Study of Physical Factors Affecting the Durability of Asphaltic Pavements

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This investigation was undertaken to study changes in asphalt and asphaltic mix properties to gain an understanding of the factors affecting the durability of asphalt pavements. In particular, pavements were constructed to determine the penetration-absolute viscosity relationship for the different asphalts used. Several different asphalts were used, varying in penetration and absolute viscosity, but the same aggregate was used for each project. Investigations were confined to the wearing course, due to its exposed position in a pavement. The test pavements were asphaltic-concrete overlays on portland cement concrete. Field data were accumulated during construction and periodically after construction; Abson recovery tests were made on the obtained samples as part of the laboratory investigation. Penetration, standard ductility, microductility, absolute viscosity, and chemical analysis tests were made and the data analyzed.

Results from one project indicate that a common (70-85 penetration, 3,000 ± 200 viscosity) asphalt is performing as well as any other asphalt used to date, as indicated by a higher percent retained penetration and ductility and a lower percent original viscosity. No degradation of aggregates is occurring under traffic use. Increasing asphaltenes indicate a hardening but no trend is indicated by the Rostler coefficient. All of the asphalts softened after the first winter cycle, hardened during the summer, and, in some cases, softened again the following winter. Further research is required in this area.

From early test data on two other projects, it appears that a definite hardening of the asphalts occurred during mixing. However, from the time of construction to the early core samples, very little change in test data took place. Some of the core data are erratic in that a slight softening occurs as indicated by decreases of absolute viscosities and increases in penetration and ductility values. This phenomenon is unexplainable at present and requires further research. At this stage of the study, final conclusions are not possible.

•DURING recent years, much research and experimentation has been performed in the asphalt field to gain a better understanding of the physical and chemical changes that occur during the age-hardening of asphalt (1, 2, 3, 4). One goal of this research is to eventually relate the observed physical and chemical changes with the durability of a roadway as measured by its longevity. The Bureau of Materials of the Pennsylvania Department of Highways, through its Bituminous Research and Development Section, is

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TABLE 1

DESCRIPTION OF TEST ROADS

County	LR No.	Spec. Gradation	Date of Construction
Clinton	219	ID-2	October 1964
Jefferson	338	FJ-1	September 1965
McKean	101	ID-2	August 1965

now engaged in an intensive effort to determine the effects of physical and chemical factors on the longevity of asphalt pavements. In addition, under the sponsorship and with the cooperation of the U. S. Bureau of Public Roads and the Pennsylvania Department of Highways, the Civil Engineering Laboratories of the Pennsylvania State University have undertaken an investigation of the physical and chemical properties of asphaltic concrete material at in-service projects.

Several projects are included in the overall study; however, this report covers only the data for LR 219—Clinton County, LR 338—Jefferson County, and LR 101—McKean County. The data and findings of the physical and chemical testing of the asphalts recovered from these three projects are presented.

OBJECTIVES

The principal aim of this investigation is to study the physical and chemical changes of the asphalt and asphaltic-concrete mixture that occur with the passage of time, with a view to gaining an understanding of the factors affecting the durability of asphaltic-concrete pavements. In particular, the asphalts in these pavements will be tested for the purpose of arriving at relationships of penetration to absolute viscosity. The objective is to verify the desirability of either complementing or supplementing penetration control with absolute viscosity control as a design specification.

An effort will be made to determine the effects of chemical changes on pavement performance, the effects of traffic on pavement density with time, and whether or not the aggregate used in the pavement is subject to degradation with use.

TEST AREAS

This interim report deals with the laboratory data accumulated from the Clinton, Jefferson, and McKean County projects. Each of these projects possesses a common characteristic in that, on each of the pavements, six different asphalts were used to produce asphaltic concrete. In Clinton County, a crushed limestone aggregate was used; in Jefferson County, a sand mixture was used; and in McKean County, a sand and gravel mixture was used. Table 1 describes the test roads.

The Clinton County project is in the central area of Pennsylvania, the Jefferson County project is in the west-central area, and the McKean County project is in the north-

TABLE 2

DESCRIPTION OF ASPHALTS

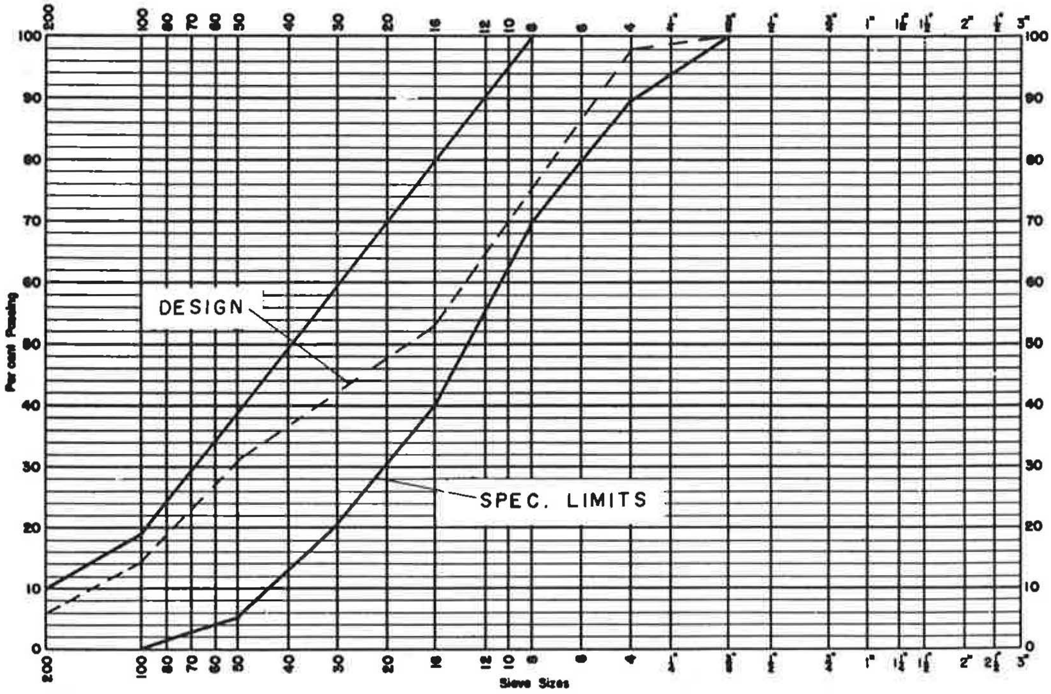
Experimental Designation	Absolute Viscosity (poises, 140 F, 30 cm Hg), Reported Values[a]				Penetration (77 F, 100 gm, 5 sec, in mm), Reported Values[a]			
	Specified Ranges	LR 219	LR 338	LR 101	Specified Ranges	LR 219	LR 338	LR 101
Type I	1500 ± 200	1732	1782	1795	50-75	59	67	59
Type II	1500 ± 200	1548	1630	1482	90-100	89	86	91
Type III	1500 ± 200	1440	1527	1701	140-160	146	136	130
Type IV	900 ± 200	949	1048	1090	90-100	110	87	84
Type V	3000 ± 200	2136[b]	3054	2970	90-100	94	84	85
Type VI	3000 ± 200	2951	3092	3124	70-85	77	74	74

[a]Average values.
[b]Out of specified range.

PENNSYLVANIA DEPARTMENT OF HIGHWAYS
GRADATION CHART

Specification FJ-1 Course Wearing

District 10-0



BASIC FORMULA A.C. 8.6

* 70 - 85 Asphalt %
* 85 - 100 Asphalt %
* Minus No. 8 Material % 75.0
Approved CONTRACTOR'S REP. M.R. Date 8-25-65
Approved P.D.H. INSPECTOR Date
Approved MATERIALS ENGR. HWB Date 9-2-65
Approved DISTRICT ENGR. WSS Date 9-2-65
* Percent by weight to be Designated by District Engineer

JOB IDENTIFICATION

County Jefferson Rt. 388 Section
Contractor or P.O. Interstate Amiesite Corp.
Plant Reynoldsville, Pa.

Figure 1. Asphalt plant report, Part A (Jefferson County).

central area. Each project contained six different asphalts. Five of the asphalts are considered experimental and the sixth is a standard type for purposes of comparison. The design penetration and absolute viscosity characteristics are given in Table 2.

Each of the experimental wearing courses was constructed in six continuous sections, placed the full width of the pavement. Approximately 8,000 gallons of each experimental type of asphalt cement were supplied for each designated experimental section. Each type of asphalt was furnished in cleaned transports in loads of approximately 4,000 gallons each. The transports were equipped to maintain the temperature of the asphalt cement at its designated mixing temperature. The experimental asphalt cements were introduced directly into the mixer from the transports through approved plant asphalt proportioning facilities and supply lines.

The total completed length of the experimental sections of wearing course was dependent on the size of the loads as delivered and the requirements of the job-mix formula. The remaining portion of paving was completed with the common 70-85 penetration grade asphalt having a 3000 ± 200 poise viscosity.

The individual paving mixtures were designed by the Pennsylvania Department of Highways (PDH) design and control method, and the roadways were constructed under the direct control of the Department using currently approved methods (5).

From previous experience, it is known that the portion of the roadway that is exposed most to environmental conditions exhibits age-hardening and consequently deteriorates first. For this reason, the testing was confined to the asphalts used in the wearing course.

PROCEDURES

Sampling and Construction

Samples of the aggregate for the binder and wearing courses were delivered to the central office of the PDH Materials Testing Laboratory in Harrisburg. Samples of the raw asphalt were also submitted so that hot asphaltic mixes could be designed, tested, and approved. Stability and flow tests were performed on laboratory-compacted test specimens according to Pennsylvania design and control specifications and the test data were recorded. Since the asphalts varied from each producer according to predetermined specifications, individual mix designs were required. Asphalt plant reports were compiled by PDH personnel as they maintained plant inspections and field control of construction. A typical plant report is shown in Figures 1 and 2.

The Pennsylvania method of testing was performed jointly during construction by PDH laboratory technicians and by those provided by the contractor. These tests consisted of compacting asphaltic concrete specimens in the field and plant laboratory, and testing for stability, flow, asphalt content, and aggregate gradation. The results conformed to Pennsylvania specifications.

Normal conditions existed during the mixing, placing, and compaction operations. Temperature measurements were made at various stages in the handling of the hot mix by PDH personnel. Separate temperature measurements were made by technicians of Pennsylvania State University's Civil Engineering Laboratory from the time of spreading to one hour after spreading. This was accomplished through the use of No. 24 gage thermoplastic copper-constantan insulated thermocouple wires placed in the wearing course. These thermocouples were connected to continuous temperature recording devices (Fig. 3) to obtain the changing temperature of the asphaltic concrete during construction. These thermocouples were placed ¼ and ⅞ in. below the compacted surface of the pavement. A typical time-temperature plot of the recorded data is shown in Figure 4; it is considered typical since it was found that the numerous graphical presentations of the data yielded similar results.

The actual construction methods used on these projects were basically similar, being those currently approved by the PDH. The initial or breakdown roller was a 12-ton, 3-steel-wheel roller. This was followed by a pneumatic-tire roller, 9 tires, 15 tons, with 14-ply tires and a tire pressure in the 90-psi range, and a 2-axle tandem wheel finishing roller of a 12-ton capacity.

Stock Gradations

Sieve Sizes	Filler	Lime	Hard Asph.	Fine Agg. No. 1 Stock	Fine Agg. No. 1 Spec.	Fine Agg. No. 2 Stock	Fine Agg. No. 2 Spec.	Sand Stock	Sand Spec.	Coarse Agg. Stock	Coarse Agg. Spec.	Cold %	Blend %	Combined Gradings
200								5.9						
100								14.2						
50								32.0						
30								42.6						
16								52.9						
8								74.8						
4								98.0						
3/8"								100						
½"														
3/4"														
1"														
1 ½"														

Bins Over Mixer

Sieve Sizes	Gradations Bin 1	Gradations Bin 2	Gradations Bin 3	Gradations Bin 4	% Combination Bin 1	% Combination Bin 2	% Combination Bin 3	% Combination Bin 4	Gradings Combined	Gradings Extraction A.C. 8.6 %	Spec. Limits
200	5.9									6.0	
100	14.2									14.0	
50	32.0									32.0	
30	42.6									43.0	
16	52.9									53.0	
8	74.8									75.0	
4	98.0									98.0	
3/8"	100									100	
½"											
3/4"											
1"											
1 ½"											

Mix Design

Material		A.C.	Hard A.C.	Flux	Naphtha or W.C.	Lime or Filler	Bin 1	Bin 2	Bin 3	Bin 4	Total
Binder Course	%										
	Lbs.										
Wearing Course	%	8.6					91.4				100
	Lbs.	344					3656				4000

Official Inspections- __________

Inspectors- __________

Checked by- __________

Remarks - __________

Figure 2. Asphalt plant report, Part B (Jefferson County).

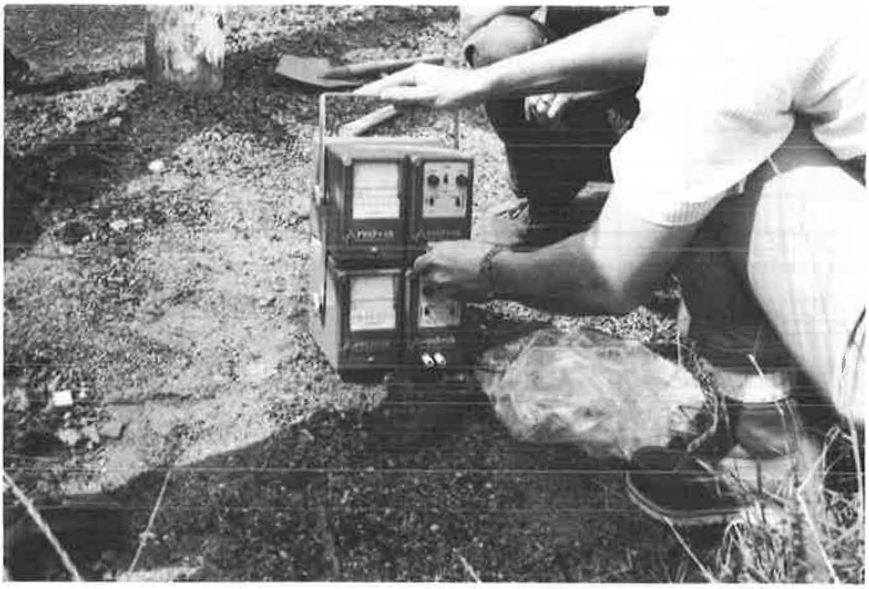


Figure 3. Continuous temperature recording devices.

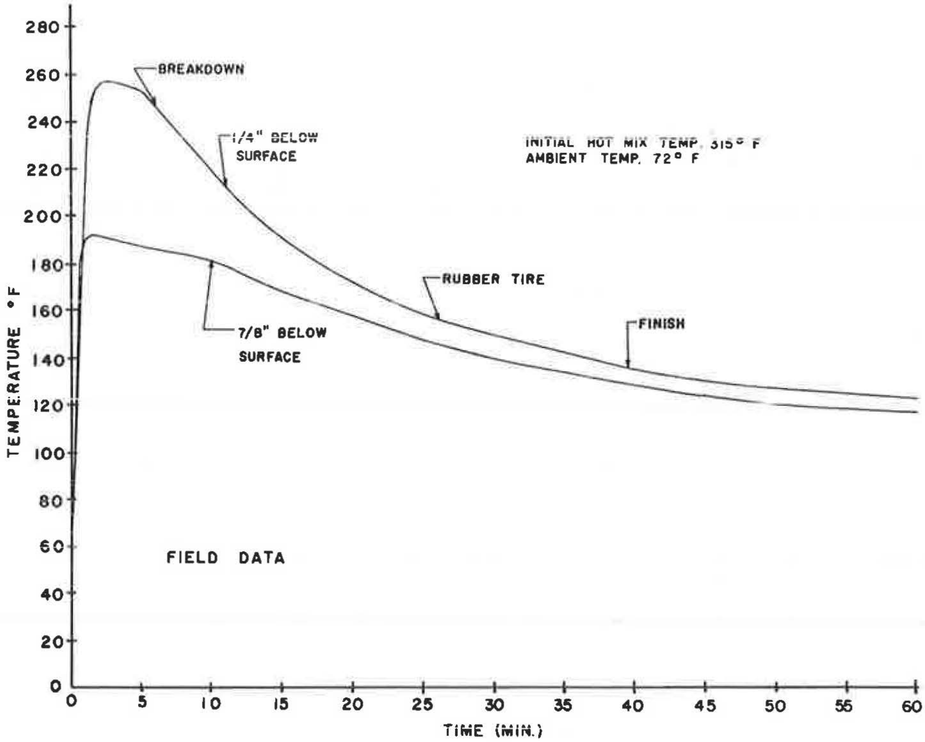


Figure 4. Typical field time-temperature plot.

Sampling procedures were formulated to isolate as completely as possible the various stages of asphalt hardening that could take place. Laboratory samples were taken for analysis by the Department of Highways and by the Pennsylvania State Civil Engineering Laboratory.

Seven 1-gallon test samples of the raw asphalt cement were drawn from the transports at the plant; the test results were used as the basis of comparison with later test data. Test samples of the hot mix were taken during the mixing at the pugmill, directly from the paver during the laydown operation, as cups one or two hours after compaction, and as compacted slabs cut from the roadway within 24 hours after actual construction. The cups were pried from the pavement while the slabs were removed using a power-driven, water-cooled, abrasive circular saw.

The samples were taken in duplicate, i.e., two such sampling operations per test transport. The asphaltic concrete in the first set was taken from a labeled test truck while the second set was taken from a randomly selected batch of the mixture. This procedure was followed for the hot mix produced from each transport of asphalt cement to ascertain the uniformity of the mix, or lack of it, being maintained in production.

Core sampling was performed on each of the test projects. This report deals with 8-month cores of the McKean County project and 7-month cores of the Jefferson County project. The 12- and 18-month cores of the Clinton County project are also discussed. The cores were taken using a rear-mounted core-drilling device. The cores taken were 6 in. in diameter as agreed upon by the participating agencies. This method of sampling should provide a relatively complete picture of the changes that are taking place in the asphalt with age and weathering. The age-hardening process will be followed further by periodically taking core samples from the pavement until complete deterioration of the roadway pavement occurs.

Testing

The testing procedures for an asphalt cement adopted for this investigation may be classified as new and routine. The routine tests include penetration, ASTM D 5-65; standard ductility, ASTM D 113-44; and absolute viscosity, ASTM D 2171-63T. Among the new tests in asphalt technology are microductility and chemical analysis. Microductility tests were performed only on the Clinton County samples.

In addition, sieve analyses were performed on the aggregates resulting from the extraction of the mix samples. The surface area (7) and fineness modulus (8) were calculated for each sieve analysis to determine whether degradation of the aggregate is occurring under handling and in-service conditions.

Specific gravity determinations, using PDH specifications, were made on the mix samples to ascertain degrees of compaction at construction and during service life. Asphalt cement samples were obtained from mix and field core specimens by the immerex (immersion-reflux) method of extraction and the Abson method of recovery, ASTM D 1856-65. Benzene was used as the solvent to minimize any chemical reaction between solvent and asphalt during the contact time of the recovery process. The recovered asphalts were then stored in 3-ounce metal containers for testing.

Penetration—Certain properties of asphalts have been found by experience to be necessary for the construction of a good asphaltic pavement. Early attempts to define the limits of these properties led to the development of the empirical penetration test. Through the years, the penetration test has been accepted as a standardized method for the classification of asphalt grades. In this study, the penetration tests conducted were in accordance with ASTM D 5-65 using test conditions of 77 F, 100 g, 5 sec.

Ductility—Another test that has been standardized to specify a desired charateristic of asphalt is the standard ductility test. The empirical test results at low temperatures appear to be better indicators of cracking occurring in asphaltic concrete pavements (9) than other current scientific means available. Earlier investigators (10, 11) indicated that asphalts with greater ductility loss failed most frequently. In this study, the standard ductility tests were conducted in accordance with ASTM D 113-44 using test conditions of 39.2 F and 1 cm/min.

In addition to standard ductilities, microductility tests of the asphalts were performed at Clinton County to investigate the possible correlation of microductility and standard ductility values. The microductility test used in this research was the one developed by the Phillips Petroleum Company of Oklahoma (12).

Absolute Viscosity—Researchers have established the importance of a more scientific approach for measurement of the consistency of an asphalt. To comply with this need, tests were made to determine the absolute viscosities of an asphalt sample. This test permits measurements of consistency in terms of poises, the unit of absolute viscosity. This fundamental property of an asphalt may be termed the internal friction that gives the material resistance to flow or to a shearing stress. A correlation of flow properties (absolute viscosity) with other physical and chemical properties as well as performance data may lead to a more scientific approach to asphalt technology.

Various types of viscometers used for highly viscous materials have been described by Heithaus (13) and Griffith and Puzinauskas (14). The viscometer used in this investigation was an instrument generally known as the Cannon-Manning vacuum capillary viscometer. The absolute viscosity data reported are based on test conditions of 140 F temperature and 30 cm Hg vacuum (ASTM D 2171-63T).

Chemical Analysis—One of the most important indicators of the consistency of a paving asphalt is its chemical composition. Since recent studies (15, 16) show a relationship between chemical composition and pavement durability, chemical analyses were performed as part of the University's laboratory investigations.

The Rostler precipitation method (16) defines asphalt as consisting of five groups of components that can be isolated and the amounts determined by weight. This method accomplishes a sharp division between resins and oily fractions, and then further subdivides the resinous fractions. The principal feature of this method is that the fractions determined are well-defined groups of like chemical activity. The use of this division process reveals not only the differences between fractions but also what changes occur during aging and in-service exposure in terms of percent change in composition, particularly in percent change of asphaltene content as it relates to durability, i.e., embrittlement or hardening.

The work of Rostler and White defines asphalts as consisting of five basic constituents: asphaltenes, nitrogen bases, first acidaffins, second acidaffins, and saturated hydrocarbons. By precipitation this method isolates these five constituents, the values of which are determined by differential weighing and then reported as percentages of the total sample weight. The samples of original and recovered asphalt cements were analyzed using this method.

Chemical analyses appear to be indicators of change in consistency of the asphalt components in the pavement. The asphaltene content, which is the first fraction in the test, appears to be an adequate predictor of age-hardening of the asphalt. Increases in asphaltene content are generally manifested in physical tests by decreasing penetrations, decreases in ductility, and increases in absolute viscosity. This trend is present, but data are insufficient regarding age to determine true relationships of physical tests to asphaltene content.

In addition to asphaltene content, the prevailing combination of components may be a determining factor. Some investigators (16) have shown that a preponderance of the nitrogen bases (N) will result in an asphalt exhibiting very rapid embrittlement. A high content of first acidaffins (A_1) will result in an asphalt that will undergo the greatest change in composition with time. An asphalt containing a high concentration of second acidaffins (A_2) appears least harmfully affected. Saturated hydrocarbons (SH) in small to moderately large amounts are beneficial. However, saturated hydrocarbons in excessive amounts result in a product that lacks cohesion and ceases to be an asphalt.

The ratio $(N + A_1):(A_2 + SH)$, which is expressive of the concentration of more reactive components to the less reactive, has been proposed by Rostler as indicative of the influence of chemical reactivity on durability. Presupposing that durability, expressed as abrasion resistance and change in abrasion resistance due to embrittlement, must depend on this ratio, Rostler illustrates a definite trend in asphalt behavior based on this ratio. A value of less than 1.14 for this ratio has been reported as being characteristic for asphalts of excellent abrasive resistance. Further work is continuing in

this area to develop a better approximation. Rostler proposes that the parameter $(N + A_1):(A_2 + SH)$ be considered only a first approximation for an expression relating composition to durability.

In using the ratio $(N + A_1):(A_2 + SH)$ to analyze data from previous work (17), inconsistencies were found. Due to these inconsistencies, a modification of the Rostler parameter was developed. The ratio $(A_1 + A_2 + N):(A + SH)$ was computed and found to give data showing a decreasing trend. At the present time, a minimum value for this ratio, that is, when the asphalt is no longer durable, cannot be estimated.

Aggregate Gradations—Sieve analyses were performed on all of the extracted mix samples so that it could be determined whether or not degradation of the aggregate is taking place. After the percentages retained were determined, fineness modulus and surface area data were computed for each sample.

The fineness modulus makes use of the percentages retained on the No. 4 to No. 200 sieves inclusive and presents repeatable data for any gradation of aggregate. Decreases in the fineness modulus indicates a degradation of aggregate. The surface area is another means of determining whether an aggregate is degrading or not. This calculation is based on predetermined coefficients multiplied by the percents retained from the No. 4 through the No. 200 sieves inclusive. Increases in the surface area, measured in pounds per cubic foot, indicate aggregate degradation.

Specific Gravities, Densitites, and Air Voids—Determinations of specific gravities were made on all the asphalt roadway samples using the procedures set forth in the PDH manual for bituminous concrete design, compaction, and control (5, pp. 46-80). Asphalt specimens were not coated with paraffin because the chemical analyses of the extracted asphalt would be adversely influenced by paraffin that would have defied removal.

These tests were performed at the time of construction on plant-compacted specimens, cups, and roadway slabs cut from the pavement. Specific gravities were also performed on the in-service core samples. After specific gravities were determined, further computations were performed to determine the density and air voids based on percent of maximum theoretical design specific gravity, and density based on plant-compacted specimen specific gravity.

It is anticipated that the changing densities and air voids will correspond to core location in the pavement and will perhaps, with future research and field investigations, contribute to a better understanding of pavement durability.

Core Locations—Some of the core samples taken from the roadways have exhibited an erratic behavior, that is, the asphalt is softening with age and use. This phenomenon is shown by the results of laboratory tests. Penetration values are increasing, ductility values are increasing, and absolute viscosity values are decreasing. The core location is suspect as a possible explanation for these erratic test data. The method of classifying which zone—namely, transition, load, or center—from which a core was obtained was presented in another report (6).

This classification method shows some promise in gaining a better understanding of the behavior of the asphaltic cement. More research is required to gain a more complete picture of the behavior of asphalt in a roadway pavement.

CLINTON COUNTY, LR 219

The Clinton County test roadway is 4.36 miles in length, located between the towns of Beech Creek and Mill Hall. The original roadway consisted of 18 to 20 ft of 8-in. reinforced concrete constructed in 1929 and 1934. This concrete pavement was in fair condition for its age but had outlived its usefulness as a smooth, high-speed traffic route, without being resurfaced.

In October 1964, the roadway was resurfaced with 1 in. of ID-2 wearing course on 2 in. of ID-2 binder course. The route can be identified as Legislative Route 219 or Traffic Route 220. It has an average daily traffic count of 4,020 to 4,220 vehicles.

Table 3 contains the physical properties of the Clinton County asphalts from the time of construction to the present. Also included are data indicating the percent retained or percent original values for the physical tests conducted, the percent asphaltenes and percent original asphaltenes for the asphalts, and the fineness modulus and surface area

TABLE 3

PHYSICAL PROPERTIES OF ASPHALTS—CLINTON COUNTY, LR 219

Asphalt Type	Line	After Mixing	After Compaction	5 Mo. Core	12 Mo. Core	18 Mo. Core	24 Mo. Core	30 Mo. Core
(a) Penetration Test—0.1 mm at 77 F, 5 sec, 100 gm								
I	59	36	31	37	24	22	18	20
II	89	69	61	67	47	51	42	50
III	146	98	90	91	75	76	63	68
IV	110	66	57	70	45	50	45	49
V	94	69	62	65	44	44	45	50
VI	77	60	50	58	40	39	33	35
(b) Percent Retained Penetration								
I	100	61	53	63	41	37	30	34
II	100	78	69	75	53	57	47	56
III	100	67	62	62	51	52	43	47
IV	100	60	52	64	41	45	41	44
V	100	73	66	69	47	47	48	53
VI	100	78	65	75	52	51	43	45
(c) Absolute Viscosity (Cannon-Manning)—poises at 140 F, 30 cm Hg Vacuum								
I	1732	3645	3731	3384	6745	8961	13267	10270
II	1548	2505	2630	2614	4553	4759	5090	4769
III	1440	2971	3028	3250	4868	5581	7021	6512
IV	949	2078	2584	2302	4772	4520	4555	5183
V	2136	3463	4035	3797	7910	9674	7901	7043
VI	2951	4770	5220	7384	9886	10695	13449	12444
(d) Percent of Original Absolute Viscosity								
I	100	210	215	195	389	517	766	593
II	100	162	170	169	294	307	329	308
III	100	206	210	226	338	388	488	452
IV	100	219	272	243	503	476	480	546
V	100	162	189	178	370	453	370	330
VI	100	162	177	250	335	362	456	422
(e) Standard Ductility—cm at 39.2 F and 1 cm per min								
I	14.0	4.1	4.5	4.0	*	*	*	*
II	53.3	11.9	11.9	15.4	6.4	8.8	5.4	7.2
III	101.0	42.2	40.4	72.1	26.7	23.4	10.7	13.7
IV	23.5	7.5	5.4	7.0	4.6	5.2	4.1	5.4
V	68.3	24.3	17.6	36.7	15.2	6.6	5.4	7.4
VI	21.9	7.3	3.3	14.1	5.0	5.6	2.0	2.4
(f) Percent Retained Standard Ductility								
I	100	29	32	28	0	0	0	0
II	100	22	22	29	12	17	10	13
III	100	42	40	71	26	23	11	14
IV	100	32	27	30	20	22	17	23
V	100	36	26	54	22	10	8	11
VI	100	33	38	64	23	26	9	11

Asphalt Type	Line	After Mixing	After Compaction	5 Mo. Core	12 Mo. Core	18 Mo. Core	24 Mo. Core	30 Mo. Core
(g) Microductilities—cm at 39.2 F and 1 cm per min								
I	8.0	1.8	*	*	*	*	*	*
II	3.6	2.4	3.1	2.6	1.4	*	5.4	0.7
III	42.3	13.0	10.0	10.6	3.9	4.0	2.4	2.5
IV	3.4	1.9	1.8	1.9	1.2	1.2	4.1	1.4
V	12.9	2.9	2.5	3.0	1.4	1.1	1.4	1.8
VI	2.5	1.8	3.0	2.1	1.4	1.1	0.7	1.2
(h) Percent Retained Microductility								
I	100	23	0	0	0	0	0	0
II	100	67	86	72	39	0	150	19
III	100	31	24	25	9	9	6	6
IV	100	56	53	56	35	35	121	41
V	100	57	51	61	29	22	29	37
VI	100	72	120	84	56	44	28	48
(i) Percent Asphaltenes								
I	20.9	22.1	20.7	19.5	24.6	26.4	23.0	25.2
II	19.2	21.2	21.2	21.0	25.1	25.0	21.7	24.8
III	26.8	28.8	31.6	29.8	32.4	32.8	32.4	34.0
IV	19.5	20.7	22.2	22.7	26.0	24.7	20.4	22.7
V	28.2	29.2	30.6	31.1	33.2	34.6	31.0	33.1
VI	28.2	29.0	29.4	30.2	31.5	31.8	30.7	33.3
(j) Percent Original Asphaltenes								
I	100	106	99	93	118	126	110	121
II	100	110	110	109	131	130	113	129
III	100	107	118	111	121	122	121	127
IV	100	106	114	116	133	127	105	116
V	100	104	109	110	118	123	110	117
VI	100	103	104	107	112	113	109	118
(k) Fineness Modulus of Aggregate								
I	—	4.15	4.06	4.04	4.08	4.05	4.00	3.98
II	—	4.10	3.99	4.03	4.02	3.95	3.96	3.90
III	—	4.17	4.02	3.93	4.05	3.98	4.02	4.00
IV	—	4.16	4.13	4.00	4.07	4.03	4.02	3.96
V	—	4.14	4.08	4.02	4.05	3.99	4.03	3.99
VI	—	4.14	4.07	3.99	4.08	3.98	3.98	3.98
(l) Surface Area of Aggregate—ft^2 per lb								
I	—	29.0	30.8	33.5	31.1	34.4	32.8	33.9
II	—	30.3	32.9	34.9	34.7	38.3	36.2	38.0
III	—	29.8	33.9	37.5	35.1	39.5	34.8	35.8
IV	—	30.0	30.4	41.0	36.9	38.9	36.8	39.9
V	—	30.4	34.2	38.2	35.8	38.5	36.5	38.7
VI	—	30.3	31.8	35.3	34.2	38.1	34.8	35.3

*Brittle fracture.

TABLE 4

AVERAGE CHANGES IN CHEMICAL PROPERTIES—CLINTON COUNTY, LR 219

Description	Line	After Mixing	After Compaction	5 Mo. Core	12 Mo. Core	18 Mo. Core	24 Mo. Core	30 Mo. Core
Asphalt No. I								
Asphaltenes	20.9	22.1	20.7	19.5	24.6	26.4	23.0	25.2
Nitrogen Bases	22.5	21.4	21.6	24.9	22.3	26.6	25.8	20.6
First Acidaffins	16.0	11.4	11.0	12.8	14.5	8.4	12.5	16.8
Second Acidaffins	29.0	32.2	30.6	31.3	27.3	28.5	28.8	27.1
Saturated Hydrocarbons	11.6	12.9	15.9	11.6	11.4	10.2	10.0	10.3
Rostler Coefficient	0.95	0.73	0.70	0.88	0.95	0.90	0.98	1.00
Mod. Rostler Coefficient	2.07	1.86	1.73	2.22	1.78	1.73	2.03	1.82
Asphalt No. II								
Asphaltenes	19.2	21.2	21.2	21.0	25.1	25.0	21.7	24.8
Nitrogen Bases	23.2	22.0	21.7	24.6	19.7	25.7	23.6	19.5
First Acidaffins	13.3	12.9	13.8	12.8	13.3	7.4	13.7	15.9
Second Acidaffins	30.5	30.0	30.5	29.7	28.0	30.1	28.4	27.6
Saturated Hydrocarbons	13.8	13.9	13.0	12.0	13.9	11.9	12.8	12.1
Rostler Coefficient	0.82	0.79	0.82	0.90	0.79	0.79	0.91	0.89
Mod. Rostler Coefficient	2.03	1.85	1.92	2.03	1.56	1.71	1.92	1.71
Asphalt No. III								
Asphaltenes	26.8	28.8	31.6	29.8	32.4	32.8	32.4	34.0
Nitrogen Bases	15.9	16.4	14.6	17.5	15.0	17.0	17.0	13.4
First Acidaffins	14.7	14.8	14.8	15.2	14.6	-2.5	13.6	15.7
Second Acidaffins	30.9	27.8	26.8	27.5	26.5	27.7	26.8	27.1
Saturated Hydrocarbons	11.8	12.2	12.3	10.1	11.5	10.1	10.2	9.7
Rostler Coefficient	0.72	0.78	0.75	0.87	0.78	0.78	0.82	0.80
Mod. Rostler Coefficient	1.59	1.44	1.28	1.51	1.28	1.33	1.46	1.29
Asphalt No. IV								
Asphaltenes	19.5	20.7	22.2	22.7	26.0	24.7	20.4	22.7
Nitrogen Bases	18.9	18.8	19.6	20.6	16.5	23.9	20.5	15.7
First Acidaffins	13.7	14.2	12.8	13.6	12.9	6.5	14.9	19.3
Second Acidaffins	33.7	31.8	31.7	31.1	29.6	31.4	31.6	28.9
Saturated Hydrocarbons	14.3	14.6	13.8	12.2	15.1	13.6	12.6	13.5
Rostler Coefficient	0.68	0.71	0.71	0.79	0.66	0.68	0.80	0.82
Mod. Rostler Coefficient	1.96	1.83	1.78	1.87	1.43	1.61	2.02	1.76
Asphalt No. V								
Asphaltenes	28.2	29.2	30.6	31.1	33.2	34.6	31.0	33.1
Nitrogen Bases	20.6	21.2	22.2	20.7	19.9	24.3	23.1	17.5
First Acidaffins	18.0	17.8	17.1	16.7	17.3	12.3	17.9	22.8
Second Acidaffins	24.3	23.3	22.8	24.0	21.1	22.0	21.2	19.74
Saturated Hydrocarbons	8.7	8.5	7.3	7.5	8.7	7.0	6.8	6.8
Rostler Coefficient	1.16	1.23	1.31	1.19	1.25	1.26	1.46	1.52
Mod. Rostler Coefficient	1.71	1.65	1.64	1.59	1.39	1.40	1.65	1.50
Asphalt No. VI								
Asphaltenes	28.2	29.0	29.4	30.2	31.5	31.8	30.7	33.3
Nitrogen Bases	22.6	21.2	21.4	22.6	19.6	25.2	22.0	16.7
First Acidaffins	17.7	16.3	16.1	16.6	16.0	10.9	14.4	19.9
Second Acidaffins	23.5	24.7	25.5	23.7	23.6	24.5	25.7	23.1
Saturated Hydrocarbons	8.0	8.6	7.7	6.9	9.4	7.7	7.2	7.0
Rostler Coefficient	1.29	1.13	1.3	1.28	1.08	1.12	1.12	1.22
Mod. Rostler Coefficient	1.76	1.66	1.70	1.70	1.44	1.53	1.64	1.48

of the recovered aggregate from the extraction process. Table 4 presents the chemical analyses of the six asphalts.

The results of the physical and chemical testing of the asphalts to date present interesting facts. In general, the test data indicate an overall hardening of the asphalts. However, from the time of compaction to the 5-month core data, a softening trend was observed that was common to all the asphalts. The degree of softening varies in magnitude depending on which test one considers, but it did exist. This 5-month period was during the winter of 1964-65. The asphalts definitely hardened over the summer of 1965, but some further softening occurred the following winter, i.e., in the 12- to 18-

month cores. The softening during the second winter was much less severe and in some asphalts was nonexistent. This fluctuation is continuing but at a less noticeable rate.

In a previous report (18), data were presented to indicate the influence various percents of motor oil have on physical and chemical test data. This was done because in many instances oil drippings were visually observed on the test projects in the area of the coring operation. Every precaution is taken to remove these drippings before extraction, but inevitably some penetration of the oil into the cores occurs. We also know that two principal reasons that an asphalt hardens are volatilization and oxidation. These are quite prevalent during the summer months and decrease in magnitude during the winter since each is a function of temperature. In view of these facts, a possible reason for this supposed seasonal hardening and softening is that, during the summer, the rates of oxidation and volatilization exceed the softening effect of motor oil drippings. In the winter, the rates of oxidation and volatilization decrease to the point that the effects of the motor oil become dominant.

The percent original and percent retained data were included in the tables because they may be better indicators of the true quality of the asphalts. It is perhaps more important to consider the relative characteristics of the asphalts rather than their actual test values. If one asphalt has a higher percent retained penetration than another asphalt, which reflects a rate of change, then the first asphalt may be more desirable.

An example of this hypothesis is the application of a simple rating system to the tabular values. If we consider actual test values, Asphalt II seems superior. However, if we consider the percent age-based data, Asphalt VI appears superior. Asphalt VI is the common 70-85 pen, 3000 ± 200 viscosity material. Some type of rating system will be developed so that a direct comparison of the asphalts will be possible in order to evaluate their durability.

JEFFERSON COUNTY, LR 338

The Jefferson County test roadway is 3.41 miles in length, located just south of the Borough of Sykesville. The original pavement consisted of 18 ft of 9- by 6- by 9-in. reinforced concrete constructed in 1924 and 1925. In 1954, the original pavement was widened with a 2-ft by 12-in. crushed aggregate base course and overlaid with 22 ft of $2\frac{1}{2}$-in. ID-2 bituminous concrete. In September of 1965, the roadway was resurfaced with 1 in. of FJ-1 wearing course on 2 in. of ID-2 binder course, as shown in Figure 5. The route can be identified as Legislative Route 338 or US 119; it has an average daily traffic count of 2,030 to 2,250 vehicles per day.

A sand aggregate was used to produce the FJ-1 wearing gradation on the entire project. The design variables were the six test asphalts; the limits of work for the different asphalts, as well as the penetration grade of the asphalts supplied, are shown in Figure 6.

Air and water flow rate determinations were made on the test pavement during the construction of this project. The complete test procedure and results have been re-

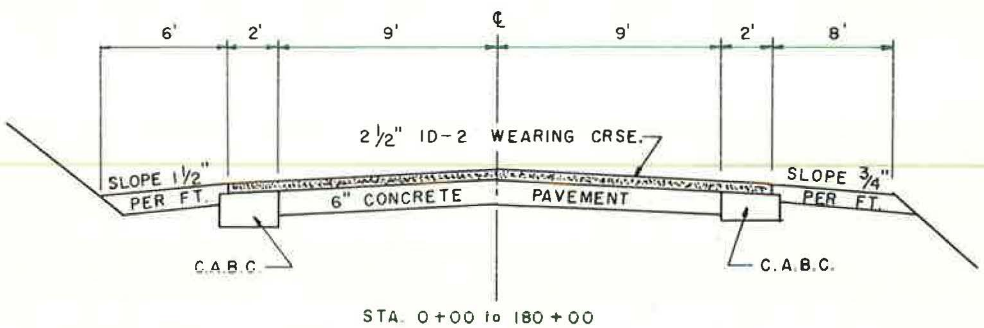


Figure 5. Typical section, LR 338.

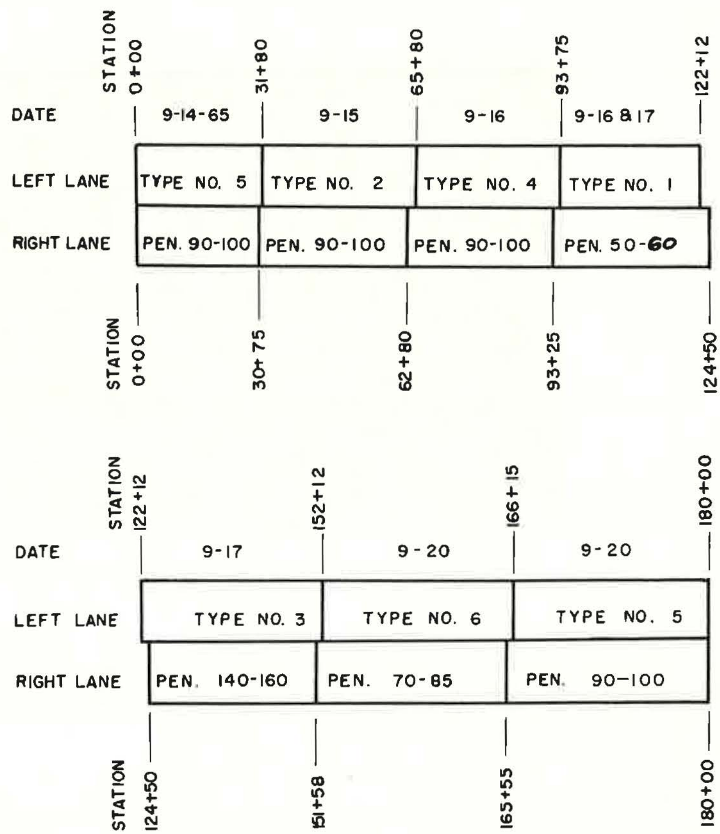


Figure 6. Asphalt producer limits, LR 338.

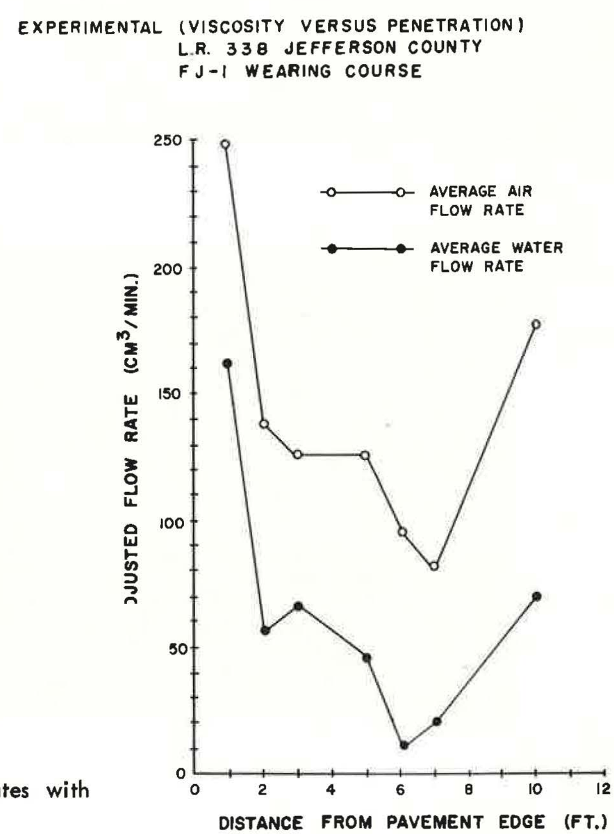


Figure 7. Variation of adjusted flow rates with transverse pavement location.

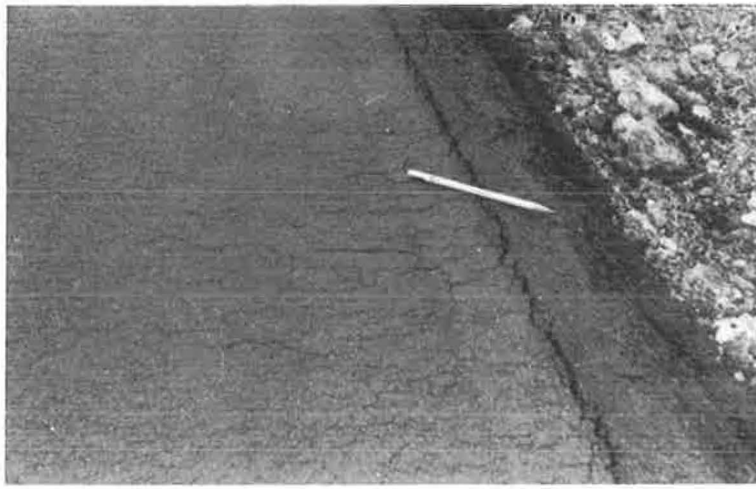


Figure 8. Surface cracking after final compaction.

ported elsewhere (19). The most interesting result of this extra testing is shown in Figure 7, which clearly indicates that more care should have been exercised during the compaction of the asphaltic concrete. It is suspected that early deterioration may begin at the pavement's edge or near the center joint.

In general, the construction of the pavement proceeded smoothly. There were some problems, however, that appeared during construction. Figure 8 shows the pavement containing numerous 3- to 12-in. cracks that opened after the finish roller completed its passes. This condition was quite severe for approximately 400 ft of pavement. Large longitudinal cracking along the edge of the pavement may also be noted. This crack appeared over the edge of the underlying pavement upon which the new surfacing was placed. Sluffing of the edge material was also noted. This phenomenon occurred immediately after the finish roller had completed its passes.

These phenomena were the result of either low temperatures during compaction or overcompaction. Data pertaining to laydown and compaction temperatures and asphalt

Figure 9. Excessive shoving of binder course.

viscosity during construction were as follows: air temperature 69 F; surface temperature 61 F; asphalt mix in truck, temperature 298 F, viscosity 1.8 poises; asphalt mix in hopper, temperature 298 F, viscosity 1.8 poises; mat before breakdown, surface temperature 258 F, viscosity 4.4 poises, interior temperature 278 F, viscosity 2.4 poises; breakdown rolling completed, surface temperature 186 F, viscosity 70 poises, interior temperature 200 F, viscosity 37 poises; pneumatic tire rolling completed, surface temperature 150 F, viscosity 500 poises, interior temperature 164 F, viscosity 210 poises; surface temperature upon completion of finished rolling was 116 F, which corresponded to a viscosity of 6500 poises. The asphalt used was Type IV.

The problem of bleeding did not present itself too often during construction and thus was not a major construction difficulty. Numerous areas of shoving were noted during the construction of the binder course, varying from slight to very severe as shown in Figure 9. The length of this shove was about 18 inches. This phenomenon was most predominant on sections of the roadway which had a grade line in excess of about 5 percent.

This test road will be quite interesting to observe, since it represents the first multi-penetration-viscosity asphalt project using an FJ-1 wearing course. The test data to date, both physical and chemical, are given in Tables 5 and 6. It is still too early to evaluate fully this test pavement or the test asphalts used on this project.

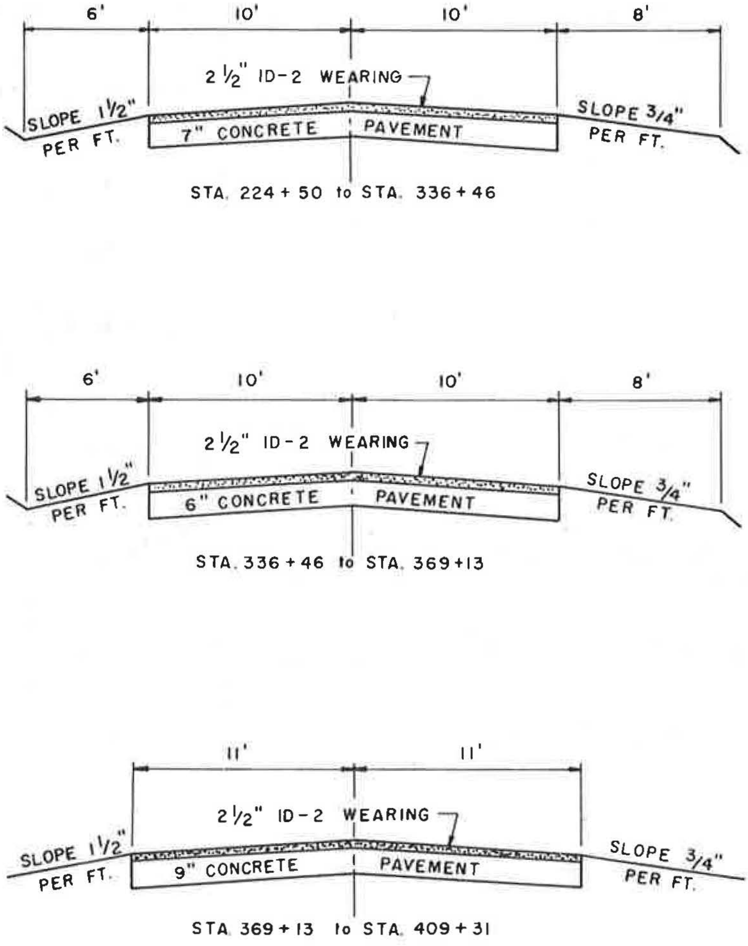


Figure 10. Typical sections, LR 101.

TABLE 5

PHYSICAL PROPERTIES OF ASPHALTS—JEFFERSON COUNTY, LR338

Asphalt Type	Line	After Mixing	After Compaction	7 Mo. Core	19 Mo. Core
(a) Penetration Test—0.1 mm at 77 F, 5 sec, 100 gm					
I	66	36	32	34	30
II	86	47	46	49	35
III	136	69	68	70	56
IV	87	54	50	47	35
V	84	45	49	47	37
VI	74	40	48	49	30
(b) Percent Retained Penetration					
I	100	54	48	52	45
II	100	55	53	57	41
III	100	51	50	51	41
IV	100	62	57	54	40
V	100	54	58	56	44
VI	100	54	65	66	40
(c) Absolute Viscosity (Cannon-Manning)—poises at 140 F, 30 cm Hg Vacuum					
I	1782	4952	6506	4925	7953
II	1629	5622	7348	4842	10277
III	1527	6116	6199	7940	9194
IV	1048	2532	2824	2820	5032
V	3051	13715	11561	11850	19042
VI	3092	13118	8485	7240	17084
(d) Percent of Original Absolute Viscosity					
I	100	278	365	276	446
II	100	345	451	297	631
III	100	400	406	520	602
IV	100	242	269	269	480
V	100	450	379	388	624
VI	100	424	274	234	552
(e) Standard Ductility—cm at 39.2 F and 1 cm per min					
I	7.4	4.0	3.6	2.2	*
II	60.5	6.4	5.8	7.3	4.2
III	105+	17.4	31.0	20.9	7.2
IV	19.6	5.9	5.9	5.4	*
V	51.2	5.6	6.5	6.3	4.4
VI	58.5	5.4	7.6	7.8	*

Asphalt Type	Line	After Mixing	After Compaction	7 Mo. Core	19 Mo. Core
(f) Percent Retained Standard Ductility					
I	100	54	49	30	0
II	100	11	10	12	7
III	100	17	30	20	7
IV	100	30	30	28	0
V	100	11	13	12	9
VI	100	9	13	13	0
(g) Percent Asphaltenes					
I	19.0	20.2	22.3	22.6	19.6
II	22.3	24.2	24.7	24.7	22.0
III	27.8	30.0	32.0	31.2	35.9
IV	16.8	18.7	19.4	21.0	19.1
V	29.5	32.2	32.1	31.9	31.7
VI	28.2	31.7	32.4	31.9	36.5
(h) Percent Original Asphaltenes					
I	100	106	117	119	103
II	100	108	111	111	99
III	100	108	115	112	129
IV	100	111	115	125	114
V	100	109	109	108	107
VI	100	112	115	113	129
(i) Fineness Modulus of Aggregate					
I	–	2.80	2.76	2.84	2.80
II	–	2.76	2.80	2.86	2.84
III	–	2.90	2.82	2.78	2.85
IV	–	2.81	2.78	2.82	2.76
V	–	2.90	2.78	2.82	2.92
VI	–	2.92	2.91	–	2.92
(j) Surface Area of Aggregate—ft^2 per lb					
I	–	58.0	60.6	62.2	59.2
II	–	59.4	60.3	67.4	57.5
III	–	57.4	60.2	67.0	58.8
IV	–	57.9	60.2	63.5	59.5
V	–	55.5	60.9	67.4	56.6
VI	–	55.5	57.1	–	57.5

*Brittle fracture.

TABLE 6

AVERAGE CHANGES IN CHEMICAL PROPERTIES—JEFFERSON COUNTY, LR 338

Description	Line	After Mixing	After Compaction	7 Mo. Core	19 Mo. Core
Asphalt No. I					
Asphaltenes	19.0	20.2	22.3	22.6	19.6
Nitrogen Bases	23.1	20.8	24.2	25.8	25.0
First Acidaffins	16.8	13.7	11.5	10.7	15.4
Second Acidaffins	29.5	27.9	29.7	28.6	27.1
Saturated Hydrocarbons	11.7	17.3	11.9	12.6	13.0
Rostler Coefficient	0.97	0.76	0.88	0.88	1.00
Mod. Rostler Coefficient	2.26	1.68	1.95	1.85	2.08
Asphalt No. II					
Asphaltenes	22.3	24.2	24.7	24.7	22.0
Nitrogen Bases	20.9	19.3	20.2	22.6	22.2
Second Acidaffins	28.6	27.3	28.6	29.4	29.6
Saturated Hydrocarbons	12.1	16.9	13.6	12.9	12.5
Rostler Coefficient	0.90	0.72	0.79	0.78	0.86
Mod. Rostler Coefficient	1.90	1.44	1.62	1.66	1.90
Asphalt No. III					
Asphaltenes	27.8	30.0	32.0	31.2	35.9
Nitrogen Bases	19.0	16.1	18.7	18.4	18.1
First Acidaffins	17.4	15.0	13.2	13.8	11.2
Second Acidaffins	27.3	25.7	25.7	27.3	25.2
Saturated Hydrocarbons	9.4	13.4	10.6	9.2	9.6
Rostler Coefficient	1.01	0.80	0.88	0.88	0.84
Mod. Rostler Coefficient	1.72	1.32	1.35	1.47	1.20
Asphalt No. IV					
Asphaltenes	16.8	18.7	19.4	21.0	19.1
Nitrogen Bases	23.0	21.4	22.7	25.0	25.2
First Acidaffins	15.6	13.9	14.6	10.9	12.8
Second Acidaffins	31.5	29.3	28.9	29.6	30.1
Saturated Hydrocarbons	13.1	16.7	14.5	13.5	12.8
Rostler Coefficient	0.87	0.77	0.86	0.84	0.88
Mod. Rostler Coefficient	2.35	1.84	1.95	1.90	2.13
Asphalt No. V					
Asphaltenes	29.5	32.2	32.1	31.9	12.7
Nitrogen Bases	17.0	14.7	16.9	18.5	12.7
First Acidaffins	17.8	13.3	13.6	10.6	17.1
Second Acidaffins	25.8	24.3	25.7	29.2	27.6
Saturated Hydrocarbons	9.9	14.5	12.0	9.8	10.8
Rostler Coefficient	0.97	0.71	0.81	0.76	0.77
Mod. Rostler Coefficient	1.54	1.14	1.29	1.40	1.35
Asphalt No. VI					
Asphaltenes	28.2	31.7	32.4	31.9	36.5
Nitrogen Bases	22.9	19.7	21.6	23.2	20.5
First Acidaffins	21.5	16.9	17.5	16.4	15.2
Second Acidaffins	21.0	19.9	21.2	21.0	21.4
Saturated Hydrocarbons	6.5	11.8	7.4	7.6	6.4
Rostler Coefficient	1.61	1.15	1.37	1.38	1.29
Mod. Rostler Coefficient	1.88	1.30	1.52	1.53	1.33

McKEAN COUNTY, LR 101

The McKean County test roadway is 3.50 miles in length, located between the towns of East Smethport and Port Allegheny. The original pavement consisted of three different sections. Section one, station 224 + 50 to station 336 + 46, consists of 20 ft of 9 by 7 by 9 in. reinforced concrete pavement that was placed in 1935. Section two, station 336 + 46 to station 369 + 13, consists of 20 ft of 8½ by 6 by 8½ in. reinforced concrete pavement that was placed in 1938. Section three, station 369 + 13 to station 409 + 31, consists of 22 ft of 9-in. reinforced concrete pavement that was placed in 1947. In 1955, section two was overlaid with 20 ft of 2½-in. ID-2 bituminous concrete wearing surface. In August of 1965, the entire test section was resurfaced with 1 in. of ID-2 wearing course on 2 in. of ID-2 binder material. Typical sections for this project are shown in Figure 10. The route can be identified as Legislative Route 101 or US 6.

In general, the construction of this roadway was performed very smoothly. Figure 11 shows the very first section of the job. This area of tender mix was approximately 300 ft in length. Considerable movement was noted as the breakdown roller began making its passes and it was immediately withdrawn. The pneumatic tire roller was then put into operation, but the problem became more severe. Figure 11 was taken at this stage. The pneumatic tire roller was removed, and the mat was left to set up for approximately 60 to 90 minutes. At that time the breakdown and pneumatic rolling was eliminated, and final compaction of this section was achieved with the finish roller at 225 F (viscosity 14 poises).

A sand and gravel aggregate was used to produce the ID-2 wearing gradation on the entire project. At the start of the job the mat temperature was high (315 F) and resulted in a viscosity of 1 poise during initial rolling. This, in combination with moisture in the aggregate, may have been responsible for the results shown in Figure 11. Upon lowering the temperature of the mix to 290 F (viscosity 1.8 poises) in this troublesome section, the mat temperature at start of rolling was 250 F (viscosity 6 poises) and paving and compaction were completed satisfactorily on this section of the project.

The design variables were the six test asphalts, and the limits of work for the different asphalts as well as the penetration grade of the asphalts supplied are shown in Figure 12. The test data to date, both physical and chemical, are given in Tables 7 and 8 of this report. It is too early to evaluate this test pavement or the test asphalts used on this project.

Other than the high-temperature problem at the very start and some low early morning temperatures that prevented early morning pavement laydown, construction proceeded on schedule. This test road will be quite interesting to observe, because it is located in

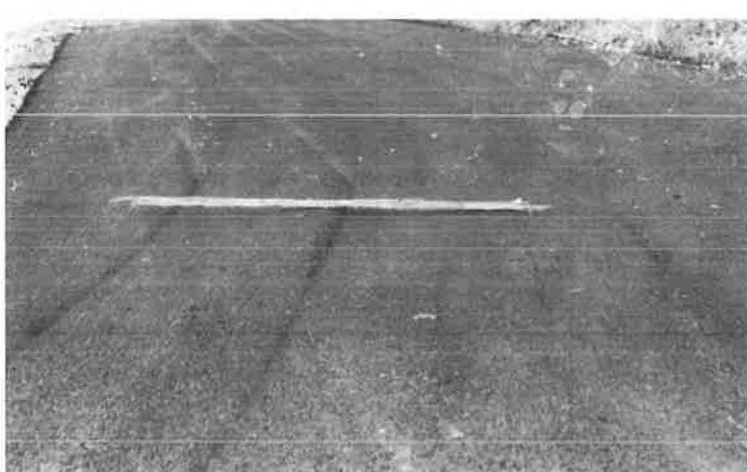


Figure 11. Extremely tender mix resisting compaction.

TABLE 7

PHYSICAL PROPERTIES OF ASPHALTS—McKEAN COUNTY, LR 101

Asphalt Type	Line	After Mixing	After Compaction	8 Mo. Core	20 Mo. Core
(a) Penetration Test—0.1 mm at 77 F, 5 sec, 100 gm					
I	59	44	40	39	36
II	90	79	78	62	60
III	130	96	84	85	82
IV	84	69	68	59	60
V	85	68	68	60	52
VI	74	49	48	53	47
(b) Percent Retained Penetration					
I	100	75	68	66	61
II	100	88	87	69	67
III	100	74	65	65	63
IV	100	82	81	70	71
V	100	80	80	71	61
VI	100	66	65	72	64
(c) Absolute Viscosity (Cannon-Manning)—poises at 140 F, 30 cm Hg Vacuum					
I	1794	3246	3269	3882	4629
II	1482	1571	1796	3109	2922
III	1701	3313	3694	4066	3930
IV	1090	1336	1604	2102	1672
V	2970	5127	5218	6965	8715
VI	3124	8334	7612	7488	8141
(d) Percent of Original Absolute Viscosity					
I	100	181	182	216	258
II	100	106	121	210	197
III	100	195	217	239	231
IV	100	123	147	193	153
V	100	173	176	234	293
VI	100	267	244	240	261
(e) Standard Ductility—at 39.2 F and 1 cm per min					
I	6.9	3.8	*	2.9	3.0
II	105+	60.9	54.0	14.7	13.8
III	105+	79.0	42.6	50.0	40.2
IV	26.4	8.8	12.8	7.6	10.8
V	49.7	18.2	16.6	12.4	6.9
VI	44.2	7.8	7.1	9.0	7.3

Asphalt Type	Line	After Mixing	After Compaction	8 Mo. Core	20 Mo. Core
(f) Percent Retained Standard Ductility					
I	100	55	0	42	43
II	100	58	51	14	13
III	100	75	41	48	38
IV	100	33	48	29	41
V	100	37	33	25	14
VI	100	18	16	20	17
(g) Percent Asphaltenes					
I	17.2	18.4	18.9	20.2	19.6
II	20.8	21.4	22.0	23.8	21.8
III	29.6	29.9	31.1	31.2	30.1
IV	15.2	15.4	16.3	19.1	17.0
V	29.6	30.4	30.5	30.5	31.4
IV	29.6	31.8	32.2	31.6	31.1
(h) Percent Original Asphaltenes					
I	100	107	110	117	114
II	100	103	106	114	105
III	100	101	105	105	102
IV	100	101	107	126	112
V	100	103	103	103	106
VI	100	107	109	107	105
(i) Fineness Modulus of Aggregate					
I	–	4.07	4.00	3.96	4.08
II	–	4.19	4.17	4.21	4.24
III	–	4.27	4.17	4.18	4.26
IV	–	4.32	4.32	4.27	4.30
V	–	4.14	4.08	4.05	4.10
VI	–	4.24	4.13	4.13	4.17
(j) Surface Area of Aggregate—ft^2 per lb					
I	–	34.2	37.0	43.0	35.0
II	–	36.0	36.1	40.1	33.9
III	–	31.2	33.0	39.7	32.5
IV	–	29.9	29.0	35.8	31.0
V	–	35.0	36.4	42.9	35.8
VI	–	31.3	34.2	40.0	34.2

*Brittle fracture.

TABLE 8

AVERAGE CHANGES IN CHEMICAL PROPERTIES—McKEAN COUNTY, LR 101

Description	Line	After Mixing	After Compaction	8 Mo. Core	20 Mo. Core
Asphalt No. I					
Asphaltenes	17.2	18.4	18.9	20.2	19.6
Nitrogen Bases	23.1	23.4	23.9	27.6	24.1
First Acidaffins	15.3	15.3	15.2	10.9	15.8
Second Acidaffins	28.0	30.0	29.4	29.3	28.3
Saturated Hydrocarbons	16.4	12.9	12.6	11.1	12.2
Rostler Coefficient	0.76	0.90	0.94	0.96	0.98
Mod. Rostler Coefficient	1.83	2.20	2.18	2.10	2.15
Asphalt No. II					
Asphaltenes	20.8	21.4	22.0	23.8	21.8
Nitrogen Bases	22.8	21.4	21.7	25.2	22.6
First Acidaffins	15.2	15.5	15.4	10.8	12.7
Second Acidaffins	26.6	29.6	28.7	28.6	30.2
Saturated Hydrocarbons	14.6	12.0	12.2	11.6	12.7
Rostler Coefficient	0.92	0.89	0.91	0.90	0.82
Mod. Rostler Coefficient	1.84	1.98	1.92	1.82	1.90
Asphalt No. III					
Asphaltenes	29.6	29.9	31.1	31.2	30.1
Nitrogen Bases	14.5	15.6	15.2	19.2	17.0
First Acidaffins	16.8	16.9	15.9	12.8	14.8
Second Acidaffins	25.2	27.3	26.3	27.0	28.1
Saturated Hydrocarbons	14.0	10.2	11.5	9.6	10.0
Rostler Coefficient	0.80	0.87	0.83	0.88	0.84
Mod. Rostler Coefficient	1.30	1.49	1.35	1.45	1.50
Asphalt No. IV					
Asphaltenes	15.2	15.4	16.3	19.1	17.0
Nitrogen Bases	25.6	24.0	23.0	27.0	26.2
First Acidaffins	16.8	14.2	16.4	9.9	13.7
Second Acidaffins	28.4	31.5	31.7	31.8	30.6
Saturated Hydrocarbons	14.0	13.8	13.0	12.3	12.5
Rostler Coefficient	1.00	0.86	0.89	0.84	0.92
Mod. Rostler Coefficient	2.42	2.42	2.44	2.18	2.40
Asphalt No. V					
Asphaltenes	29.6	30.4	30.5	30.5	31.4
Nitrogen Bases	15.0	16.7	16.1	22.0	18.6
First Acidaffins	16.6	16.7	16.2	11.3	12.0
Second Acidaffins	25.4	26.6	27.0	27.0	27.4
Saturated Hydrocarbons	13.4	9.6	9.2	9.2	10.6
Rostler Coefficient	0.82	0.92	0.92	0.92	0.80
Mod. Rostler Coefficient	1.33	1.50	1.52	1.52	1.38
Asphalt No. VI					
Asphaltenes	29.6	31.8	32.2	31.6	31.1
Nitrogen Bases	20.6	21.2	20.9	25.4	21.2
First Acidaffins	18.8	19.1	18.9	13.9	20.6
Second Acidaffins	19.4	20.6	20.8	21.9	19.5
Saturated Hydrocarbons	11.6	7.2	7.1	7.3	7.6
Rostler Coefficient	1.26	1.45	1.42	1.36	1.54
Mod. Rostler Coefficient	1.43	1.56	1.54	1.58	1.58

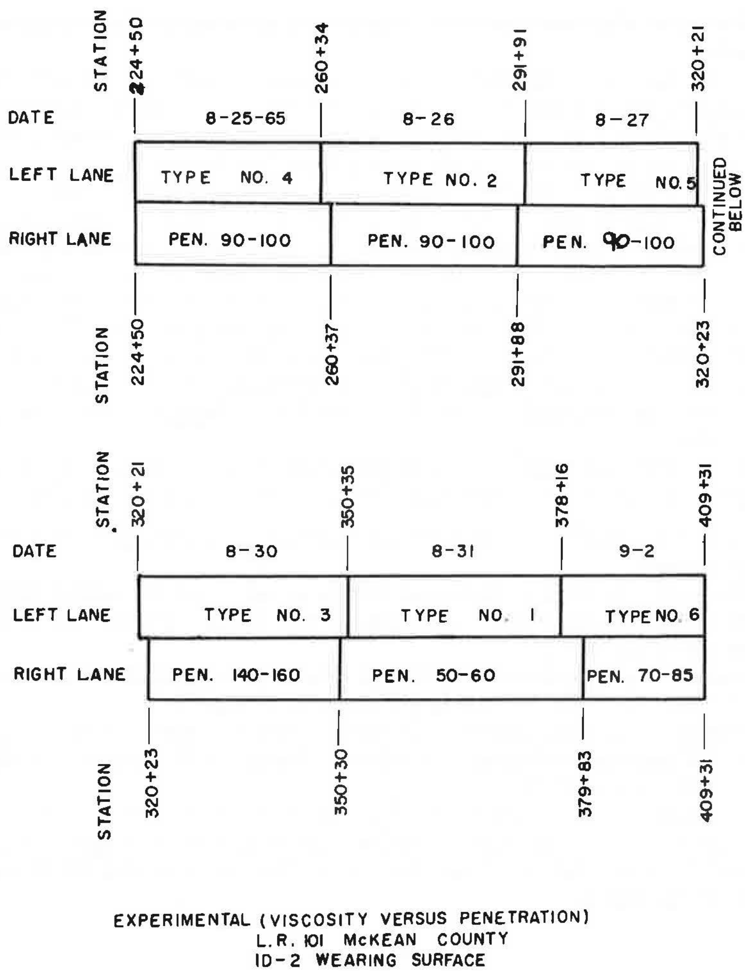


Figure 12. Asphalt producer limits, LR 101.

a northern county. It will probably undergo the severest cold temperature exposure of any of the pavements under evaluation.

SUMMARY

Of all the projects in our overall research programs, the Clinton, Jefferson, and McKean County projects are of the greatest importance. It is still too early to evaluate the quality and aging characteristics of the asphalts used on the Jefferson and McKean roadways. However, on the Clinton County project, using a very basic rating system, the common type asphalt, i.e., 70-85 penetration and 3000 ± 200 viscosity, is as good as, or better than, any of the test asphalts. This statement will be validated if the test project is studied until final deterioration occurs or until portions of the pavement are reclaimed, reconstituted, or resurfaced. It is then that a true evaluation of the asphalts can be made.

From Table 2 it can be seen that some of the asphalt cements used on the projects are somewhat out of specifications. One of the asphalts, Type V on LR 219, was in violation of the viscosity specification. The test value shown was observed at the Penn State laboratory and the value confirmed by the PDH laboratory. Rather than reject the material, it was accepted so as to not impede the progress of construction. It was considered a test asphalt and on this basis accepted. However, this fact will make it impossible to

compare the Clinton County data with the Jefferson and McKean County data for asphalt Type V in the future.

There seemed to be numerous construction problems on the Jefferson and McKean projects, such as improper plant mixing temperatures, insufficient edge and centerline rolling, the introduction of wet aggregates into the pugmill, and the absence of corrective measures for field problems. These two projects were not constructed according to the rigid specification and inspection methods that existed on the Clinton County project. Since it is a foregone conclusion that the inevitable durability of an asphaltic-concrete pavement is greatly influenced by proper construction methods and control, a great need exists in this area. Much improvement can and should be made in the area of quality control of batching operations and more rigid construction techniques.

A recent inspection tour of these projects was made by personnel from the Highway Department, University, and others. The pavements appear to be in excellent physical condition except for some minor base reflection cracking. It was not possible to distinguish visually any test asphalt section from another. Future inspection tours of this nature will be made.

It is difficult to draw any conclusions at the present time concerning all the projects. The following general conclusions are based only on the Clinton County test data:

1. In general, all the asphalts are hardening with time based on physical test data and percent asphaltenes.
2. During the winter months (from compaction to the 5-month cores and from the 12- to 18-month cores) no field age-hardening is indicated. In fact, some softening is indicated during these periods.
3. The percent retained and percent original concept of analyzing data may be a better indicator of the relative merits of the six test asphalts.
4. Some degradation of aggregates is occurring during construction. The breakdown occurs when the hot mixture is being compacted. Very slight changes, if any, are occurring under traffic compaction.
5. The Rostler coefficient is not producing any trend at this time to indicate chemical changes of the asphalts. The modified Rostler coefficient is decreasing somewhat with time, but this may be a reflection of increasing asphaltene contents which are used in the denominator of the ratio.

REFERENCES

1. Brown, A. B., Sparks, J. W., and Larson, D. Rate of Change of Softening Point, Penetration, and Ductility of Asphalt in Bituminous Pavement. Proc. AAPT, Vol. 26, p. 66-81, 1957.
2. Hveem, F. N., Zube, E., and Skog, J. Progress Report on the Zace-Wigmore Asphalt Test Project. ASTM STP No. 277, p. 3-45, Sept. 1960.
3. Kenis, W. J., Sr. Progress Report on Changes in Asphaltic Concrete in Service. HRB Bull. 333, p. 39-65, 1962.
4. Gotolski, W. H., Ciesielski, S. K., and Heagy, L. N. Progress Report on Changing Asphalt Properties of In-Service Pavements in Pennsylvania. Proc. AAPT, Vol. 33, p. 285-319, 1964.
5. Department of Highways, Commonwealth of Pennsylvania. Instructions and Procedures for Design, Control, Compaction of Bituminous Concrete. Harrisburg, Jan. 1962.
6. Gotolski, W. H., Ciesielski, S. K., Lucas, J. M., and Kofalt, J. A. A Study of Physical Factors Affecting the Durability of Asphaltic Pavements. Interim Report No. 4, Oct. 1965.
7. Goode, J. F., and Owings, E. P. A Laboratory-Field Study of Hot Asphaltic Concrete Wearing Course Mixtures. ASTM STP No. 309, p. 1-21, June 1961.
8. Baumen, E. W. Discussion of Goode, J. F., and Owings, E. P., A Laboratory-Field Study of Hot Asphaltic Concrete Wearing Course Mixtures. ASTM STP No. 309, p. 16-21, June 1961.
9. Highway Research Board Annual Meeting. Open Discussion at Conference Session on Low-Temperature Properties of Bituminous Materials, January 1964.

10. Flood, W. H. Ductility at Low Temperatures. Proc. AAPT, Vol. 6, p. 60, 1935.
11. Shattuck, C. L. Measurement of the Resistance of 50-60 Penetration and Ductility at Plant Mixing Temperature. Proc. AAPT, Vol. 11, p. 186, 1940.
12. Reid, J. A. Director of Research, Phillips Petroleum Company, Bartlesville, Oklahoma. Correspondence, Aug. 1961.
13. Heithaus, J. J. Measurement of Asphalt Viscosity With a Vacuum Capillary Viscometer. ASTM STP No. 309, p. 63-73, June 1961.
14. Griffith, J. M., and Puzinauskas, V. P. Relation of Empirical Tests to Fundamental Viscosity of Asphalt Cement. ASTM STP No. 328, p. 64-88, 1960.
15. Rostler, F. S., and White, R. M. Influence of Chemical Composition of Asphalts on Performance, Particularly Durability. ASTM STP No. 277, p. 64-88, Sept. 1960.
16. Rostler, F. S., and White, R. M. Composition and Changes in Composition of Highway Asphalts, 85-100 Penetration Grade. Proc. AAPT, Vol. 31, p. 35, Jan. 1962.
17. Gotolski, W. H., Lucas, J. M., and Ciesielski, S. K. Properties of Paving Asphalts—Stage IV. Fourth Year Summary Report to the Pennsylvania Department of Highways, June 1965.
18. Gotolski, W. H., Lucas, J. M., Ciesielski, S. K., and Kofalt, J. A. A Study of Physical Factors Affecting the Durability of Asphaltic Pavements. Interim Report No. 5, Pennsylvania Department of Highways and the Bureau of Public Roads, March 1966.
19. Gotolski, W. H., Ciesielski, S. K., Lucas, J. M., and Kofalt, J. A. A Study of Physical Factors Affecting the Durability of Asphaltic Pavement. Special Report No. 1, June 1966.