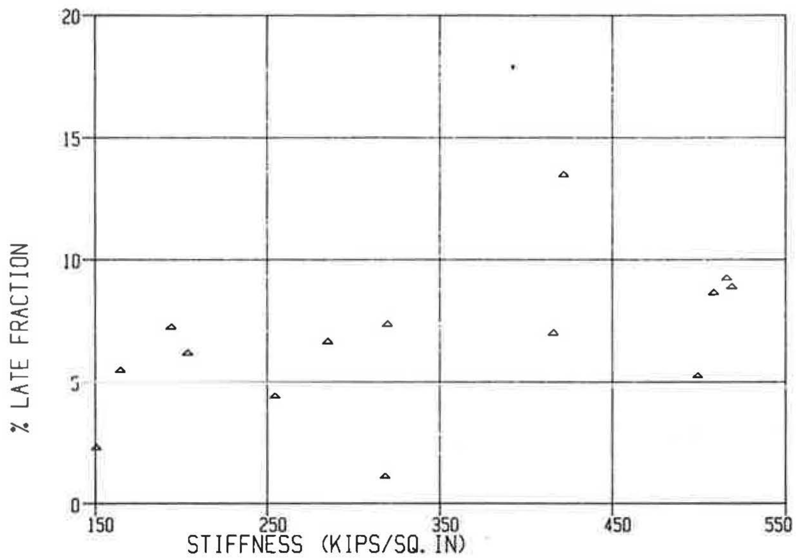

FIGURE 14 Late fraction as a function of stiffness.

If an asphalt cement does not possess the required adhesive characteristics, the aggregate particles with which it has been mixed will be dislodged by the passage of traffic, particularly in the presence of moisture, and the surface will disintegrate. However, if an asphalt layer is not properly compacted, there is a high probability that the surface will disintegrate, but, in this case, disintegration is not due to any intrinsic characteristic of the asphalt cement.

The situation becomes much more complex when cracking is considered. Laboratory testing has shown that fatigue-type cracking is related to the characteristics of the asphalt in the mix. These studies also show that fatigue-type cracking is related to the volume of asphalt cement in the mix. That is, low binder content or poor compaction can accelerate cracking in a mix with a perfectly satisfactory binder. Even if the mix is well compacted and contains adequate asphalt cement, if it is placed over a weak structure and is therefore subjected to large tensile strains it will crack. Hence there are many potential causes of fatigue cracking that are not related to intrinsic characteristics of the asphalt cement.

This discussion could be extended to other forms of cracking as well as other modes of distress; however, it is hoped that sufficient comments have been made to emphasize the necessity of extremely careful monitoring and investigation of pavement performance before any useful conclusions can be drawn with respect to the relationship between chromatographic data and pavement performance.

CONCLUSIONS

The technique of dividing the complete chromatograph obtained from an asphalt sample into three sections as described permits the following conclusions to be drawn:

1. There is no relationship among the early, intermediate, or late partial areas that can be used to predict penetration, viscosity, penetration index, viscosity, temperature sensitivity, and resilient modulus.

2. The technique does not differentiate between different grades of asphalt obtained from the same refinery.

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