For Reference Photographs for Table 10 see index copy

ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR

Progress Report

FIELD INSPECTIONS AND LABORATORY TESTS ON ASPHALTS AND ASPHALT PAVEMENTS

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Project 2249

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SUMMARY AND OBJECTIVE

This report gives the results obtained from an investigation of the service behavior of hot-mixed pavements in which asphalts manufactured from Wyoming crude oils were used, together with data collected from other sources for purposes of comparison. As the investigation is sponsored by the Ohio Oil Company, the areas visited were those in which the products of that company have been used or may find a future market.

The primary objective was a determination of the service behavior of asphalt as reflected by its change in physical or chemical properties due to construction practices, traffic conditions, climatic exposure, etc. The project was divided into three phases:

1. a field performance survey,

2. a laboratory investigation of samples taken from many locations, and

3. an investigation of asphalt characteristics and properties for the purpose of developing a more accurate definition of those qualities which are significant in highway construction.

Phase 1 was completed during the past year with Phase 2 being carried on concurrently, resulting in the accumulation of data included in this report. Phase 3 has not been started except as the attached data may contribute to its development.

From about May 1 to October, 1954, Mr. William M. Aldous, Research Engineer, representing the Engineering Research Institute, University of Michigan, traveled extensively over the states of Wyoming, Nebraska, Colorado, Iowa, and Minnesota, making a thorough survey of the hot-mixed asphaltic paving laid on state highway routes and on some city streets, chiefly those of Colorado Springs, Colorado; McCook, Nebraska; and Minneapolis, Minnesota. In addition, short periods were spent in Idaho on the WASHO Test Road in the spring of 1954, and samples were taken in 1955 from a selected group of highways in Michigan. Information also was obtained with respect to the experimental project on US-10, Michigan, in which asphalts from various sources, including Wyoming, were used. The field inspections included visits to refineries at Lovell, Casper, and Cheyenne and to offices of the highway organizations involved. Although information was difficult to obtain from refineries in some instances, all the state and city officials were most cooperative, and records of test data and construction procedures were freely made available. Figure 1 is a map

upon which are indicated locations which were visited and where field surveys were made.

Unfortunately, records were far from complete in many instances. Test data concerning the asphalt as received and used in the pavements sometimes were very limited. Complete analyses had not always been made and in others the test records had been discarded. In such cases it was necessary to accept general averages of original test properties or to assume that those which were available were applicable to an entire project. Among such cases were those of Colorado Springs, McCook, and several projects in Wyoming and Nebraska.

Pavements were sampled extensively after thorough visual inspections were made. A total of 162 sawed specimens were taken. In earlier inspections in Wyoming, the highway organizations supplied cutting equipment. Later it became necessary to assemble the project's own equipment; a University truck was acquired and the power unit, water supply, and diamond tip saw were mounted on it. This apparatus is shown in Photograph 339 of Appendix 12. Samples were boxed and shipped to Ann Arbor, where all the testing was done. The samples were very carefully cut and packed in order that valid test results might be obtained. Many photographs of the samples are in the picture sections of the appendices of this report. In some instances, older data on pavements which had been resurfaced due to deterioration were collected. Such cases were those from a group of Michigan projects of various ages dating to 1934, where test results on the hardening of the asphalt cement were available. Inspection reports and brief discussions of these results are included in this report as appendices. Included also in the appendices are tables containing detailed analyses of the field samples and such information as was available in the several highway offices pertaining to the asphalts used, construction densities, etc. From these tables, data have been summarized for comparison and comment in this discussion.

Projects in which asphalts from crudes produced by Ohio Oil Company were used are as follows:

Location	Reported in Appendix
City of Colorado Springs	2
Minnesota Trunk Highway 13	10
Minnesota Trunk Highway 53	10
Michigan Experimental Highway on US-10	11

Other companies which produced asphalt involved in this survey are as follows:

Company	Reported in Appendix
American Bitumuls	11
American Liberty	11 and 12
Asphalt Products Co.	12
Barber	11a and 11b
Carter	10
Frontier	4 and 5
Husky	7, 9, and 10
Lion	11 and 12
Northwest Refining	10
Phillips	6
Saunders	10
Sinclair	1
Socony-Vacuum	10
Standard Oil of Indiana	11, 11a, and 11b
Standard Oil of New Jersey	11a, 11b, and 12
Standard Oil of Wyoming	3 and 8
Texas Company	1, 10, and 11b
Trumbull	11
Warner Quinlan	11b

Particular attention was given those pavements in which Wyoming asphalts were used. Except for the city streets of McCook and Minneapolis, all contained gravel aggregate. The asphalt was of a much softer grade than that used in the heavy traffic trunkline surfacing of Michigan and, except perhaps in Minnesota, both design and construction were less carefully controlled. With the possible exception of the projects containing Frontier asphalt, all pavements were giving satisfactory service at the time of inspection. Local failures were explainable on the basis of factors not related to the asphaltic binder. Traffic generally was not as intense or as heavy as on the most densely traveled routes of Michigan, but such highways as Wyoming US-30 do carry much through-freight traffic, and others are subjected to very heavy loads incident to oil-field development and operation.

In Michigan, only the Experimental Test Road of 1954 contains Wyoming asphalt. This was processed from Ohio Oil Company crudes to the somewhat harder grades used in Michigan asphaltic concrete mixtures for heavy-duty surfaces. This asphalt was selected in order to compare its behavior with that of other sources. The pavement has been in service less than one year, and at this time there is no apparent difference between the behavior of sections containing the asphalt from Ohio Oil Company crudes and those from other sources.

OBSERVATIONS ON COLLECTED DATA

The objective of specifications for asphaltic cement is to define a material which will serve as a satisfactory binder for aggregates without serious deterioration over a long period of years. In order to satisfy the overall requirement, the asphalt must coat the aggregate with a film of adequate thickness at temperatures which permit drying of the aggregate. In the mixing and laying processes, the asphalt must not harden excessively at temperatures required to produce the necessary pavement density. Also, it is often required that the asphalt be a homogeneous combination of hydrocarbons as defined by a test based on selective solubility. This requirement also is an attempt to exclude those materials which, through manufacturing processes or natural composition, are classed as nonhomogeneous and may deteriorate more rapidly in service. It has long been known that those pavements which contain asphalts which have reached a certain degree of hardness and which also lack plasticity are susceptible to rapid disintegration.

In this investigation little information was developed about relationships between mixing temperatures and asphalt fluidity; information simply was not available. However, in the Michigan Experimental Road* this relationship was considered. Under careful plant control, mixtures were laid at temperatures which produced in the laboratory Saybolt Furol viscosities of 75 seconds and 200 seconds. For the asphalts from the five sources these viscosities were secured with temperatures as follows:

Source	Minimum	Maximum
Wyoming	275	315
Venezuela	290	330
Winkler	275	315
Smackover	290	330
Talco	290	330

These batch temperatures were, in general, closely maintained at the paving plant, and no aggregate drying difficulties were experienced. No significant difference in compaction in the pavements resulted from these relatively small variations in temperature.

*Discussed in detail in "Progress Report, Michigan State Highway Experimental Bituminous Paving Construction Project," Parr and Serafin. Proceedings, Association of Asphalt Paving Technologies, Volume 24, 1955.

DISCUSSION OF TEST DATA

Hardening of an asphalt occurs both during the hot-mixing process and later when the pavement is in service. Specifications limit the permissible drop in penetration in terms of various laboratory tests and, in the case of Michigan, by defining the allowable degree of hardening during the construction process.

Asphalts do harden progressively with age. Table 1 compares the penetrations of recovered asphalts from the samples taken during this investigation with the best available information on the original consistency. Other data in this table are from Michigan records relating to the Michigan Test Road of 1954, Project F83-13 from Cadillac to Manistee, and some twenty-five other miscellaneous projects, the details being summarized in Appendices 11, 11a, 11b, and 12.

The percentage reductions in penetration of the asphalts from the five sources used in Michigan Test Road of 1954 (Appendix 11) are reproduced from the Progress Report on that project as Table 2.

TABLE 2

AVERAGE TEST RESULTS ON RECOVERED ASPHALTS FROM TEST ROAD

Asphalt	Wyom.	Venez.	Wyom.	Winkler	Smack'r.	Talco
Average Mix Temp. at Plant-°F	300	315	305	300	305	310
Asphalt Recovered at Time of Construction*						
Percent of original penetration	74	72	66	78	74	71
Ductility, cm	150+	150+	150+	150+	150+	140+
Oliensis spot test	pos	neg	pos	neg	neg	neg
Asphalt Recovered from Cores 3 Months after Construction**						
Percent of original penetration	70	63	63	72	72	68
Ductility, cm	150+	150+	150+	150+	150+	116+
Oliensis spot test	pos	neg	pos	neg	neg	neg

*Recoveries from samples taken at time of construction - average of 17 to 21 separate samples.

**Recoveries from cores taken 3 months later - average of 6 separate samples.

These asphalts averaged sixty-two penetration when received from the producers. The loss of twenty-eight percent presents a reduction of seventeen points up to the time the pavement was placed in service. The average additional hardening in three months amounted to three points in penetration.

Figure 2 indicates rates of penetration decreases of asphalt from Husky Refining, Ohio Oil, and ten sources used on Michigan project F83-13 laid in 1936 and sampled periodically thereafter (Appendix 11a). The group of Husky Refining results on asphalt cement having an original penetration of about sixty-five were from the City of Minneapolis pavements of various ages. The connected points of Ohio Oil from Colorado Springs represent construction of 1948, 1950, and 1952. The Ohio Oil from the two Minnesota state highway projects represent the original and subsequent penetrations made on samples from these individual projects. The Michigan data are merely averages of the penetration of the ten different asphalts sampled at various ages on a single state-highway route.

Table 3 is a summation of penetration changes in asphalts of 261 to 102 penetration in Minnesota and Michigan pavements, where it is felt that they have served under similar climatic conditions. These are simple percentages of the retained penetration at the ages indicated.

In Table 4 the relative hardening of the asphalts tabulated in Table 2 are compared, with 261, the highest penetration observed, designated as the index material. In these computations the original penetration and the recovered penetration were each expressed as a percentage of the index material (261). The difference between these two percentages expresses the relative drop in penetration with reference to the index.

In only a few cases were marked changes in ductility noted between the original laboratory tests and those on the recovered material. In Table 1 and in the appendices, when results are reported as 100+ cm or 150+ cm, this indicates that the test simply was discontinued at those elongations.

In the western area covered by the study, only a few marked decreases were found. The Sinclair on Wyoming US-30 (Sample M25) is from broken edges, probably poorly compacted and thus exposed to severe weathering. The recovered asphalt was harder as well as much less ductile than companion samples which represent average construction of this generally satisfactory pavement.

The McCook sample M42 represents another case of extreme hardening and loss of ductility. This pavement was virtually unused for a period of ten years or so and now carries only light traffic. Also, it apparently was constructed on new fill, as subsidence is evident.

The Husky asphalt of Minnesota F4001 (Appendix 10) shows evidence of change, with three samples having ductility of 150+, 75, and 36. The

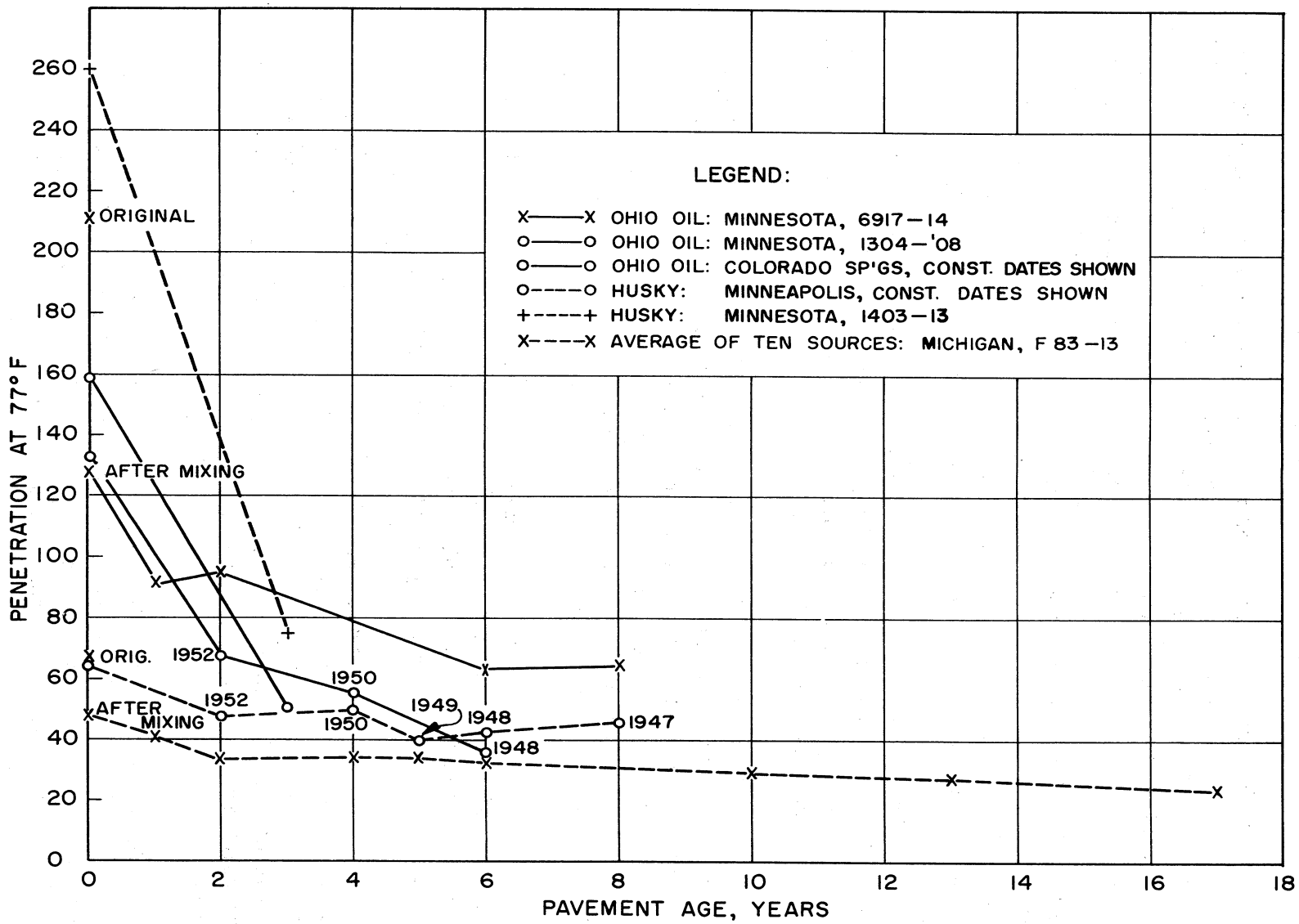


Figure 2. Progressive Hardening of Asphalts as Indicated by Penetration Tests at Different Ages.

TABLE 3

REDUCTION IN PENETRATION OF SOFTER GRADES
OF ASPHALT FROM MINNESOTA AND MICHIGAN PAVEMENTS

Source	User	Const.	Orig. Pen.	Rcvd. Pen. 1954	Pen. of Rcvd. Asphalt - % of Original at Indicated Age								
					After Mixing	1	2	3	4	5	6	7	8
Husky	Minn	1951	261	75	--			28.7					
Carter	Minn	1946	261	60	--	38.3	44.4		21.5			23.0	23.0
Texas	Minn	1948	255	57	--						22.4		
S.O.	Minn	1951	235	73	--			31.1					
Saunders	Minn	1951	216	59	--			27.3					
S.O.	Minn	1948	219	38	--						17.4		
Socony	Minn	1946	217	38.5	--								17.7
Ohio Oil	Minn	1946	215	65	--	38.1						26.0	30.2
Saunders	Minn	1951	212	58.5	--			27.6					
Ohio Oil	Minn	1946	208	71	62.0	47.6	45.7					34.6	34.1
N.W. Ref.	Minn	1948	168	31.5	54.8						18.8		
Asph. Prod.	Mich	1949	167	70.5	59.3						42.2		
Lion	Mich	1949	165	42.	72.1						25.5		
Lion	Mich	1949	165	60	72.1						36.4		
Husky	Minn	1947	164	26	62.2	36.0					20.7	15.9	
Asph. Prod.	Mich	1949	164	68	59.8						41.5		
Am. Lib.	Mich	1950	162	54.5	74.7					33.6			
Asph. Prod.	Mich	1952	161	60	62.7			37.3					
Ohio Oil	Minn	1951	159	50.5	--			31.8					
Lion	Mich	1952	159	108.5	73.6		68.2						
Am. Lib.	Mich	1952	159	75	73.6		47.2						
Lion and Std.	Mich	1950	158	88	69.6					55.7			
Am. Lib.	Mich	1952	149	63	73.2			42.3					
Am. Lib.	Mich	1948	114	42.5	67.5			65.6			37.3		
Am. Lib.	Mich	1948	113	56	46.9			66.4				49.6	
Carter	Minn	1951	112	41	--			36.6					
Lion	Mich	1949	111	48.5	80.2					43.7			
Carter	Minn	1951	107	44	--			41.1					
Asph.Prod.	Mich	1949	102	28.5	49.0					27.9			

TABLE 4

REDUCTION OF PENETRATION OF SOFTER GRADES
OF ASPHALT REFERRED TO AN INDEX MATERIAL

Source of Asphalt	User	Date of Const.	Init. Indiv. Pen.	Percentage Referred to Index Pen.	Percent Penetration Drop Referred to Index Material								
					After Mix	Service Life, Years							
						1	2	3	4	5	6	7	8
Carter	Minn	1946	261	100.0	--	61.7	55.6		78.5			77.0	77.2
Ohio	Minn	1946	215	82.4	--	51.0						60.9	57.7
Ohio	Minn	1946	208	79.7	30.3	41.8	43.3					52.1	52.8
Socony	Minn	1946	217	83.2	--								68.5
Husky	Minn (a)	1947	164	62.8	23.7	40.2					49.8	53.5	
N.W. Ref.	Minn (b)	1948	168	64.3	29.1						52.2		
Texas	Minn	1948	255	97.7	--						75.9		
S.O.	Minn	1948	219	83.9	--						69.4		
Am. Lib.	Mich (c)	1948	114	43.7	14.2	15.0					27.6		
Am. Lib.	Mich (c)	1948	113	43.3	23.0	14.6					21.9		
Lion	Mich	1949	111	42.5	8.4					23.6			
Asph. Prod.	Mich (d)	1949	102	39.1	19.9					23.4			
Asph. Prod.	Mich (e)	1949	164	62.8	25.3					40.5			
Asph. Prod.	Mich (f)	1949	167	64.0	26.1					42.0			
Lion	Mich	1949	165	63.2	17.6					43.7			
Lion	Mich	1949	165	63.2	19.1					42.2			
Am. Lib.	Mich	1950	162	62.1	15.7				41.2				
Lion and Std.	Mich	1950	158	60.5	18.4				26.9				

NOTE: (a) Badly cracked paving
(b) Paving dry in appearance
(c) Paving deficient in asphalt
(d) Paving map-cracked
(e) Map-cracked edge
(f) Map-cracked edge

TABLE 4 (Cont.)

Source of Asphalt	User	Date of Const.	Init. Indiv. Pen.	Percentage Referred to Index Pen.	Percent Penetration Drop Referred to Index Material								
					After Mix	Service Life, Years							
						1	2	3	4	5	6	7	8
Ohio	Minn	1951	159	60.9	--	--		19.4	--	--	--	--	--
Husky	Minn	1951	261	100.0	--	--		71.3					
Carter	Minn	1951	107	41.0	--			21.8					
Carter	Minn	1951	112	42.9	--			27.2					
Saunders	Minn	1951	220	84.3	--			61.5					
Saunders	Minn	1951	212	81.2	--			59.8					
S.O.	Minn	1951	235	90.0	--			62.9					
Am. Lib.	Mich	1952	149	57.1	15.3		32.8						
Asph. Prod.	Mich	1952	161	61.7	23.0		38.7						
Lion	Mich	1952	159	60.9	16.1		19.4						
Am. Lib.	Mich	1952	159	60.9	18.8		32.2						

Northwest Refining material of Minnesota F6206 (Appendix 10) still has a high ductility, although the paving appears dry. On Michigan Project CS-11 and CS-77 (Appendix 12), American Liberty asphalt showed erratic drops in ductility, the pavement having failed, due probably to a deficiency in asphalt. Another instance is the material from Asphalt Products, Michigan M54-27 and M37-12, showing very low ductility and a pavement which has a very dry appearance.

A study of the data from the Western projects indicated that a measure of aging and deterioration of asphalt might be developed through the relationship between the standard penetration and the ring-and-ball softening-point tests. Complete test results on asphalts as originally used were seldom available but it was found that the magnitude of the ratio between penetration and softening point of recovered asphalt correlated reasonably well with pavement conditions. Table 5 indicates the relationship between consistency at a constant temperature and flow characteristics expressed by a penetration softening-point ratio. The notes following this table describe the condition of the pavements from which the samples were taken.

TABLE 5

SOFTENING-POINT PENETRATION RATIO ON RECOVERED ASPHALTS CORRELATED WITH PAVING CONDITION

Number of Samples	For All Paving Samples			Max Ratios		Min Ratios	
	Max	Min	Avg	1926 Pvg.	1952 Pvg.	1926 Pvg.	1952 Pvg.
85 (a)	4.500	1.420	2.631	4.313	4.500	3.325	1.420
24 (b)	2.646	1.314	1.663	In service since 1947.			
14 (c)	5.917	4.567	5.352	Service life ranged from 1926 to 1949.			
2 (d)	5.810	5.320	6.065	In service since 1947.			
1 (e)	15.364	15.364	15.364	In service since 1926.			

NOTES:

(a) Paving in good serviceable condition and of normal appearance.
(b) Paving containing excess asphalt, shoving and rutting badly.
(c) Paving still serviceable but having a dry lifeless appearance.
(d) Paving badly map cracked and broken particles displaced by traffic.
(e) Paving having excessive checking and map cracking.

It will be noted that the 85 samples from pavements described as serviceable and normal contain asphalts with s.pt./pen. ratios up to 4.50. The fourteen which are still serviceable but appear dry show ratios above 4.50. The asphalt

TABLE 6

COMPARATIVE SOFTENING-POINT/PENETRATION RATIOS
OF ASPHALTS FROM MINNESOTA AND MICHIGAN PAVEMENTS

Using Agency	Year of Const.	Source of Asphalt	Softening Point/Penetration Ratio*			
			1	2	3	4
Minn	1946	Socony	3.250	3.459		
Minn	1946	Ohio	1.906	1.877	1.758	1.526
Minn	1946	Carter	2.034	2.000	2.017	2.017
Minn (a)	1947	Husky	5.071	5.917	6.810	
Minn (b)	1948	N.W. Ref.	3.649	5.346		
Minn	1948	Texas	2.158	2.193		
Minn	1948	Standard	3.943	3.341		
Minn	1951	Ohio	2.604	2.358		
Minn	1951	Carter	2.440	3.395	3.395	2.864
Minn	1951	Saunders	2.246	2.097	2.286	2.082
Minn	1951	Standard	1.481	1.803		
Mich (c)	1948	Amer. Lib.	3.197	3.316	2.264	2.392
Mich	1949	Lion	2.859	3.252	2.291	2.429
Mich	1949	Lion	2.909	2.156		
Mich	1949	Lion	2.119	2.419		
Mich (d)	1949	Asph. Prod.	5.070	5.604		
Mich (e)	1949	Asph. Prod.	1.614	2.268	3.659	
Mich (f)	1949	Asph. Prod.	1.543	2.159	4.852	
Mich	1950	Amer. Lib.	2.126	2.584		
Mich	1950	Lion and Std.	1.311	1.437	1.271	
Mich	1952	Amer. Lib.	2.006	1.848		
Mich	1952	Asph. Prod.	2.078	2.069		
Mich	1952	Lion	1.041	0.999		
Mich	1952	Amer. Lib.	1.527	1.694		

*Determinations from 2 to 4 samples from same project.

NOTE:

(a) Paving badly cracked, 6.810 value from map-cracked area.
(b) Paving appears dry but still serviceable.
(c) Paving failure probably due to insufficient asphalt, not due to asphalt properties.
(d) Paving only 1 in. thick over old concrete. Map cracked in wheel paths.
(e) Sample from map-cracked edge area.
(f) Sample from map-cracked edge area.

in service since 1926 is the Standard Oil product on one of the McCook pavements which is in poor condition.

In this group, the twenty-four samples of Frontier asphalt show lower s.pt./pen. ratios but the pavements from which they are taken, Nebraska S-10 and 170 (6), are not satisfactory. It is true that they contain an excess of asphalt but the surface was very oily, giving the impression that a non-adhesive constituent of the asphalt was exuded in the hot weather which prevailed at the time of inspection. Nothing is known of the source of the crude and of the refining of this material. The company personnel at the Cheyenne refinery of Frontier were decidedly reticent. At any rate, there is an indication that an asphalt with a lower s.pt./pen. ratio at these ages may possess other objectionable properties even though it does not harden excessively.

Table 6 is a tabulation of s.pt./pen. ratios determined from samples taken from Minnesota and Michigan projects. Notes on condition are added and generally seem to confirm the earlier comments on the significance of higher values of the ratio. There is an indication, moreover, that the s.pt./pen. ratio may reflect some property not developed by the ductility test, as indicated by the results on samples from Minnesota 6206-11, a hard, dry pavement, in which the asphalts retained 150+ cm ductility, but showed high s.pt./pen. ratios. That marked decreases in ductility may be accompanied by high s.pt./pen. ratios is indicated by samples M312 and M315, both representing badly map-cracked pavement.

All the comments have applied to asphalts which have been mixed and laid under undeterminable conditions and have been exposed to weathering under various climates in pavements which were compacted to different densities. No ratios are included upon asphalts as delivered, except those of the Michigan Test Road (Appendix 11) which are presented below and compared with the results on recovered asphalts after three months of service.

TABLE 7

SOFTENING POINT/PENETRATION ON
ASPHALTS FROM MICHIGAN TEST ROAD

Source	S.Pt./Pen as Delivered	S.Pt./Pen. after Three Months in Service
Trumbull	1.905	2.900
Am. Bit.	2.087	3.571
Leonard	1.770	2.872
St. Oil (Ind)	2.055	3.074
Lion	1.967	3.152
Am. Lib.	1.911	3.255

TABLE 8

SOFTENING POINT/PENETRATION AS COMPUTED
FROM BUREAU OF PUBLIC ROADS DATA

Asphalt Source	Refining Method	Spot Char.	(1) Original Asphalt			325°F (2) 5Hr. Thin-Film Exp			Diff.	325°F (3) 24Hr Thin-Film Exp			Diff.
			Pen	S.Pt	S.Pt/Pen	Pen	S.Pt	S.Pt/Pen	(2)-(1)	Pen	S.Pt	S.Pt/Pen	(3)-(1)
Calif.	red. and steam	neg	54	119	2.204	33	128	3.879	1.675				
Calif.	red. and steam	neg	90	112	1.244	51	121	2.373	1.129	16	147	9.188	7.944
Calif.	red. and steam	neg	131	107	0.817	68	118	1.735	0.918				
Calif.	San Joaquin	neg	89	111	1.247	47	126	2.681	1.434				
Calif.	-----	neg	102	111	1.088	62	119	1.919	0.831	18	149	8.278	7.190
Venez.	pipe still, vac.	neg	51	130	2.549	33	143	4.333	1.784				
Venez.	pipe still, vac.	neg	88	118	1.341	51	132	2.588	1.247	25	171	6.840	5.499
Venez.	pipe still, vac.	neg	138	110	0.797	74	123	1.662	0.865				
Venez.	air and steam	pos	97	117	1.206	50	140	2.800	1.594				
Venez.	pipe still, vac.	neg	105	105	1.000	62	128	2.065	1.065				
Venez.	-----	neg	64	125	1.953	40	141	3.525	1.572				
Arkansas	vac. at low temp.	neg	96	113	1.177	63	126	2.000	0.823				
Arkansas	vac. 89 mp flux	neg	98	121	1.235	61	135	2.213	0.978				
Mexican	Trumble pipe	neg	106	117	1.104	54	136	2.519	1.415	24	174	7.250	6.146
Mexican	still	pos	101	118	1.168	46	143	3.109	1.941	18	219	12.167	10.998
Wyoming	fire and steam (c)	pos	95	115	1.211	50	135	2.700	1.489				
Wyoming	-----	neg	85	119	1.400	50	132	2.640	1.240	24	165	6.875	5.475
Trinidad	fluxed	neg	100	112	1.120	47	126	2.681	1.561				
Bermudez	fluxed	neg	102	112	1.098	33	136	4.121	3.023*				
Kansas	shell still	neg	61	129	2.115	40	146	3.650	1.535				
Kansas	shell still	neg	83	121	1.458	50	138	2.760	1.302	25	183	7.320	5.862
Kansas	shell still	neg	137	110	0.803	73	127	1.740	0.937				
Kansas	shell still (c)	pos	92	115	1.250	60	141	2.350	1.100				

* Apparent high degree of change.
(c) Denotes cracked asphalt.

TABLE 8 (Cont.)

Asphalt Source	Refining Method	Spot Char.	(1) Original Asphalt Pen	S.Pt	S.Pt/Pen	325°F (2) 5Hr. Thin-Film Exp Pen	S.Pt	S.Pt/Pen	Diff. (2)-(1)	325°F (3) 24Hr Thin-Film Exp Pen	S.Pt	S.Pt/Pen	Diff. (3)-(1)
Kansas	----- (c)	pos	75	115	1.533	22	137	6.227	4.694*	6	191	31.833	30.300
Kansas	-----	neg	75	123	1.640	45	141	3.133	1.493	23	187	8.130	6.490
Kansas	-----	neg	76	122	1.605	52	133	2.558	0.953	28	166	5.929	4.324
Kansas	-----	neg	87	119	1.368	52	133	2.558	1.189	27	170	6.259	4.891
Kentucky	Dubbs (c)	pos	87	113	1.299	28	139	4.964	3.665*				
Kentucky	Dubbs (c)	pos	102	111	1.088	28	142	5.071	4.083*				
Ky or Ill	fire and steam, blown	neg	105	119	1.133	79	127	1.608	0.475	48	148	3.083	1.950
Ky or Ill	-----	neg	93	116	1.609	60	127	2.117	0.508	26	157	6.038	4.429
Ky or Ill	-----	neg	89	122	1.371	63	132	2.095	0.724				
Columbia	pipe still, vac.	neg	110	112	1.018	66	124	1.879	0.861				

* Apparent high degree of change.
(c) Denotes cracked asphalt.

A procedure for predicting the degree of hardening would doubtless involve tests on original asphalt for comparison with later tests after some sort of an accelerated weathering or exposure had been completed. As an indication of what might be expected in a thin-film oven test, softening-point and penetration data were taken from a Bureau of Public Roads paper* and the s.pt./pen. ratios computed. These are given in Tables 8 and 9.

TABLE 9

SUMMARY OF DATA OF TABLE 8

Source of Asphalt	Refining Method Used	Condition of Asphalt		Avg. Change in S.Pt./Pen. Ratio			Asph Rat'g
		Spot	Type	Orig Asp	5-Hr Exp.	24-Hr Exp.	
Calif.	red. and steam	neg	normal	1.320	1.197	7.567	4
Venez.	pipe still	neg	normal	1.474	1.355	5.499	7
Arkansas	vac-low temp	neg	normal	1.206	0.901	---	3
Mexican	Trumble still	-	normal	1.136	1.678	8.572	10
Wyoming	fire and steam	pos	cracked	1.211	1.489	---	8
Wyoming	fire and steam	neg	normal	1.400	1.240	5.475	6
Trinidad	fluxed	neg	normal	1.120	1.561	---	9
Bermudez	fluxed	neg	normal	1.098	3.023	---	12
Kansas	shell still	neg	normal	1.498	1.235	5.392	5
Kansas	shell still	pos	cracked	1.392	2.897	30.300	11
Kentucky	Dubbs	pos	cracked	1.194	3.874	---	13
Ky. or Ill.	fire and steam	neg	blown	1.371	0.569	3.190	1
Columbia	vac. still	neg	normal	1.018	0.861	---	2

The s.pt./pen. ratio has been discussed at some length since it does appear to possess a degree of correlation with service, especially with the group of Wyoming asphalts. It is recognized that asphalts tend not to change rapidly in softening point and, therefore, the predominant factor in the ratio is the more rapid change in penetration. Indeed, this ratio may prove to be another way of expressing a fluidity relationship. It is generally recognized that extreme hardening, as measured by penetration and low ductility, represents deterioration which sooner or later is reflected in pavement failure. Ductility changes are not easy to measure, especially in the upper ranges. Perhaps the substitution of a more quantitative softening-point value for the less definite

*"Hardening Properties of Asphaltic Materials", Pauls and Welborn. Proceedings, Association of Asphalt Paving Technologists, Vol. 21.

ductility may be an improvement. As far as it has been investigated, the s.pt./pen. ratio seems to substantiate and parallel indications of aging which are furnished by penetration and ductility, and there is some evidence that it may be a more sensitive and reliable index.

The Oliensis spot test, using Skellysolve S, was made on all asphalts recovered from ERI samples, using standard A.A.S.H.O. method designation T-102-42, except that another operation was included to facilitate the interpretation of the test results. The presence of small amounts of fine mineral matter, not removed by the recovery procedure, may cause a slightly darker nucleus within the spot. This could be misinterpreted as characteristic of the asphalt itself, so that a negative asphalt would be reported as positive. For that reason a straight xylene spot test was run on a duplicate sample of the asphalt at the same time the standard Oliensis test was performed. If, after 24 hours, there was sufficient contrast between the spots obtained using xylene and Skellysolve, the result was considered to indicate a positive spot asphalt. If there was only a slight nucleus within the spot obtained from both solutions, with no appreciable contrast between them, the asphalt was considered as being a negative spot material.

A range of typical test results, using both Skellysolve S and straight C.P. xylene, have been photographed and are used for reference in Table 10. The xylene spots, in cases where contrast can be observed within the spotted area, indicate the presence of finely dispersed mineral matter. As the xylene is capable of completely dissolving the bituminous material, it is considered that only the presence of the mineral dust could cause variation in the coloration. The Skelly spot series show a range of spots from "no contrast" to "definite contrast", corresponding to asphalt having negative to positive spot characteristics. In the photographs all xylene spots have been designated (a), (b), and (c), and the Skellysolve spots bear the designations (A), (B), and (C). All asphalt is identified with respect to sample number, sample location, source of asphalt, and date of construction.

In response to a suggestion from Ohio Oil Company, an additional series of spot tests was made using 15% xylene and 85% Skelly S. The results of these spot tests are listed in Table 11.

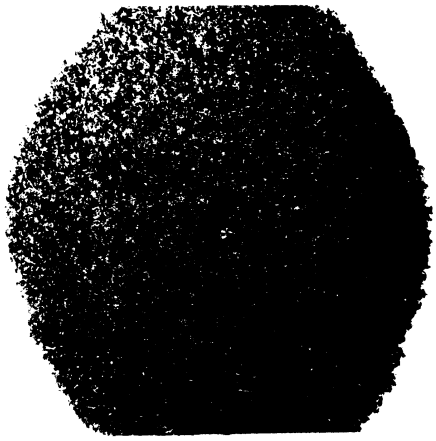
Pavement behavior could in no instance be correlated with the spot test characteristic of the recovered asphalt.

Reference Photographs for Table 10

Spot Test Interpretation

C. P. XYLENE

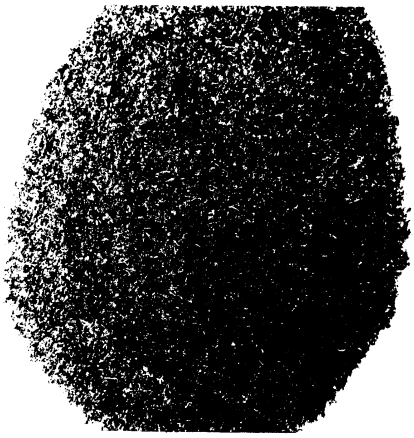
SKELLY SOLVE (S)

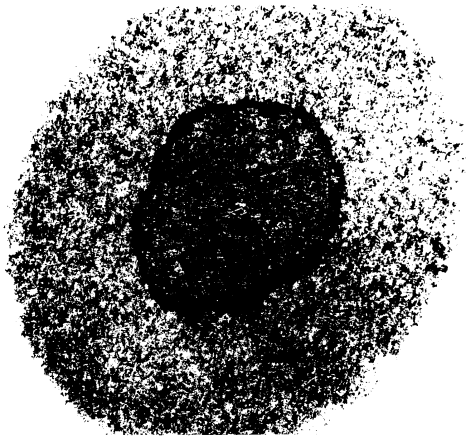


No
Contrast

(a)

(A)
Negative





Slight
Contrast

(b)

(B)
Slightly Positive

Definite
Contrast

(c)

(C)
Positive

TABLE 10

SPOT TEST RESULTS USING C.P.C.
XYLENE VS SKELLY S ON RECOVERED ASPHALTS

Sample No.	Source of Asphalt	Location of Test Sample	Classification		Spot Test Category	Date of Const.
			Xylene	Skelly S		
M 1	Texas	Wyoming No. 87	b	C	positive	1948
M 2	Texas	Wyoming No. 87	b	B	sl. positive	1948
M 3	S.O. Co.	Wyoming No. 87	b	C	positive	1950
M 4	S.O. Co.	Wyoming No. 87	b	C	positive	1950
M 5	S.O. Co.	Wyoming No. 87	c	C	positive	1952
M 6	S.O. Co.	Wyoming No. 87	b	C	positive	1952
M 7	Ohio	Colorado Spgs.	a	C	positive	1950
M 8	Ohio	Colorado Spgs.	b	C	positive	1950
M 9	Ohio	Colorado Spgs.	c	C	positive	1952
M 10	Ohio	Colorado Spgs.	c	C	positive	1952
M 11	Ohio	Colorado Spgs.	a	C	positive	1952
M 12	Ohio	Colorado Spgs.	a	C	positive	1952
M 13	Ohio	Colorado Spgs.	b	C	positive	1948
M 14	Ohio	Colorado Spgs.	b	C	positive	1948
M 15	Ohio	Colorado Spgs.	c	C	positive	1948
M 16	Ohio	Colorado Spgs.	b	C	positive	1948
M 17	Ohio	Colorado Spgs.	a	C	positive	1950
M 18	Ohio	Colorado Spgs.	a	C	positive	1950
M 19	Ohio	Colorado Spgs.	a	C	positive	1952
M 20	Ohio	Colorado Spgs.	a	C	positive	1952
M 21	Ohio	Colorado Spgs.	a	B	sl. positive	1950
M 22	Ohio	Colorado Spgs.	b	C	positive	1950
M 23	Ohio	Colorado Spgs.	b	C	positive	1950
M 24	Ohio	Colorado Spgs.	a	C	positive	1950
M 25	Ohio	Colorado Spgs.	a	C	positive	1952
M 26	Ohio	Colorado Spgs.	a	C	positive	1952
M 27	Sinclair	Wyoming US-30	b	C	positive	1948
M 28	Phillips	W.A.S.H.O.	a	C	positive	1952
M 29	Phillips	W.A.S.H.O.	a	C	positive	1952
M 30	Phillips	W.A.S.H.O.	a	C	positive	1952
M 31	Phillips	W.A.S.H.O.	a	C	positive	1952
M 32	Phillips	W.A.S.H.O.	a	C	positive	1952
M 33	Phillips	W.A.S.H.O.	b	C	positive	1952
M 34	Ohio	USAF, Rapid City	b	C	positive	1951
M 35	Sinclair	Wyoming US-30	c	C	positive	1948
M 36	Sinclair	Wyoming US-30	c	C	positive	1948
M 37	S.O. Co.	McCook, Neb.	c	C	positive	1926
M 38	S.O. Co.	McCook, Neb.	b	C	positive	1926

TABLE 10 (Cont.)

Sample No.	Source of Asphalt	Location of Test Sample	Classification		Spot Test Category	Date of Const.
			Xylene	Skelly S		
M 39	S.O. Co.	McCook, Neb.	c	C	positive	1926
M 40	S.O. Co.	McCook, Neb.	b	C	positive	1926
M 41	S.O. Co.	McCook, Neb.	b	C	positive	1926
M 42	S.O. Co.	McCook, Neb.	c	C	positive	1926
M 43	S.O. Co.	McCook, Neb.	a	C	positive	1926
M 44	S.O. Co.	McCook, Neb.	c	C	positive	1926
M 45	S.O. Co.	McCook, Neb.	b	C	positive	1926
M 46	S.O. Co.	McCook, Neb.	b	C	positive	1926
M 47	S.O. Co.	McCook, Neb.	b	C	positive	1926
M 48	S.O. Co.	McCook, Neb.	a	C	positive	1926
M 49	Frontier	Nebraska S10	b	C	positive	1948
M 50	Frontier	Nebraska S10	b	C	positive	1948
M 51	Frontier	Nebraska S10	a	B	sl. positive	1948
M 52	Frontier	Nebraska S10	b	C	positive	1948
M 53	Frontier	Nebraska S10	c	C	positive	1948
M 54	Frontier	Nebraska S10	b	C	positive	1948
M 55	Frontier	Nebraska S10	c	C	positive	1948
M 56	Frontier	Nebraska S10	c	C	positive	1948
M 57	Frontier	Nebraska S10	b	C	positive	1948
M 58	Frontier	Nebraska S10	a	C	positive	1948
M 59	Frontier	Nebraska S10	a	C	positive	1948
M 60	Frontier	Nebraska S10	a	C	positive	1948
M 61	Frontier	Nebraska S10	a	C	positive	1948
M 62	Frontier	Nebraska S10	a	C	positive	1948
M 63	Frontier	Nebraska S10	a	C	positive	1948
M 64	Frontier	Nebraska S10	a	C	positive	1948
M 65	Frontier	Nebraska S10	b	C	positive	1948
M 66	Frontier	Nebraska S10	a	C	positive	1948
M 67	Frontier	Nebraska S10	a	C	positive	1948
M 68	Frontier	Nebraska S10	b	C	positive	1948
M 69	Frontier	Nebr. 170(6)	b	C	positive	1947
M 70	Frontier	Nebr. 170(6)	c	C	positive	1947
M 71	Frontier	Nebr. 170(6)	b	C	positive	1947
M 72	Frontier	Nebr. 170(6)	b	C	positive	1947
M 73	Frontier	Nebr. 170(6)	b	C	positive	1947
M 74	Frontier	Nebr. 170(6)	a	C	positive	1947
M 75	Husky	Iowa Rt. 64	a	C	positive	1952
M 76	Husky	Iowa Rt. 64	a	C	positive	1952
M 77	Husky	Iowa Rt. 64	a	C	positive	1952
M 78	Husky	Iowa Rt. 64	b	C	positive	1952
M 79	Husky	Iowa Rt. 64	a	C	positive	1952

TABLE 10 (Cont.)

Sample No.	Source of Asphalt	Location of Test Sample	Classification		Spot Test Category	Date of Const.
			Xylene	Skelly S		
M 80	Husky	Iowa Rt. 64	b	C	positive	1952
M 81	S.O. Co.	Iowa Rt. 65	a	B	sl. positive	1949
M 82	S.O. Co.	Iowa Rt. 65	a	B	sl. positive	1949
M 83	S.O. Co.	Iowa Rt. 65	a	C	positive	1949
M 84	S.O. Co.	Iowa Rt. 65	a	C	positive	1949
M 85	S.O. Co.	Iowa Rt. 65	a	C	positive	1949
M 86	S.O. Co.	Iowa Rt. 65	a	C	positive	1949
M 87	N.W. Ref.	Minn T.H. 10	a	C	positive	1948
M 88	N.W. Ref.	Minn T.H. 10	b	C	positive	1948
M 89	Ohio	Minn T.H. 61	b	C	positive	1951
M 90	Ohio	Minn T.H. 61	b	C	positive	1951
M 91	Socony	Minn T.H. 61	b	B	sl. positive	1946
M 92	Socony	Minn T.H. 61	c	C	positive	1946
M 93	Ohio	Minn T.H. 53	c	C	positive	1946
M 94	Ohio	Minn T.H. 53	c	B	negative	1946
M 95	Ohio	Minn T.H. 53	a	B	sl. positive	1946
M 96	Ohio	Minn T.H. 53	b	C	positive	1946
M 97	Carter	Minn T.H. 34	a	C	positive	1946
M 98	Carter	Minn T.H. 34	a	C	positive	1946
M 99	Carter	Minn T.H. 34	a	C	positive	1946
M100	Carter	Minn T.H. 34	b	C	positive	1946
M101	Husky	Minn T.H. 32	a	C	positive	1951
M102	Husky	Minn T.H. 32	a	C	positive	1951
M103	Carter	Minn T.H. 10	a	C	positive	1951
M104	Carter	Minn T.H. 10	c	C	positive	1951
M105	Carter	Minn T.H. 10	b	C	positive	1951
M106	Carter	Minn T.H. 10	c	C	positive	1951
M107	Texas Co.	Minn T.H. 71	c	C	positive	1948
M108	Texas Co.	Minn T.H. 71	b	C	positive	1948
M109	Saunders	Minn T.H. 75	b	C	positive	1951
M110	Saunders	Minn T.H. 75	a	A	negative	1951
M111	Saunders	Minn T.H. 75	a	C	positive	1951
M112	Saunders	Minn T.H. 75	b	B	sl. positive	1951
M113	S.O. Co.	Minn T.H. 5	b	C	positive	1948
M114	S.O. Co.	Minn T.H. 5	b	C	positive	1948
M115	Husky	Minn T.H. 13	b	C	positive	1947
M116	Husky	Minn T.H. 13	a	B	sl. positive	1947
M119	Husky	Minn T.H. 13	a	C	positive	1947
M117	S.O. Co.	Minn T.H. 42	a	C	positive	1951
M118	S.O. Co.	Minn T.H. 42	a	C	positive	1951
M120	Husky	Minneapolis	a	A	negative	1946

TABLE 10 (Cont.)

Sample No.	Source of Asphalt	Location of Test Sample	Classification		Spot Test Category	Date of Const.
			Xylene	Skelly S		
M121	Husky	Minneapolis	-	-	----	1946
M122	Husky	Minneapolis	a	A	negative	1952
M123	Husky	Minneapolis	a	C	positive	1952
M124	Husky	Minneapolis	a	C	positive	1948
M125	Husky	Minneapolis	a	C	positive	1948
M126	Husky	Minneapolis	b	B	sl. positive	1949
M127	Husky	Minneapolis	b	B	sl. positive	1949
M128	Husky	Minneapolis	b	B	sl. positive	1950
M129	Husky	Minneapolis	b	B	sl. positive	1950
		Michigan				
M300	Am. Lib.	Marine City	a	A	negative	1950
M301	Am. Lib.	Marine City	a	A	negative	1950
M302	Am. Lib.	US-23	a	A	negative	1952
M303	Am. Lib.	US-23	a	A	negative	1952
M304	Asph. Prod.	US-23	a	A	negative	1952
M305	Asph. Prod.	US-23	a	A	negative	1952
M306	Lion	M66, McBain	a	A	negative	1952
M307	Lion	M66, McBain	a	A	negative	1952
M308	Asph. Prod.	US-10, Baldwin	a	A	negative	1949
M309	Asph. Prod.	US-10, Baldwin	a	A	negative	1949
M310	Asph. Prod.	M20, E. Remus	a	A	negative	1949
M311	Asph. Prod.	M20, E. Remus	a	A	negative	1949
M312	Asph. Prod.	M20, E. Remus	a	A	negative	1949
M313	Asph. Prod.	M20, E. Remus	a	A	negative	1949
M314	Asph. Prod.	M20, E. Remus	a	A	negative	1949
M315	Asph. Prod.	M20, E. Remus	a	A	negative	1949
M316	Lion	M62, Dowiagac	a	A	negative	1949
M317	Lion	M62, Dowiagac	a	A	negative	1949
M318	Am. Lib.	Sodus-EauClair	a	A	negative	1948
M319	Am. Lib.	Sodus-EauClair	a	A	negative	1948
M320	Am. Lib.	Sodus-EauClair	a	A	negative	1948
M321	Am. Lib.	Sodus-EauClair	a	A	negative	1948
M322	Lion	M50, Charlotte	a	A	negative	1949
M323	Lion	M50, Charlotte	a	A	negative	1949
M324	Am. Lib.	M47, Perry	a	A	negative	1952
M325	Am. Lib.	M47, Perry	a	A	negative	1952
M326	Lion Std	Liberty Rd	a	A	negative	1950
M327	Lion Std	Liberty Rd	a	A	negative	1950
M328	Lion Std	Liberty Rd	a	A	negative	1950
M318a	Lion	Sodus-EauClair	a	A	negative	1949

TABLE 10 (Concl.)

Sample No.	Source of Asphalt	Location of Test Sample	Classification		Spot Test Category	Date of Const.
			Xylene	Skelly S		
M319a	Lion	Sodus-EauClair	b	B	sl. positive	1949
M320a	Lion	Sodus-EauClair	a	A	negative	1949
M321a	Lion	Sodus-EauClair	b	B	sl. positive	1949
	Trumbull	US-10 Exp.	c	C	positive	1954
	Am. Bitumuls	US-10 Exp.	a	A	negative	1954
	Leonard	US-10 Exp.	c	C	positive	1954
	S.O. Indiana	US-10 Exp.	a	A	negative	1954
	Lion	US-10 Exp.	a	A	negative	1954
	Amer. Lib.	US-10 Exp.	a	A	negative	1954

TABLE 11

SPOT TEST RESULTS USING
MIXTURE OF 15% XYLENE - 85% SKELLY S

Sample No.	Source of Asphalt	Location of Test Sample	Classification	Spot Test Category	Date of Const.
			15% Xylene-85% Skelly S		
M 1	Texas	Wyoming No. 87	A	neg	1948
M 2	Texas	Wyoming No. 87	A	neg	1948
M 3	S.O. Co.	Wyoming No. 87	B	sl. pos	1950
M 4	S.O. Co.	Wyoming No. 87	B	sl. pos	1950
M 5	S.O. Co.	Wyoming No. 87	A	neg	1952
M 6	S.O. Co.	Wyoming No. 87	A	neg	1952
M 7	Ohio	Colorado Springs	C	pos	1950
M 8	Ohio	Colorado Springs	C	pos	1950
M 9	Ohio	Colorado Springs	B	sl. pos	1952
M 10	Ohio	Colorado Springs	A	neg	1952
M 11	Ohio	Colorado Springs	C	pos	1952
M 12	Ohio	Colorado Springs	C	pos	1952
M 13	Ohio	Colorado Springs	B	sl. pos	1948
M 14	Ohio	Colorado Springs	B	sl. pos	1948
M 15	Ohio	Colorado Springs	C	pos	1948
M 16	Ohio	Colorado Springs	A	neg	1948
M 17	Ohio	Colorado Springs	A	neg	1950
M 18	Ohio	Colorado Springs	A	neg	1950

TABLE 11 (Cont.)

Sample No.	Source of Asphalt	Location of Test Sample	Classification 15% Xylene-85% Skelly S	Spot Test Category	Date of Const.
M 19	Ohio	Colorado Springs	A	neg	1952
M 20	Ohio	Colorado Springs	A	neg	1952
M 21	Ohio	Colorado Springs	A	neg	1950
M 22	Ohio	Colorado Springs	A	neg	1950
M 23	Ohio	Colorado Springs	A	neg	1950
M 24	Ohio	Colorado Springs	A	neg	1950
M 25	Ohio	Colorado Springs	A	neg	1952
M 26	Ohio	Colorado Springs	B	sl. pos	1952
M 27	Sinclair	Wyoming US-30	C	pos	1948
M 28	Phillips	W.A.S.H.O.	A	neg	1952
M 29	Phillips	W.A.S.H.O.	C	pos	1952
M 30	Phillips	W.A.S.H.O.	A	neg	1952
M 31	Phillips	W.A.S.H.O.	A	neg	1952
M 32	Phillips	W.A.S.H.O.	C	pos	1952
M 33	Phillips	W.A.S.H.O.	B	sl. pos	1952
M 34	Ohio	USAF, Rapid City	B	sl. pos	1951
M 35	Sinclair	Wyoming US-30	C	pos	1948
M 36	Sinclair	Wyoming US-30	C	pos	1948
M 37	S.O. Co.	McCook, Neb.	C	pos	1926
M 38	S.O. Co.	McCook, Neb.	C	pos	1926
M 39	S.O. Co.	McCook, Neb.	C	pos	1926
M 40	S.O. Co.	McCook, Neb.	A	neg	1926
M 41	S.O. Co.	McCook, Neb.	C	pos	1926
M 42	S.O. Co.	McCook, Neb.	C	pos	1926
M 43	S.O. Co.	McCook, Neb.	C	pos	1926
M 44	S.O. Co.	McCook, Neb.	C	pos	1926
M 45	S.O. Co.	McCook, Neb.	A	neg	1926
M 46	S.O. Co.	McCook, Neb.	C	pos	1926
M 47	S.O. Co.	McCook, Neb.	C	pos	1926
M 48	S.O. Co.	McCook, Neb.	C	pos	1926
M 49	Frontier	Nebraska S-10	A	neg	1948
M 50	Frontier	Nebraska S-10	A	neg	1948
M 51	Frontier	Nebraska S-10	A	neg	1948
M 52	Frontier	Nebraska S-10	A	neg	1948
M 53	Frontier	Nebraska S-10	A	neg	1948
M 54	Frontier	Nebraska S-10	A	neg	1948
M 55	Frontier	Nebraska S-10	A	neg	1948
M 56	Frontier	Nebraska S-10	A	neg	1948
M 57	Frontier	Nebraska S-10	A	neg	1948
M 58	Frontier	Nebraska S-10	A	neg	1948

TABLE 11 (Cont.)

Sample No.	Source of Asphalt	Location of Test Sample	Classification 15% Xylene-85% Skelly S	Spot Test Category	Date of Const.
M 59	Frontier	Nebraska S-10	A	neg	1948
M 60	Frontier	Nebraska S-10	A	neg	1948
M 61	Frontier	Nebraska S-10	A	neg	1948
M 62	Frontier	Nebraska S-10	A	neg	1948
M 63	Frontier	Nebraska S-10	A	neg	1948
M 64	Frontier	Nebraska S-10	A	neg	1948
M 65	Frontier	Nebraska S-10	A	neg	1948
M 66	Frontier	Nebraska S-10	A	neg	1948
M 67	Frontier	Nebraska S-10	A	neg	1948
M 68	Frontier	Nebraska S-10	A	neg	1948
M 69	Frontier	Nebraska 170 (6)	C	pos	1947
M 70	Frontier	Nebraska 170 (6)	A	neg	1947
M 71	Frontier	Nebraska 170 (6)	B	sl. pos	1947
M 72	Frontier	Nebraska 170 (6)	A	neg	1947
M 73	Frontier	Nebraska 170 (6)	A	neg	1947
M 74	Frontier	Nebraska 170 (6)	A	neg	1947
M 75	Husky	Iowa Rt. 64	A	neg	1952
M 76	Husky	Iowa Rt. 64	A	neg	1952
M 77	Husky	Iowa Rt. 64	A	neg	1952
M 78	Husky	Iowa Rt. 64	B	sl. pos	1952
M 79	Husky	Iowa Rt. 64	A	neg	1952
M 80	Husky	Iowa Rt. 64	B	sl. pos	1952
M 81	S.O. Co.	Iowa Rt. 65	A	neg	1949
M 82	S.O. Co.	Iowa Rt. 65	A	neg	1949
M 83	S.O. Co.	Iowa Rt. 65	A	neg	1949
M 84	S.O. Co.	Iowa Rt. 65	A	neg	1949
M 85	S.O. Co.	Iowa Rt. 65	A	neg	1949
M 86	S.O. Co.	Iowa Rt. 65	A	neg	1949
M 87	N.W. Ref.	Minn T.H. 10	A	neg	1948
M 88	N.W. Ref.	Minn T.H. 10	A	neg	1948
M 89	Ohio	Minn T.H. 61	A	neg	1951
M 90	Ohio	Minn T.H. 61	A	neg	1951
M 91	Socony	Minn T.H. 61	A	neg	1946
M 92	Socony	Minn T.H. 61	A	neg	1946
M 93	Ohio	Minn T.H. 53	A	neg	1946
M 94	Ohio	Minn T.H. 53	A	neg	1946
M 95	Ohio	Minn T.H. 53	A	neg	1946
M 96	Ohio	Minn T.H. 53	A	neg	1946
M 97	Carter	Minn T.H. 34	A	neg	1946
M 98	Carter	Minn T.H. 34	A	neg	1946

TABLE 11 (Cont.)

Sample No.	Source of Asphalt	Location of Test Sample	Classification 15% Xylene-85% Skelly S.	Spot Test Category	Date of Const.
M 99	Carter	Minn T.H. 34	A	neg	1946
M100	Carter	Minn T.H. 34	A	neg	1946
M101	Husky	Minn T.H. 32	A	neg	1951
M102	Husky	Minn T.H. 32	A	neg	1951
M103	Carter	Minn T.H. 10	A	neg	1951
M104	Carter	Minn T.H. 10	A	neg	1951
M105	Carter	Minn T.H. 10	A	neg	1951
M106	Carter	Minn T.H. 10	A	neg	1951
M107	Texas	Minn T.H. 71	A	neg	1948
M108	Texas	Minn T.H. 71	A	neg	1948
M109	Saunders	Minn T.H. 75	A	neg	1951
M110	Saunders	Minn T.H. 75	A	neg	1951
M111	Saunders	Minn T.H. 75	A	neg	1951
M112	Saunders	Minn T.H. 75	A	neg	1951
M113	S.O. Co.	Minn T.H. 5	B	sl. pos	1948
M114	S.O. Co.	Minn T.H. 5	A	neg	1948
M115	Husky	Minn T.H. 13	B	sl. pos	1947
M116	Husky	Minn T.H. 13	A	neg	1947
M117	S.O. Oil	Minn T.H. 42	C	pos	1951
M118	S.O. Oil	Minn.T.H. 42	B	sl. pos	1951
M119	Husky	Minn T.H. 13	A	neg	1947
M120	Husky	Minneapolis	A	neg	1946
M121	Husky	Minneapolis	A	neg	1946
M122	Husky	Minneapolis	A	neg	1952
M123	Husky	Minneapolis	A	neg	1952
M124	Husky	Minneapolis	A	neg	1948
M125	Husky	Minneapolis	A	neg	1948
M126	Husky	Minneapolis	A	neg	1949
M127	Husky	Minneapolis	A	neg	1949
M128	Husky	Minneapolis	A	neg	1950
M129	Husky	Minneapolis	A	neg	1950
M300	Am. Lib.	Marine City	A	neg	1950
M301	Am. Lib.	Marine City	A	neg	1950
M302	Am. Lib.	US-23	A	neg	1952
M303	Am. Lib.	US-23	A	neg	1952
M304	Asph. Prod.	US-23	A	neg	1952
M305	Asph. Prod.	US-23	A	neg	1952
M306	Lion	M66, McBain	A	neg	1952
M307	Lion	M66, McBain	A	neg	1952
M308	Asph. Prod.	US-10, Baldwin	A	neg	1949

TABLE 11 (Concl.)

Sample No.	Source of Asphalt	Location of Test Sample	Classification 15% Xylene-85% Skelly S	Spot Test Category	Date of Const.
M309	Asph. Prod.	US-10, Baldwin	A	neg	1949
M310	Asph. Prod.	M20, E. Remus	A	neg	1949
M311	Asph. Prod.	M20, E. Remus	A	neg	1949
M312	Asph. Prod.	M20, E. Remus	A	neg	1949
M313	Asph. Prod.	M20, E. Remus	A	neg	1949
M314	Asph. Prod.	M20, E. Remus	A	neg	1949
M315	Asph. Prod.	M20, E. Remus	A	neg	1949
M316	Lion	M62, Dowiagac	A	neg	1949
M317	Lion	M62, Dowiagac	A	neg	1949
M318	Am. Lib.	Sodus-EauClair	A	neg	1948
M319	Am. Lib.	Sodus-EauClair	A	neg	1948
M320	Am. Lib.	Sodus-EauClair	A	neg	1948
M321	Am. Lib.	Sodus-EauClair	A	neg	1948
M322	Lion	M50, Charlotte	A	neg	1949
M323	Lion	M50, Charlotte	A	neg	1949
M324	Am. Lib.	M47, Perry	A	neg	1952
M325	Am. Lib.	M47, Perry	A	neg	1952
M326	Lion-Std.	Liberty Rd	A	neg	1950
M327	Lion-Std.	Liberty Rd	A	neg	1950
M328	Lion-Std.	Liberty Rd	A	neg	1950
M318a	Lion	Sodus-EauClair	A	neg	1949
M319a	Lion	Sodus-EauClair	A	neg	1949
M320a	Lion	Sodus-EauClair	A	neg	1949
M321a	Lion	Sodus-EauClair	A	neg	1949

CONCLUSIONS

A tremendous amount of data has been assembled from the field inspection, laboratory tests of pavement samples, and records of cooperating highway organizations. From the field studies and analyses, certain conclusions can be drawn, some definite and others of a tentative nature.

1. Hot-mixed asphalt pavements using Wyoming asphalt are giving satisfactory service under a wide range of traffic and climatic conditions. Service life of such pavements at the time of inspection was up to eight years, except for the streets in McCook, Nebraska, where they were giving satisfactory service after twenty-eight years.

2. Most of the recovered asphalts from construction inspected outside of Michigan were heterogeneous in the sense that positive spots resulted from the Oliensis test with Skelly S. No definitely positive results were obtained on any asphalt from Michigan construction except the Experimental Test Road of 1954. No difference in pavement behavior could be correlated with spot test characteristics.

3. The factors of mixture design, gradation, absorption, etc., of the aggregates, conditions of mixing and placing, sub-grade support, drainage, and climatic conditions affect the service behavior of the asphalt. For instance, high voidage in the mixture and an excessive flexibility of the pavement structure unnecessarily expose films of asphalt to weathering agencies.

4. Asphalts of high original penetration within a rather short time revert to the commonly used construction grades with apparently a large part of the hardening occurring during the mixing and laying process. The properties of the asphalt itself and the characteristics of the pavement structure should be such as to minimize further changes in the asphalt.

5. From the collected data it is not possible to correlate sources of crude or refining processes with pavement behavior. Limited information was available concerning sources and refining processes. The only indications of such correlations which were observed in this survey were in connection with the pavements containing Frontier asphalt, where marked surface oiliness occurred under extremely hot weather conditions in mixtures which contained excessive percentages of asphalt.

6. The investigation was handicapped by the lack of detailed authoritative information concerning the asphalts received and the conditions of use and service. In the rush of construction seasons and with the customary lack of funds for long-term investigations, highway departments have generally failed to derive all available information from their many years of construction, which might have contributed to the development of significant information with respect to asphalt properties. It is felt, also, that many producing companies too often have been satisfied with merely furnishing asphalts which conform to specifications which definitely are subject to improvement. Producers, also should be vitally concerned with the development of requirements which will insure high quality and so contribute to the construction of economical pavements.

7. Among the most significant properties are those which resist excessive hardening and loss of cohesion and flexibility. Accelerated exposure tests supplemented by some measure of property changes, such as the softening-point penetration ratio, accompanied by studies of the physical constitution of asphalts and by constant correlation with service performance, seem to offer the most promising approach to the definition and measurement of the properties necessary in a satisfactory paving asphalt.

TEST AND COMPUTATION PROCEDURES AND DEFINITION OF TERMS

This section will be devoted to the presentation and explanation of methods employed for the purpose of preparing and interpreting the test data presented in the following appendices. Where established or standard tests have been used, no explanation will be made.

For more convenient reference, the several operations have been assigned an identification number.

1. Maximum theoretical specific gravity—Determined by the Michigan State Highway Department method, using a special volumetric flash with trichloroethylene as the liquid medium.

2. The actual or apparent specific gravity of the paving—Determined by the water displacement method.

3. Unit weight of paving in pounds per cubic foot—Determined by multiplying the actual specific gravity by 62.4

4. Determination of voids in paving— $\frac{\text{theor. s.g. -act. s.g. (100)}}{\text{theor. s.g.}}$

5. Determination of voids in paving filled with asphalt—

$$\frac{\text{(act. s.g. pvg)(\% asphalt in pvg.)}}{\text{(\% voids in pvg.)(s.g. asphalt) + (act. s.g. pvg)(\% asphalt in pvg)}}$$

6. Total voids in mineral aggregate— $\frac{\text{(voids in pvg from No. 4)}}{\text{1 - (total voids filled with ac)}}$

7. Unit weight of aggregate in paving— $U_a = \frac{U_t(100 - W_b)}{100}$

Where:

U_t = unit weight of total mix in lb/cu ft
W_b = % asphalt by weight of mix.

8. Percent of solids in mix— $S_t = 100\ G_m/G_t$.

Where

G_m = actual specific gravity of paving sample,
G_t = theoretical specific gravity of paving mixture.

9. Percent of voids in total mix— $V_t = 100 - S_t$

Where

V_t = % voids in total mix.
S_t = % solids in mix as found from No. 8.

10. Percent by volume of asphalt in paving mixture— $S_b = \frac{G_m \times W_b}{G_b}$

Where:

G_m = actual specific gravity of paving,
W_b = % asphalt by weight of mixture,
G_b = specific gravity of asphalt.

11. Percent of solids in aggregate only— $S_a = S_t - S_b$

Where:

S_t = % solids in total mixture,
S_b = % by volume of asphalt in mixture.

12. Percent of voids in aggregate only— $V_a = 100 - S_a$

Where:

V_a = % voids in aggregate only,
S_a = % solids in aggregate only from No. 11.

13. Percent of voids filled with asphalt— $V_f = S_b/V_a \times 100$.

Where:

V_f = % voids filled with asphalt.
S_b = % by volume of asphalt in mixture.
V_a = % voids in aggregate only.

14. Fineness modulus of aggregate—This has been included to provide an index of the composition of the aggregate and for future application in the determinating of the load transfer potential of the aggregate and bituminous mixture in other successive investigations. Values shown in this report were obtained as follows:

Sieve Series	Retained Each Sieve.
1-1/2"	---
3/4"	---
3/8"	---
No. 4	---
No. 8	---
No. 16	---
No. 30	---
No. 50	---
No. 100	---
No. 200	---
Sum of ret'd	

The sum of the retained percentages on each sieve divided by 100 is taken to represent the fineness modulus of the material. Larger values indicate the coarser, and lesser values the finer mixture.

15. The asphalt-void relationship in a given mixture may be expressed in terms of percent by weight of the asphalt. In many instances, due to the common practice of expressing asphalt as a percentage by weight of mixture, this relationship is more readily understood and requires somewhat less computation.

Using the V_a (from No. 12) and S_a (from No. 11) and further assuming that the voids in the mineral aggregate (V_a) are completely filled with asphalt, then the sum of V_a and S_a times their individual specific gravities, will equal the weight of their combined mass.

Through this relationship:

$$\frac{V_a\text{-considered as filled with a.c. x the s.g. of the a.c.}}{\text{weight of the mass}} =$$

the percentage of asphalt by weight required to completely fill the voids in the aggregate.

Throughout the appendices to this report, tables have been employed to present the test data. The tabular values are identified by a descriptive notation which appears in the column headed by "Control Items" located on the left side of the table. Most of these notations are self-explanatory and conventional. Those which are not common will be explained below:

Location of sample: Designates the point in the paving from which the ERI test specimen was obtained. This information usually appears in the column containing the ERI "M" number which has been assigned to the paving sample for identification. For example, Edge E. Bnd, or OWP E. Bnd., locates the sample as having been taken from the edge of the east bound traffic lane or the outer wheel path, respectively. Similar abbreviations have been used, such as N.S., and W. for lane traffic direction and OWP, IWP, mid. or bet. W.P. for outer, inner, and between wheel paths respectively.

Identification of recovered asphalt: All values preceded by the capital letter (R) designate recovered material, irrespective of source of information.

Ash in recovered asphalt: Values so designated have no counterpart in state highway or refinery test data. It has been used as a control factor by the Michigan State Highway Department. Their experience has indicated that the presence of fines or dust above 3% in the asphalt extracted from the mixture and recovered by the modified Abson recovery test, will tend to produce erroneous results.

APPENDIX NO. 1

STATE OF WYOMING

ASPHALTIC CONCRETE PAVING

FIELD INSPECTION REPORT

State of Wyoming Project FI 219(3)
U.S. Route 30. Granger Junction to 10 Miles West of Green River
(Picture Reference—No. 1)

The asphaltic concrete on this project was constructed in 1948. Asphalt was supplied by the Sinclair Oil Company, Rawlins, Wyoming, and was 120-150 penetration grade. The paving was laid to a width of 30 ft and an average thickness of 2 in. The gravel-base course consisted of 1-in.-maximum size gravel, having a thickness of 1-1/2 in. at the center and 3 in. at the edge. This selected material was placed over a gravel sub-base containing 2-in.-maximum size pit run material and having a depth of from 7-1/2 in. to 8 in. The central 24 ft of the paving was sealed by an application of RC 2 cutback with No-strip additive, applied at the rate of 0.3 gal/sq yd. Throughout the project the edges of the paving extend above the abutting gravel shoulder for the full paving thickness.

There are no detailed construction records in the files of the Wyoming Highway Department relative to this project. Such information as was obtainable was assembled from fragmentary laboratory records and is unreliable. For that reason, although the paving inspection was made at 0.5-mile intervals, the results of the survey will be summarized.

Throughout the length of the project the seal-coat application obscured the asphaltic concrete surface except for a 3-ft width at each edge. This was the original seal coat applied in 1948 and was in excellent condition.

Paving edge cracking, extending inward for a distance of from 4 in. to 12 in., occurred at random intervals throughout the project. This condition apparently had not been caused by traffic action, as the outer wheel paths in both lanes were well defined at a distance of between 2.5 to 3 ft from each edge. It was apparent that the coincidence of the wheel paths and the outer edge of the seal coat application was caused by the use of the sharply defined difference in color between the seal coat and the untreated outer edges as a traffic guide, especially in night driving. These cracked edges appeared to have been caused by the combined effects of the seepage of snow melt water into the supporting subgrade, apparent inadequate initial compaction, and subsequent drying out of the mixture.

Throughout the project there was a consistent occurrence of variably spaced transverse and random longitudinal cracking. No appreciable vertical displacement or raveling at the cracked edges was observed. Such conditions were apparently due to subgrade settlement or base and subgrade consolidation.

There was no evidence of shoving, traffic corrugations, measurable rutting in wheel paths, flushing, raveling, stripping, or pitting over the sealed or unsealed surface.

The condition of the paving surface, due to the absence of surface irregularities, is adequate for the high-speed passenger car and heavy truck traffic which it is carrying. The riding qualities are excellent. The records of the District Engineer, District No. 3, at Rock Springs, Wyoming, indicate that the maintenance work performed during the service life of this paving has been negligible.

PAVING MATERIAL TEST DATA

State of Wyoming Project FI 219(3)
U. S. Route 30. Granger Junction to 10 Miles West of Green River
Asphaltic Concrete Surface on Gravel Base and Sub-base
120-150 Pen. Asphalt-Sinclair Refining Company, Rawlins, Wyoming

INTRODUCTION

This project was constructed in 1948. The data as obtainable consisted of the compilation of project averages and fragmentary information remaining in the office of the District Engineer at Rock Springs, Wyoming. As presented in Table 1, they are indicative rather than representative.

The typical road section and the composition of the paving structure are approximately as follows:

RC-3 seal applied at the rate of 0.3 gal/sq yd, with 1% No-strip additive
17 lb of 1/2-in.-maximum size gravel chips, per sq yd
2-in. thickness of asphaltic concrete
Crushed gravel base—1-1/2-in. center and 3-in. edge thickness, maximum size—3/4 in.
Pit-run gravel base—2-in. maximum size, 7-1/2 to 8 in. thick
Asphalt content—average for job—5.48%, 120-150 penetration

The paving, located on U.S. Route 30, carries the highest volume and concentration of traffic in the State of Wyoming. In addition to movement of passenger cars, the commercial trucking and bus traffic is considerable.

PRESENTATION OF TEST DATA

Reference is made to the tabulated test data presented in Table 1 of this appendix. As only average data was available from state records, comprehensive comparison of test results with the specific samples as obtained by the project laboratory is not significant.

In general, the gradation of the aggregate obtained from the samples compares favorably with the state average. The asphalt content as extracted from the composite sample of the cracked edges is 0.68% below the average value of 5.48%. In contrast, the samples from the paving under traffic, obtained from Westvaco Junction, contained 0.72% more asphalt than the average.

The test data on the original asphalt, obtained by averaging a limited number of available Sinclair certified analyses, is presented for comparison with tests made on the asphalt extracted from the three paving samples.

DISCUSSION OF TEST DATA

The contrast between composite sample M27, obtained from the cracked outer edges throughout the length of the project, and samples M35 and M36 from Westvaco Junction, is interesting.

To facilitate discussion these data are tabulated below:

Control Items	Wyoming Data	Sample M27	Sample M35	Sample M36	
Specific gravity of aggregate		2.511	2.530	2.470	(a)
Density of agg.-lb/ft^3		124.40	129.61	130.30	(b)
Voids in min. agg.-%		20.66	17.89	19.56	(c)
Voids filled with a.c.-%		47.71	70.10	69.10	(d)
Asphalt by volume-%		9.86	12.46	13.52	(d)
Solids in mixture-%		89.20	94.57	93.96	(c)
Solids in aggregate-%		79.34	82.11	80.44	(c)
Theor. max s.g. of paving		2.348	2.340	2.367	(e)
Actual s.g. of paving		2.093	2.213	2.224	(e)

Control Items	Wyoming Data	Sample M27	Sample M35	Sample M36	
Paving density - lb/ft^3		130.60	138.20	138.80	(e)
Voids in paving - %		10.80	5.43	6.04	(e)
Orig. pen. of asphalt	134	R-25	R-40	R-44	(f)
Flash pt. C.O.C. - °F	440				
Ductility - 77°F - cm	100+	R-31	R-150+	R-150+	(f)
Loss on heating - %	0.235				
Pen. after l. on h.	95.6				
Spot test - 15% xylene naphtha	neg	R-pos	R-pos	R-pos	
Ring and ball - soft. pt. - °F		R-133.9	R-124.5	R-124.2	(f)
Ash in rcvd. asph.		R-0.98	R-1.02	R-0.53	
Finess modulus of agg.	5.82	5.19	5.15	5.17	(a)

With no other considerations than the items shown in the above table, it is possible to demonstrate that the condition of the paving comprising sample M27, obtained from the cracked edges, is principally due to the lack of initial compaction. The small letters in parentheses at the right of the table refer to the following comments:

(a) The relatively narrow range in the specific gravity and fineness modulus indicates a relatively uniform aggregate.

(b) The low density of the aggregate in M27 as compared with M35 and M36 indicates the lower degree of compaction of the mixture along the edges of the paving.

(c) The voids in the mineral aggregate in M27, while markedly more than for
and M35, are only 1.1% more than for M36. The voids filled with asphalt and
(d) the asphalt content by volume are much less in M27 than in both M35 and M36, and indicate the open paving structure existing in M27.

(e) The actual specific gravity and paving density values referred to maximum theoretical specific gravity of the paving support the foregoing hypothesis and disclose in general terms the inadequacy of initial or subsequent compactive effort.

(f) The marked decrease in the penetration of the asphalt recovered from sample M27 (18.65% of original) as compared with M35 (29.85%) and M36 (32.85%), coupled with the variance in the softening points (133.9°F, 124.5°F, and 124.2°F for M27, M35, and M36, respectively) indicate the pronounced effect of the structural composition of the paving itself upon the behavior of the contained asphalt.

The comparative test values for the original and recovered asphalt are tabulated below.

PROPERTIES OF ASPHALT—ORIGINAL AND RECOVERED

ERI No.	Sample Location	Orig Asphalt*		Recovered Asphalt		% Change		Ratio ERI
		pen	s.pt	pen	s.pt	pen	s.pt	s.pt/pen
M27	Composite failed edge	134		25	134	-81.3		5.360
M35	North edge Westvaco	134		40	125	-70.1		3.125
M36	OWP Westvaco	134		44	124	-67.2		2.818

*Highway Department averages.

State of Wyoming, Project 220(3)
U.S. Route 87, from 6 Miles North of Casper to a Point 16.85 Miles North to the Junction with Project 220(7)
(Picture Reference—No. 6, 7, 9)

The asphaltic concrete paving on this project was constructed in 1948. Asphalt was supplied by the Texas Company, Casper, Wyoming, and was 120-150 penetration grade. The paving was laid to a width of 24 ft and an average thickness of 2-1/2 in. Upon completion of the asphaltic concrete the paving surface was sealed with an application of RC-2, applied at the rate of 0.3 gal/sq yd and covered with stone chips, for the full width.

A detailed inspection of the paving surface was made at each half-mile interval and at locations where there was evidence of paving irregularities. General conditions will be summarized and, for specific locations where failures had occurred, a detailed description of the conditions will be presented.

Throughout the length of the project the appearance of the stone-chip-sealed surface was excellent. Transverse and longitudinal cracking had occurred at fairly wide intervals, which appeared to be due largely to fill settlement, combined with some possible consolidation of the base and subgrade. There was no indication of loss of cohesion in the mixture, which was examined at each half-mile interval by picking into the surface and examining the material removed. The asphalt was invariably rich black in color, had coated the particles very well, and the mixture was live and tacky under air temperatures of between 80 and 85°F.

Two specific locations in this project showed marked distress, apparently due to conditions produced by inadequate snow removal. The most

extensive area occurred between 1.7 and 2 miles from the start of the project. This location was in a cut section from which the gravel aggregate used in the asphaltic concrete had been obtained, and is the site of the Fairbanks pit. This cut section, located at the top of a ridge, was provided with shallow ditches. There is inadequate area between the edges of the paved roadway and the backslope for the storage of the snow removed from the highway during winter maintenance operations. A considerable amount of the accumulated snow had to be stored upon the shoulders, and the snow melt water percolated beneath the paving surface. Freezing and frost damage ensued, with the result that for a distance of approximately 1000 ft, there is extensive map cracking, some serious rutting, broken paving, and evidence of extensive resurfacing operations. A typical location is shown in picture no. 9. This condition extends over the full width of the paving. An examination of the mixture in this failed area indicates that the asphalt is live and tacky, even in the smaller broken fragments, and that the cause of the difficulty can be attributed only to subgrade failure due to the presence of excess moisture.

Another location, exhibiting similar paving condition, but much less extensive in area, is in the northbound traffic lane, on the inside of a curve at mile 14.0 from the start of the project. This map-cracked area is approximately 4 ft in width and 15 ft in length. Samples of the broken paving taken from this trouble zone indicate that the paving thickness was only 1.5 in., instead of the customary 2-1/2 in. As in the more extensive failed area described above, there is inadequate ditching to handle the snow bladed from the highway during winter maintenance operations. It is apparent that the melting snow, stored on the abutting shoulders, has created a saturated and unstable subgrade and base condition.

PAVING MATERIAL TEST DATA

State of Wyoming Project 220(3)
U.S. Route 87. From 6 Miles North of Casper City Limits a Distance of 16.850 Miles North to the Junction with Project 220(7)
Asphaltic Concrete Surface on Gravel Base and Sub-base
120-150 Pen. Asphalt—The Texas Company, Casper, Wyoming

INTRODUCTION

This project was constructed in 1948. Only portions of the detailed construction and laboratory records remain in the files of the State Highway Department, and a comprehensive comparison between initial construction and present paving cannot be made.

The typical road section and the composition of the paving are approximately as follows:

Pavement width, 24 ft
RC-2 seal applied at the rate of 0.3 gal/sq yd
17 lb of 1/2-maximum size stone chips per sq yd
2-1/2-in. thickness of asphaltic concrete
Pit-run gravel base of varying thickness
Asphalt content ranges from 4.2% to 5.6% by weight of mixture

The paving carries relatively light traffic, according to annual records, but has been subjected to intensive and heavy traffic since placed in service, due to the activity in the oil fields to which it provides access from Casper, Wyoming. Maintenance records and the present appearance of the paving indicate that it has required little repair. Local failures can be definitely attributed to lack of subgrade support, and have occurred only in cuts, where the inability to remove melting snow from the paved area has produced saturated conditions in the base and subgrade, with attendant detrimental frost action. The riding properties of the existing surface are extremely good. There is no appreciable rutting, shoving, or raveling except in the sections where subgrade failures have occurred.

PRESENTATION OF TEST DATA

Reference is made to the tabulated test data presented in this appendix, Table 1.

DISCUSSION OF TEST DATA

The tabulated test data are presented in Table 1. There is considerable variation between the gradation of the aggregate obtained by ERI and the Highway Department records for the same general paving locations. The ERI tests show about 7% more retained on the No. 4 sieve, but about 6% less passing the No. 200 sieve than do the State Highway Department tests.

The properties of the aggregate and the mixture in the samples cannot be compared with the original material because of the absence of original data. However, pavement densities determined at the time of construction are available. ERI results indicate substantial increase in density in service. These comparisons are shown by tests on sample M-1, from a traffic lane, and to a lesser degree by sample M-2, taken from a relatively untravelled area.

The necessity for averaging the initial asphalt tests may have established test values which are not entirely valid for the location of

samples M1 and M2. However, there is reasonable agreement between the averaged properties of the supplied asphalt and that recovered from samples M1 and M2.

A summary of the penetration and softening point values is given below:

PROPERTIES OF ASPHALT—ORIGINAL AND RECOVERED

ERI No.	Sample Location	Orig Asphalt		Recovered Asphalt		% Change		Ratio ERI
		pen	s.pt	pen	s.pt	pen	s.pt	s.pt/pen
M1	Station 492 east edge	128		47	125	-63.3		2.659
M2	Station 492 on c/l	128		45	127	-64.8		2.822

FIELD INSPECTION REPORT

State of Wyoming Project 220(7)
U.S. Route 87, from a Point Approximately 22.85 Miles North of Casper, the North Terminus of Project 220(3), Northward for a Distance of 11.457 Miles to the Junction with the Succeeding Project 220(8)
(Picture Reference—No. 13,14)

The asphaltic concrete paving on this project was constructed in 1950. Asphalt was supplied by the Standard Oil Company, Casper, Wyoming, and was 120-150 penetration grade. The paving was laid to a width of 24 ft and an average thickness of 2 in. Upon completion of the asphaltic concrete the paving surface was sealed with RC-2 at the rate of approximately 0.2 gal/sq yd and covered with sand for the full width, at the rate of 15 lb/sq yd.

Complete coverage of the sand seal prevented direct inspection of the asphaltic concrete. This sand seal was composed of material containing numerous soft particles and, according to the reports from the maintenance personnel, was unevenly applied during construction. There was consistent evidence of pitting and abrasion of the seal throughout the project. Numerous areas had been replaced under maintenance operations. Throughout the project the examination of the underlying paving mixture, accomplished by removing numerous samples at random locations with a pick, indicated that the

mixture was rich black in color, live, and tacky. This condition was observed under rather low temperature conditions. The air temperatures ranged between 58 and 63°F. Rain and high winds were also experienced throughout the day.

The paving on this project had been subjected to heavy and extensive oil field traffic, producing concentrations considerably above that which would normally be expected. At distances of 6, 9, 10, 11, and 11.7 miles from the start of the project, there was a pronounced increase in raveling of the sand seal coat, with this condition extending into the asphaltic concrete in many instances. There were numerous areas of surface resealing, and locations where edge repairs were quite extensive. As the asphaltic concrete mixture was always found to be live and tacky, such conditions were apparently caused by inadequate base course and softening of the subgrade due to the seepage of snow melt water.

This section of the highway traversed more level country. The absence of pronounced cut-and-fill sections resulted in less transverse and longitudinal cracking of the paving surface than was observed on Project 220(3).

PAVING MATERIAL TEST DATA

State of Wyoming Project 220(7)
U.S. Route 87. From a Point Approximately 22.85 Miles North of Casper, the North Terminus of Project 220(3), Northward for a Distance of 11.457 Miles to the Junction with the Succeeding Project 220(8)
Asphaltic Concrete Surface on Gravel Base and Sub-base
120-150 Pen. Asphalt—Standard Oil Company, Casper, Wyoming

INTRODUCTION

This project was constructed in 1950. The State Highway Department aggregate grading records on the project are sufficiently complete to permit correlation with the areas from which pavement samples were taken. Data relative to the percentage of asphalt used were not available, and the average as previously obtained by the Highway Department was employed. There were no detailed test results on the asphalt, making it necessary to use the average of such limited information as was available.

DISCUSSION OF TEST DATA

There is considerable variation between the aggregate gradation in the paving reported by the Highway Department and the values obtained from

the analysis of the ERI samples. The original averaged Highway Department analysis reported approximately 8% less material retained on the No. 10 sieve and 6.8% more passing the No. 200 sieve. The asphalt content is in substantial agreement.

With respect to the asphalt, it is believed that the information relative to the original material is representative. Both the refinery and Highway Department tests have been reported. As the Standard Oil Company laboratory has included the softening point in their original data, their analysis is used for comparison and is included in the tabulated values shown below.

PROPERTIES OF ASPHALT—ORIGINAL AND RECOVERED

ERI No.	Sample Location	Orig Asphalt pen	Orig Asphalt s.pt	Recovered Asphalt pen	Recovered Asphalt s.pt	% Change pen	% Change s.pt	Ratio ERI s.pt/pen
M3	Station 1488 east edge	134	107	49	126	-63.4	+17.8	2.571
M4	Station 1488 on c/l	134	107	55	124	-59.0	+15.9	2.255

	Ratio Orig Asphalt s.pt/pen	Ratio ERI and Original Ratio
M3	0.799	2.571/0.799 = 3.218
M4	0.799	2.255/0.799 = 2.822

FIELD INSPECTION REPORT

State of Wyoming Project 220(8)
U.S. Route 87. From a Point Approximately 34.307 Miles North of Casper, the Northern terminus of Project 220(7), Northward for a Distance of 11.013 Miles to a Point 3.9 Miles Northwest of Midwest Wyoming, the End of the Project and the Junction with Continuing Road Mix Type Paving
(Picture Reference—No. 19,20)

The asphaltic concrete paving on this project was constructed in 1952. Asphalt was supplied by the Standard Oil Company, Casper, Wyoming, and was 120-150 penetration grade. The paving was laid to a width of 24 ft and an average thickness of 2 in. Upon completion, the paving received a seal-coat application of RC-3 at the rate of 0.2 gal/sq yd and was covered for the full width with sand applied at the approximate rate of 15 lb/sq yd.

On this project the aggregate for the asphaltic concrete was of inferior quality. It was obtained from a wayside location, the Bar-B pit, located approximately 1500 ft left of Station 2267+37, at the north end of the project. This material was taken from the banks and bed of a watercourse and consisted largely of sandstone particles, with a large percentage of soft shale and soapstone. Numerous preliminary field and laboratory tests had indicated its undesirable properties and it was employed for paving only when more acceptable material would have required a dead haul of more than 35 miles. The aggregate, in addition to being of fine gradation, possessed high absorptive properties and extremely high dust content, which was increased through the handling and drying operations. During paving operations the removal of excess fines became such a problem that the dust collector was removed entirely and the excessive amount of fines was discharged into the air. It has been estimated that the dust loss from the aggregate during processing and drying amounted to approximately 25% of the material handled.

The sand seal was obtained from the same source and the larger particles in both the mix and seal were heavily coated with a fine powdery material which was detrimental to satisfactory adhesion of the asphalt.

A general observation of the present condition of this paving may be used to sum up the accumulated difficulties that have developed. Within the two years of service the sand seal has become badly pitted, due to the crushing or disintegration of the larger soft particles and initial improper spreading. Most of the seal coat has been removed from the wheel paths by traffic and weathering action. The extensive deep pitting, extending into the asphaltic concrete, is further evidence of the poor quality of the aggregate in the mixture. Inspection of picked samples taken from the roadway indicate that the finer fraction or matrix material is quite well covered with asphalt, which is live and tacky. However, the larger particles of sandstone gravel usually show only a faint stain instead of adequate coverage by bitumen.

Prior to this inspection the highway officials had scheduled this paving for resurfacing together with that comprising Project 220(7). It was their expressed opinion that failure to resurface the existing paving, particularly on 220(8), would result in excessive breakup during the winter and spring of 1954-55.

PAVING MATERIAL TEST DATA

State of Wyoming Project 220(8)
U.S. Route 87. From a Point Approximately 34.307 Miles North of Casper, the Northern Terminus of Project 220(7), Northward for a Distance of 11.013

Miles to 3.9 Miles Northwest of Midwest Wyoming, the End of the Project and the Junction with Continuing Road Mix Type Paving
Asphaltic Concrete Surface on Gravel Base and Sub-base
120-150 Pen. Asphalt—Standard Oil Company, Casper, Wyoming

INTRODUCTION

The asphaltic concrete paving on this project was constructed in 1952. The present condition of the paving, which can be largely attributed to the unsatisfactory aggregate in the mixture as well as the seal-coat material, has been described in the Field Inspection Report.

The only information available from existing job records has been assembled in Table 1 of this appendix. There is relatively close agreement between the gradation of the aggregate in the original paving mixture and the samples, as well as the asphalt, in the respective mixtures.

DISCUSSION OF TEST DATA

The comparative properties of the aggregate in the mixture and the composition of the paving indicate that there has been considerable consolidation of the paving during the two years of service. As it has been quite well established that the present condition of the paving is due to the unsatisfactory physical properties of the aggregate, there will be no extensive discussion of the mineral component of the paving mixture.

Since it was possible to obtain definite test data on the asphalt used during the construction of the section of paving from which the samples were taken, that information will be employed for comparison with the recovered material. To facilitate presentation and discussion, these data will be assembled in the following table.

PROPERTIES OF ASPHALT—ORIGINAL AND RECOVERED

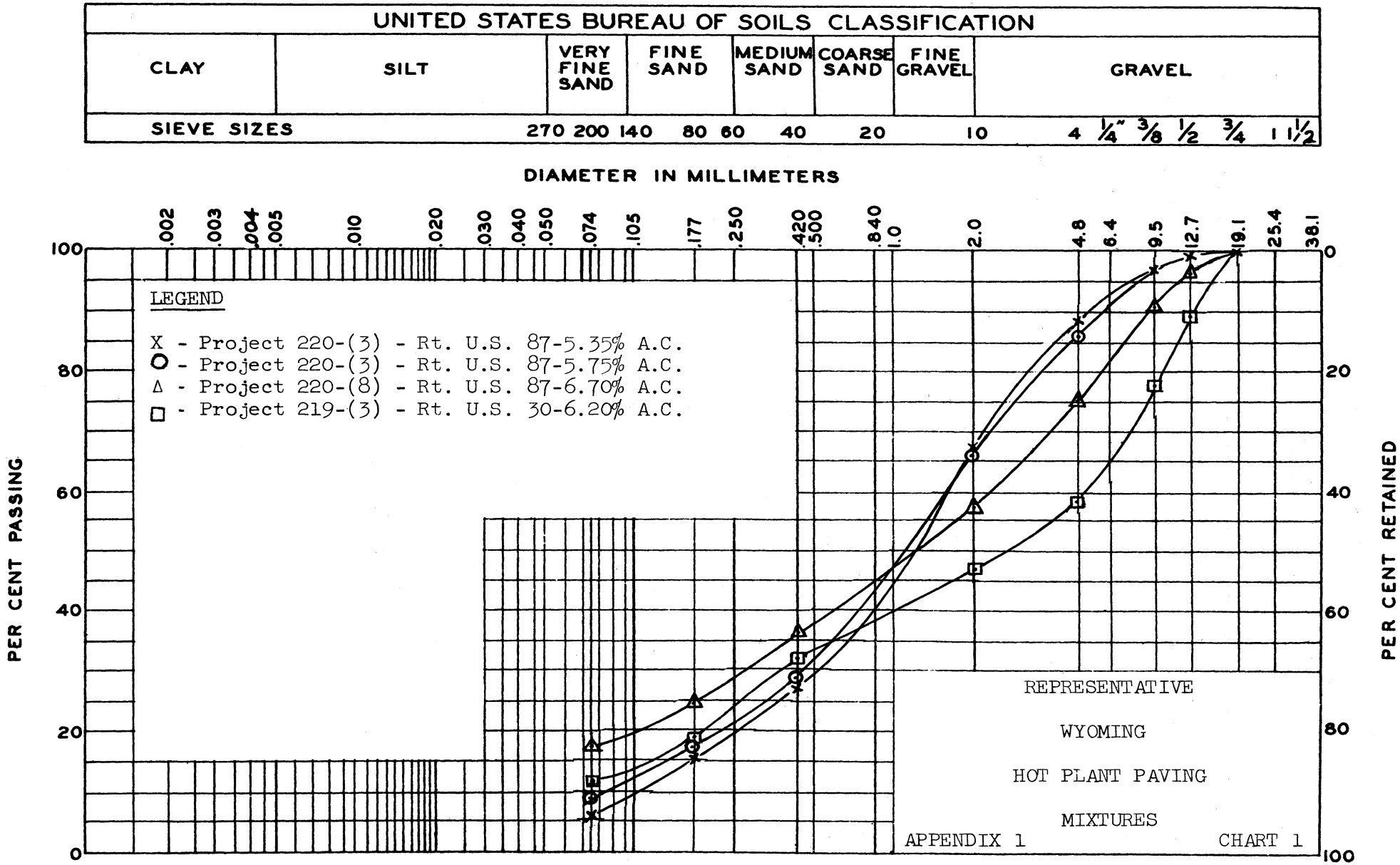
ERI No.	Sample Location	Orig Asphalt		Recovered Asphalt		% Change		Ratio ERI
		pen	s.pt	pen	s.pt	pen	s.pt	s.pt/pen
M5	Station 1940 east edge	132	106	62	120	-53.0	+13.21	1.935
M6	Station 1940 on c/l	132	106	60	122	-54.5	+15.09	2.033

	Ratio Orig Asphalt s.pt/pen	Ratio ERI and Original Ratio
M5	0.803	2.410
M6	0.803	2.532

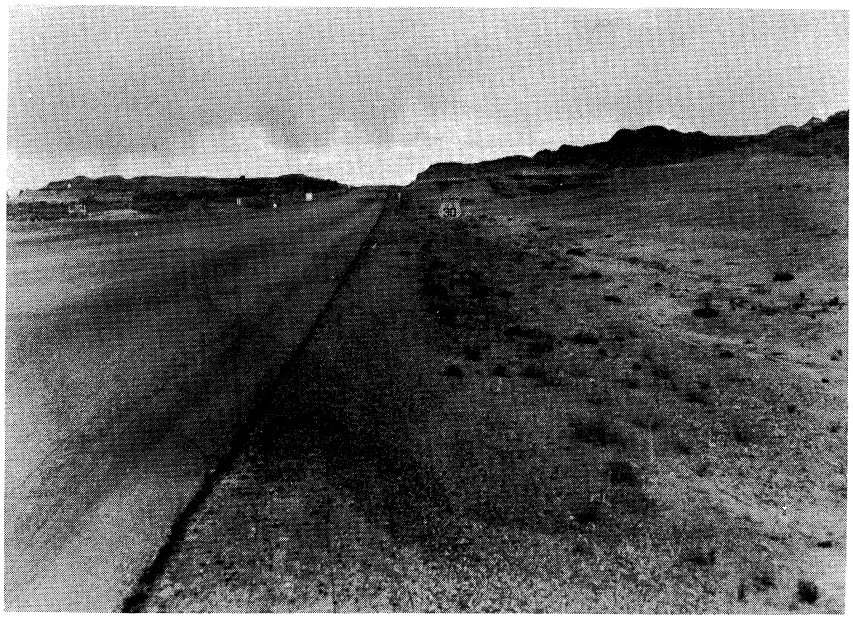
STATE OF WYOMING

SAMPLE INDEX

Sample No.	Date Constd	Asphalt Pen	Asphalt Source	Sample Obtained From
U.S. Route 30, Project 219(3). Granger Junction to 10 miles west of Green River:				
M27	1948	120-150	Sinclair	Composite made up of broken edge pieces over the length of the project.
M35	1948	120-150	Sinclair	Unsealed paving edge at Westvaco Junct.
M36	1948	120-150	Sinclair	Sealed OWP in westbound traffic lane at Westvaco Junction.
U.S. Route 87, Project 220(3). Casper north to Midwest, Wyoming:				
M1	1948	120-150	Texas Co.	East edge of northbound lane, 1 mile north of start of project.
M2	1948	120-150	Texas Co.	Center lane of paving, 1 mile north of start of project.
U.S. Route 87, Project 220(7). Casper north to Midwest, Wyoming:				
M3	1950	120-150	S.O. Co.	East edge of northbound lane, 3 miles north of start of project.
M4	1950	120-150	S.O. Co.	Center lane of paving, 3 miles north of start of project.
U.S. Route 87, Project 220(8). Casper north to Midwest, Wyoming:				
M5	1952	120-150	S.O. Co.	East edge of northbound lane, 2.5 miles north of start of project.
M6	1952	120-150	S.O. Co.	Center lane of paving, 2.5 miles north of start of project.

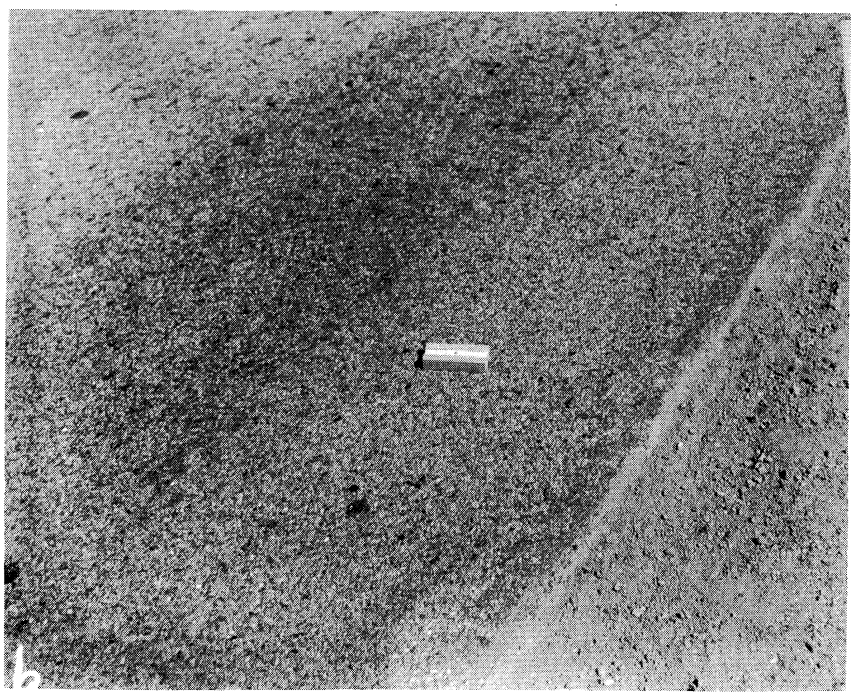

UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
PER CENT RETAINED
LEGEND
X - Project 220-(3) - Rt. U.S. 87-5.35% A.C.
O - Project 220-(3) - Rt. U.S. 87-5.75% A.C.
Δ - Project 220-(8) - Rt. U.S. 87-6.70% A.C.
□ - Project 219-(3) - Rt. U.S. 30-6.20% A.C.
REPRESENTATIVE
WYOMING
HOT PLANT PAVING
MIXTURES
APPENDIX 1
CHART 1

Project FI 219(3) - U.S. 30



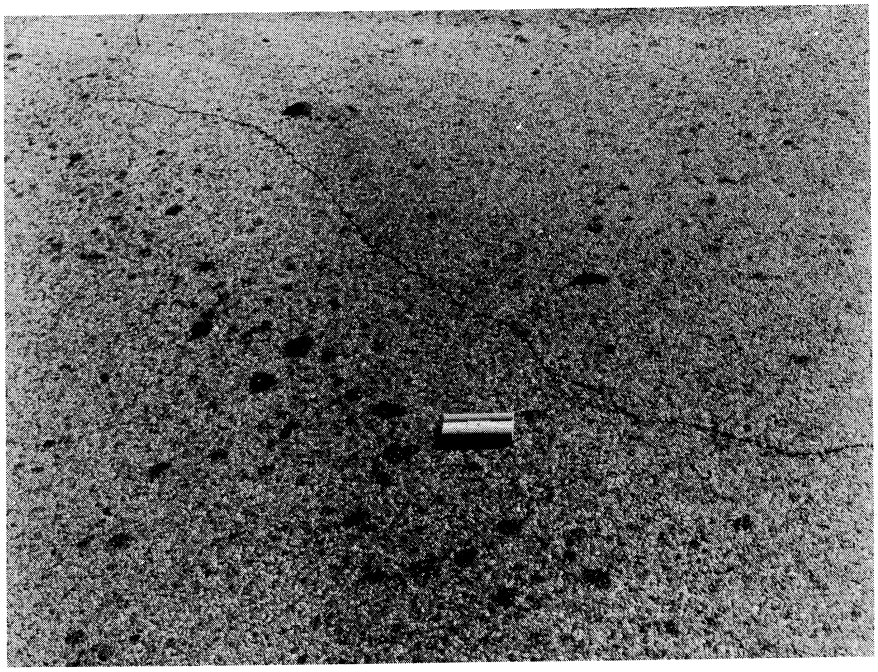
Picture 1. (1948) General view of Highway U.S. 30, eastward from Granger Junction, Wyoming.

Project 220(3) - U.S. 87



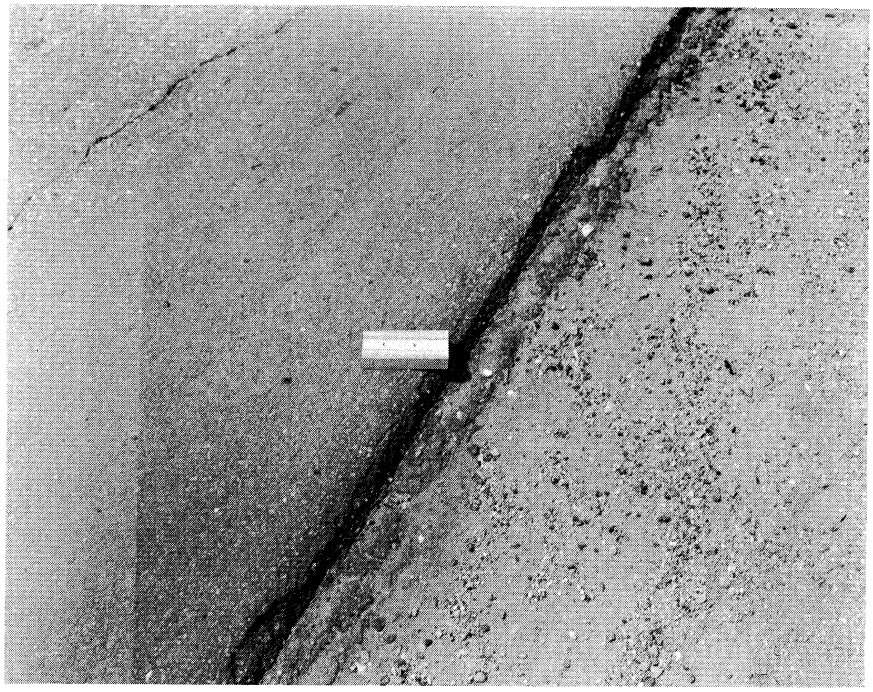
Picture 6. (1948) View of typical stone-chip-sealed texture paving surface covered full width with the seal coat.

NOTE: Dates shown in parentheses following picture numbers refer to the date of construction of highway surface. Picture numbers are not consecutive or in order.



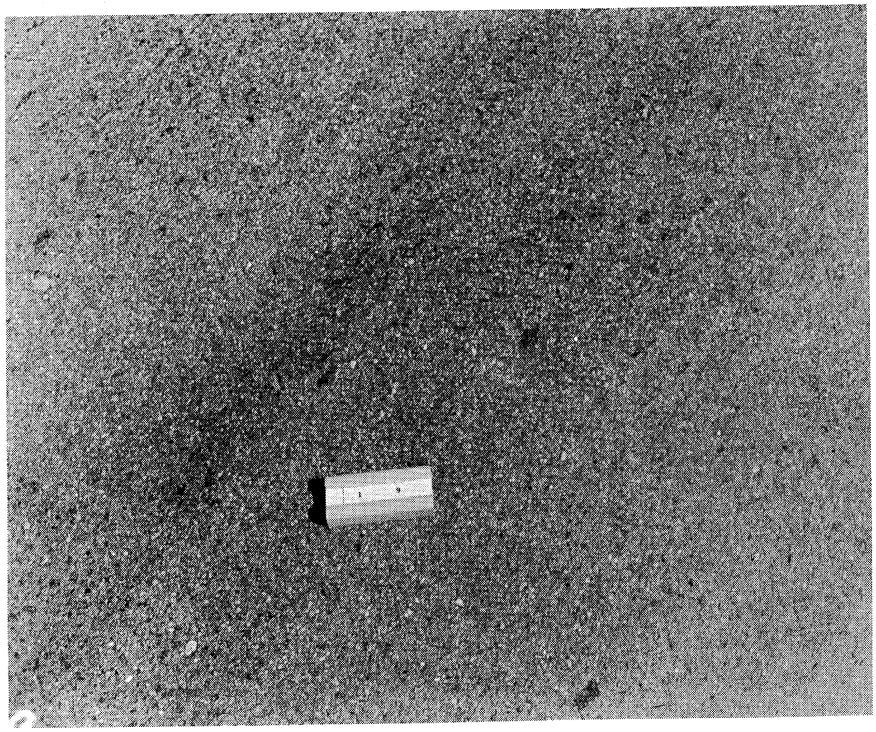
Picture 7. (1948) View showing typical longitudinal cracking which was present at random intervals throughout project. No spalling can be noted at crack edges.

Picture 9. View of map-cracked area in cut section. Portions of map-cracked surfacing have been displaced by traffic action. Maintenance personnel advised that melt water from snow had saturated the subgrade and was the primary cause of paving failure.

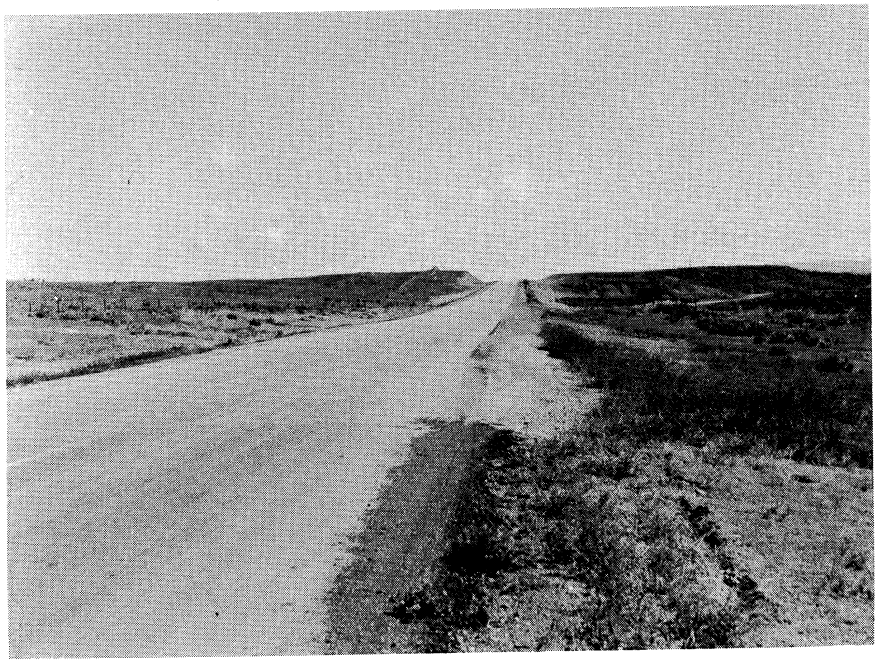


Picture 13. View of the exposed east edge of paving in northbound traffic lane and the fine texture of the sand-sealed surface.

Picture 14. Typical close-up view of the texture and surface pitting present in the sand-sealed surface.



Picture 19. View of typical fine-sand-sealed texture. Due to the use of soft sandstone and shale particles in the hot mixed aggregate and a silty sand for seal-coat material, extensive pitting of the asphalt concrete surface has resulted over the entire paved area of this project.



Picture 20. General view of roadway at the end of the project, looking northward toward Sheridan, Wyoming. The contrast in paving color between that in 220(8) and adjacent surface-sealed road mix is quite apparent.

APPENDIX NO. 2

CITY OF COLORADO SPRINGS, COLORADO

ASPHALTIC CONCRETE PAVING

CITY OF COLORADO SPRINGS, COLORADO

SAMPLE INDEX

Sample No.	Date Const'd	Asphalt Pen.	Asphalt Source	Sample Obtained From	
M7	1950	120-150	Ohio	Colorado Ave., between 15th and 16th Sts. on c/l	
M8	1950	120-150	Ohio	" " " " " " .,	traffic
M9	1952	120-150	Ohio	18th St., between Platte and Bijou Sts.,	traffic
M10	1952	120-150	Ohio	" " " " " " ,	parking
M11	1952	120-150	Ohio	30th St., between Boulder and St. Vrain,	parking
M12	1952	120-150	Ohio	" " " " " " ,	traffic
M13	1948	120-150	Ohio	Colorado St., between Wahsatch and Weber,	parking
M14	1948	120-150	Ohio	" " " " " " ,	traffic
M15	1948	120-150	Ohio	Vermijo St., between Weber and Nevada Sts.,	parking
M16	1948	120-150	Ohio	" " " " " " " .,	traffic
M17	1950	120-150	Ohio	Rio Grande St., between Weber and Nevada,	traffic
M18	1950	120-150	Ohio	" " " " " " " ,	parking
M19	1952	120-150	Ohio	Maple St., between Royer and El Paso Sts.,	traffic
M20	1952	120-150	Ohio	" " " " " " " .,	parking
M21	1950	120-150	Ohio	Weber St., between Fontanerro and Jefferson Sts. ----------	parking
M22	1950	120-150	Ohio	" " " "	traffic
M23	1950	120-150	Ohio	Jackson St., between Cascade and Tejon,	parking
M24	1950	120-150	Ohio	" " " " " " ,	traffic
M25	1952	120-150	Ohio	Paseo St., between Constitution and Van Buren Sts., ----------	parking
M26	1952	120-150	Ohio	" " " "	traffic

FIELD INSPECTION REPORT

City of Colorado Springs, Colorado

INTRODUCTION

The paving inspected and sampled was constructed between 1948 and 1952, so it was possible to evaluate the service behavior of the asphalt over a period of 6 years. All of the asphalt was supplied by the Ohio Oil Company and was 120-150 penetration grade. Considerable difference in the aggregate used during successive years had the effect of changing the composition and texture of the paving. All mixtures were processed in a Madsen 3000-lb-capacity batching plant and the control appeared to be satisfactory, as evidenced by the uniform paving thickness, texture, color, and service behavior.

There were no marked irregularities in the service behavior of the paving on any of the areas, with the exception of Colorado Avenue, which is City Route U. S. 24, and carries extensive traffic westward from Colorado Springs. (Spot checks indicate a traffic intensity of between 11,000 and 12,000 vehicles per day of all categories, in both directions.)

The uniform appearance and satisfactory conditions of paving on all other streets are shown by the photographs which are identified and described in the accompanying Picture Index. For that reason, those satisfactory sections will not be discussed further. Special comment and attention will be directed to certain unsatisfactory conditions observed on Colorado Avenue.

COLORADO AVENUE (Picture Reference No. 54, 55, 56, 57)

This asphaltic concrete paving was constructed in 1950. The paving operation extended from the viaduct to the west city limits at Golden Lane, covering 27 city blocks, 60 ft in width, with the central 40 ft placed over old concrete paving and car tracks. The 10 ft widths on each edge were laid over old road mix made from gravel aggregate and SC oil. The total area paved was 91,740 sq yd.

Due to heavy traffic conditions the mixture contained the best available aggregate, consisting of 55% Cripple Creek breccia, 26% Dent pit gravel, 13% fines and filler from available mill tailings, and 6% asphalt by weight of mixture.

The inspection indicated satisfactory paving conditions throughout, with the exception of the area lying between 24th and 26th Streets, near the west end of the project. This is a business area bordered by shops and stores, and the paving is subjected to extensive diagonal parking on both sides of the central traffic lanes. In each parking space there are pronounced depressions caused by the wheels of standing vehicles. These depressions range from 2 to 3 inches in depth and are accompanied by shoving of the pavement both laterally and ahead of the vehicle wheel. The removal of sections of this displaced paving failed to indicate any material amount of gravel base or subgrade difficulty and it appeared that all movement occurred in the asphalt surfacing. The asphaltic concrete mixture in these displaced areas is extremely tacky and cohesive, and is similar to that found in the satisfactory sections along Colorado Avenue. There is also pronounced shoving and rutting of the paving at bus stops, but these conditions are not apparent elsewhere on Colorado Avenue. Such depressions at the bus stops vary in depth from 2 to 5 inches as measured from the top of the existing paving material. There is also a slight indication of transverse corrugations or rippling of the pavement in the traffic lanes and at such locations the paving appears to be considerably darker in color than elsewhere, indicating the tendency of the bituminous material to flush to the surface. It should be noted that the asphaltic concrete in the central traffic lanes was placed over old concrete paving, whereas the side parking lanes and bus stop areas were placed over old SC road mix. During the high temperatures prevailing at the time of this inspection there was a pronounced odor of oil commonly associated with such slow-curing material, and it appeared that there was a tendency toward migration of the more fluid bitumen from the base course into the asphaltic concrete. In common with the rest of the paving, cracking was not excessive and appeared to follow the pattern developed from the underlying old concrete paving.

PAVING MATERIAL TEST DATA

City of Colorado Springs, Colorado
Paving of Various City Streets Constructed 1948 to 1952
Asphaltic Concrete Over Various Types of Base
120-150 Pen. Asphalt-Ohio Oil Company, Lovell, Wyoming

INTRODUCTION

The city of Colorado Springs has used asphalt produced by the Ohio Oil Company at Lovell, Wyoming, since 1948. All mixtures have been prepared and laid by municipal forces: the city owns its paving plant. The specific streets included in this study were selected because they had not received any subsequent chip or seal coat. The paving, having been laid at two-year

intervals, permitted the progressive evaluation of the behavior of both paving and the contained asphalt.

PRESENTATION OF TEST DATA

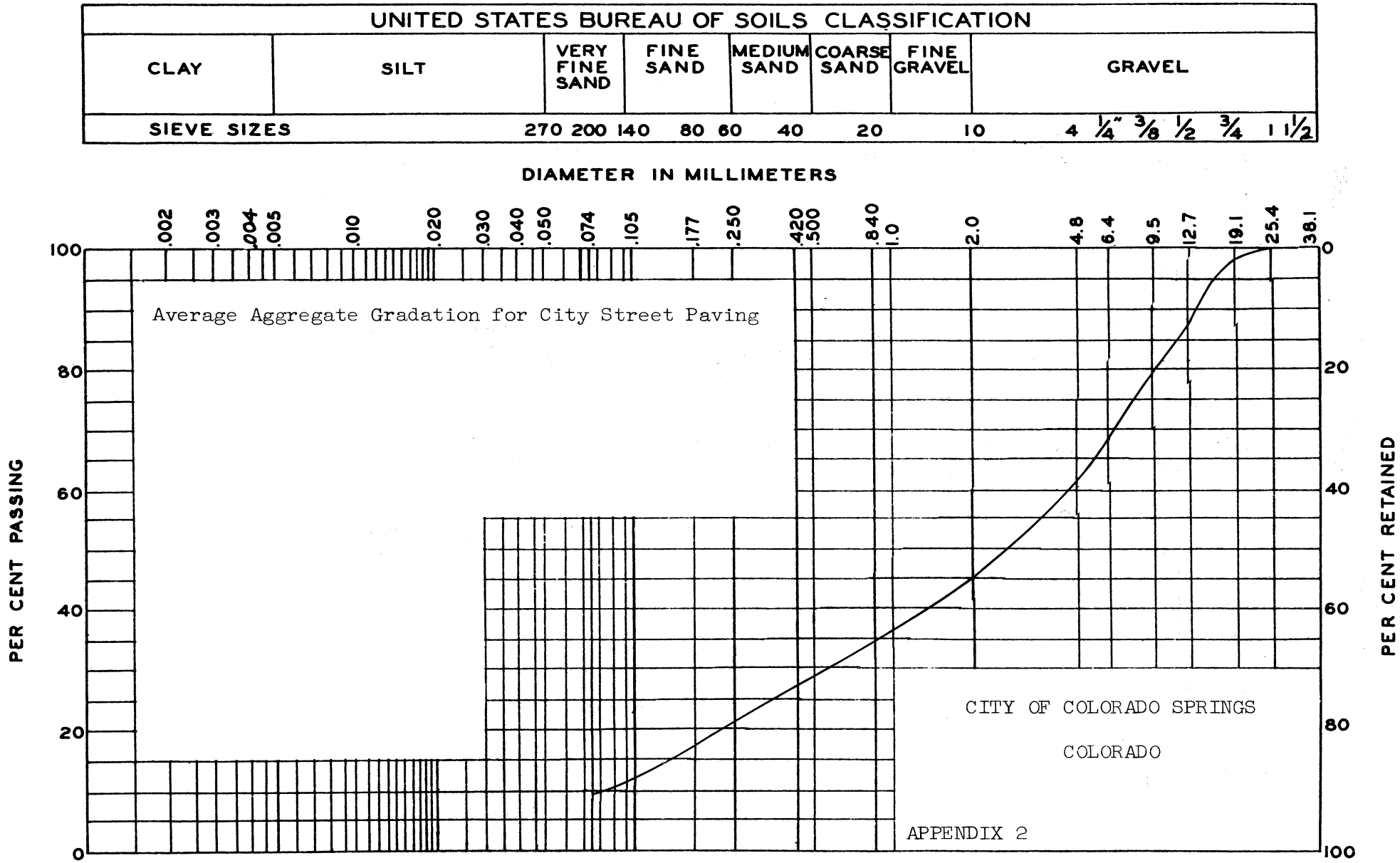
It was possible to obtain some data concerning the asphalt used in the original construction (except for 1948 paving) for comparison with the material recovered from the samples. The data for the 1948 construction was not available from either city or Ohio Oil company records in as complete detail as that for 1950 and 1952. The comparative test values will be presented in the following discussion.

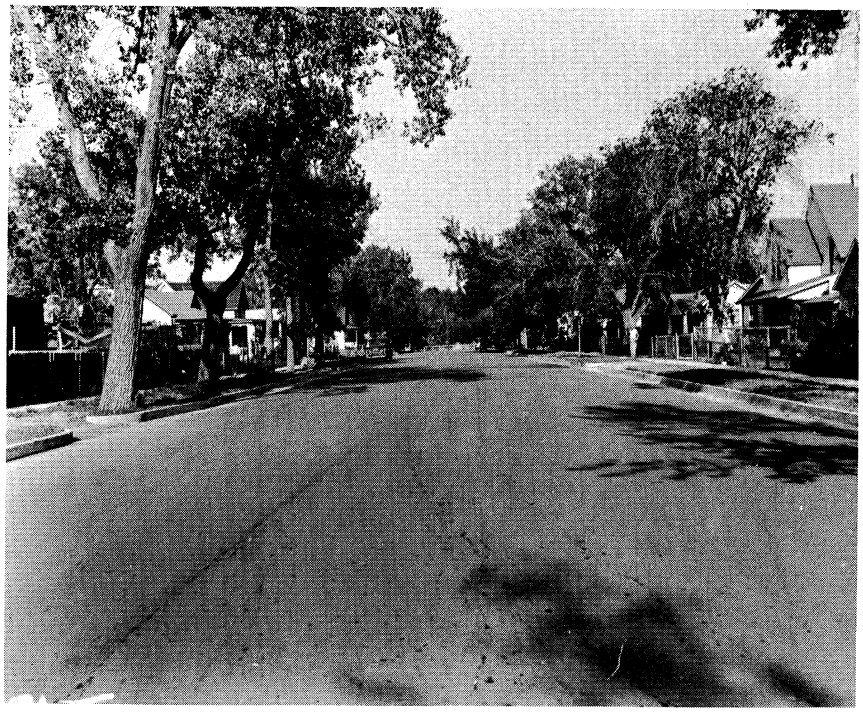
DISCUSSION OF TEST RESULTS

Summarized data concerning consistency and softening point are given in the following table. It should be mentioned that the ductility as reported on original asphalt and on that recovered from pavement samples was about 100 cm in all cases.

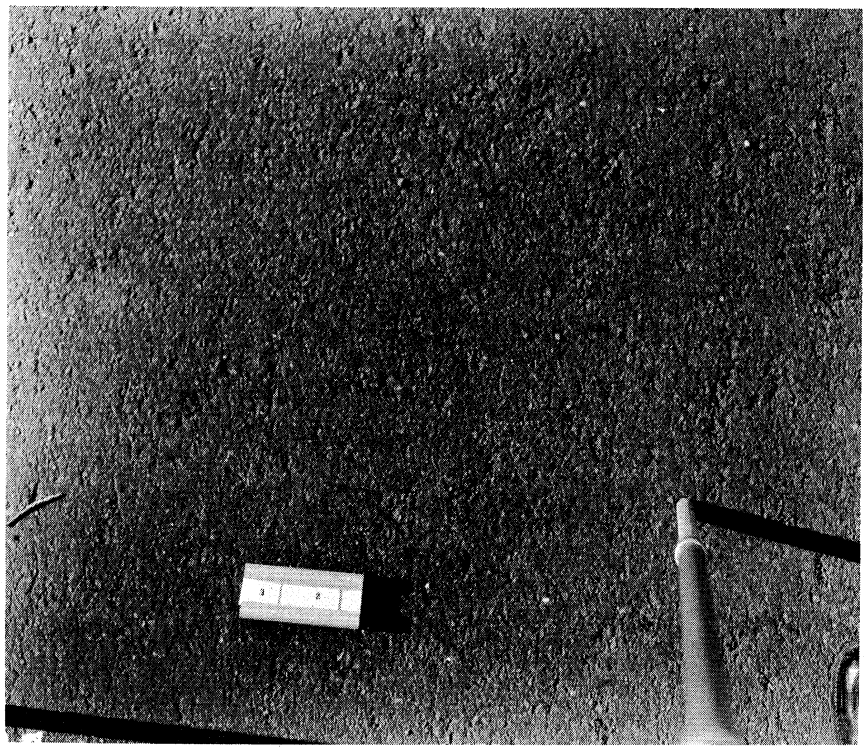
PROPERTIES OF ASPHALT--ORIGINAL AND RECOVERED

ERI No.	Orig Asphalt pen	Orig Asphalt s. pt	Rcvd Asphalt pen	Rcvd Asphalt s. pt	%Change pen	%Change s. pt	ERI s. pt/pen
1948 Construction:							
M15	132		28	139	-78.8		4.964
M16	132		34	135	-74.2		3.971
M13	132		48	128	-63.6		2.667
M14	132		37	134	-72.0		3.622
1950 Construction:							
M7	136		51	130	-62.5		2.549
M8	136		56	129	-58.8		2.304
M17	132		56	126	-57.6		2.250
M18	132		55	126	-58.3		2.291
M21	127		66	123	-48.0		1.864
M22	127		63	121	-50.4		1.921
M23	136		53	122	-61.0		2.302
M24	136		45	127	-66.9		2.282
1952 Construction:							
M11	133		72	122	-45.9		1.694
M12	133		77	118	-42.1		1.532
M9	139		63	124	-54.7		1.968
M10	139		69	124	-50.4		1.797
M19	130		55	125	-57.7		2.273
M20	130		79	120	-39.2		1.519
M25	130		61	119	-53.1		1.951
M26	130		65	120	-50.0		1.846

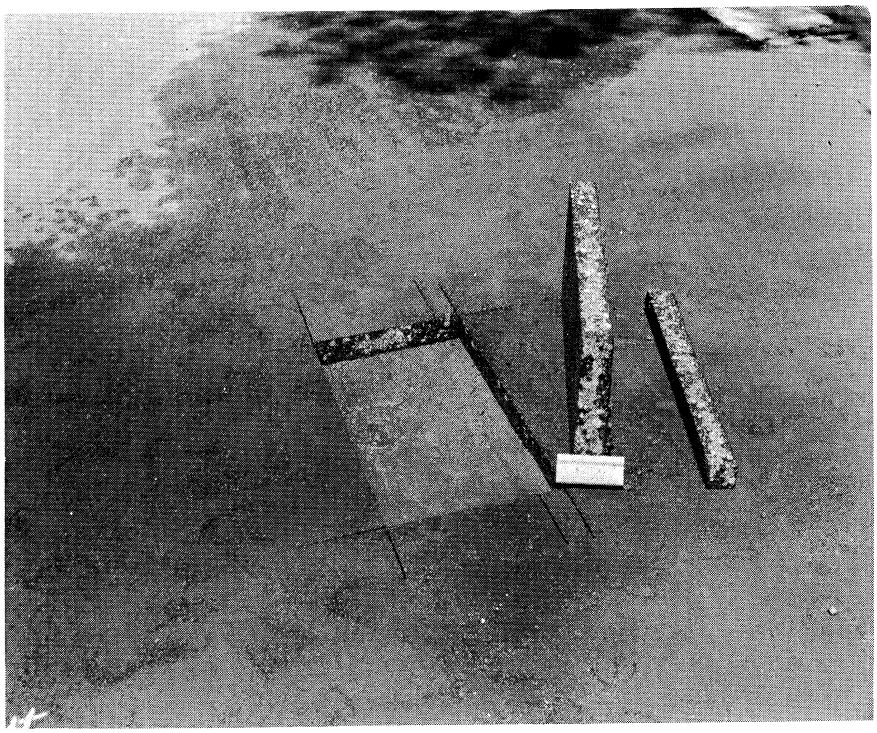

UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
PER CENT RETAINED
0 20 40 60 80 100
Average Aggregate Gradation for City Street Paving
CITY OF COLORADO SPRINGS
COLORADO
APPENDIX 2



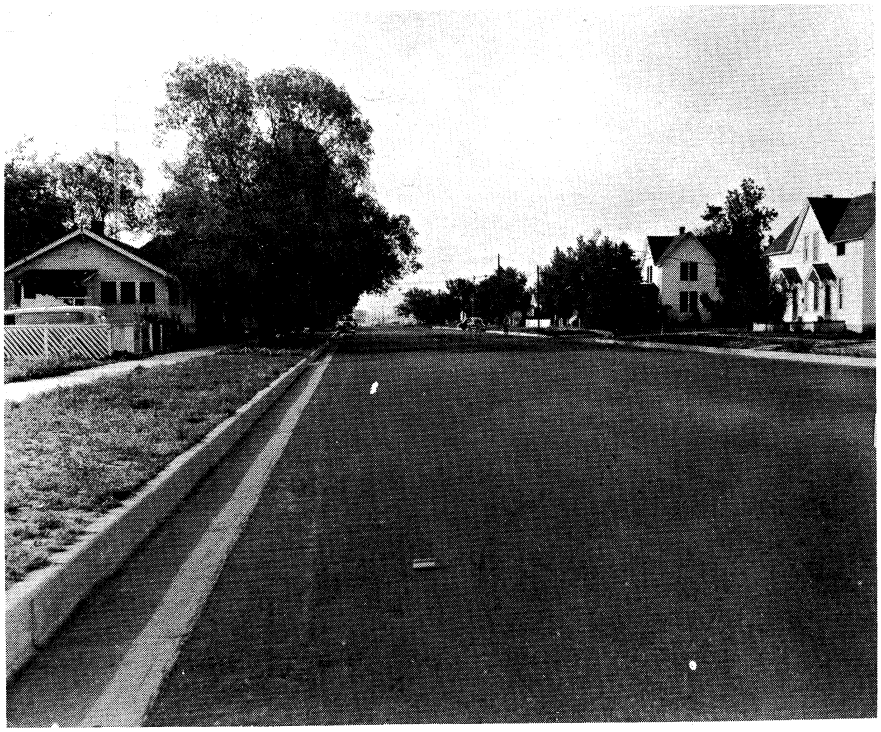
Picture 31. (1952) General view of Maple Street, a light-traffic residential location, between Royer and El Paso Streets.



Picture 32. (1952) Close-up view of typical Maple Street paving texture.

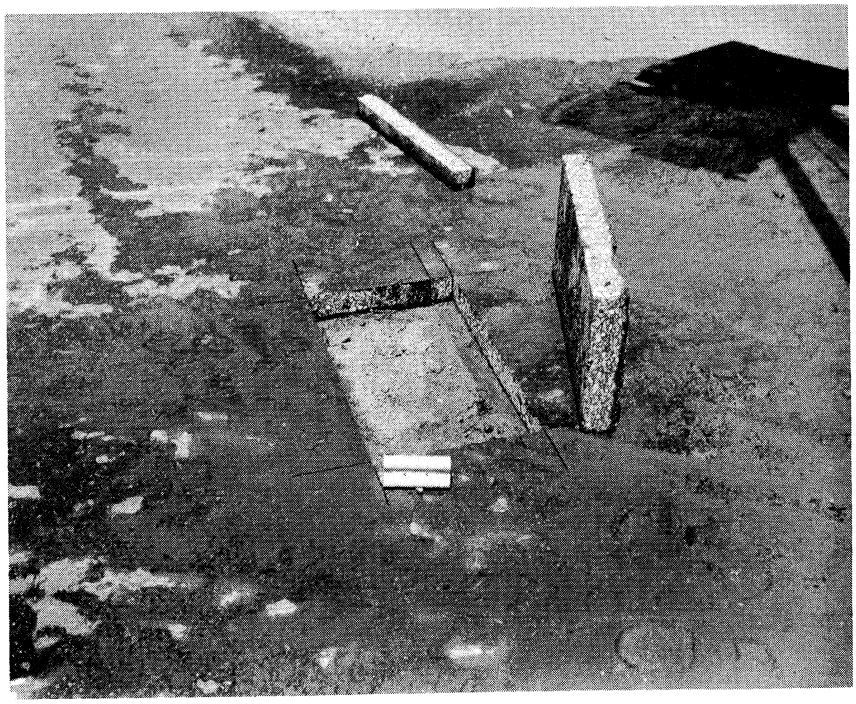


Picture 64. Maple Street, between Royer and El Paso Streets. View of sample cut, sample section, and underlying gravel base. Paving thickness 2-1/4 in.



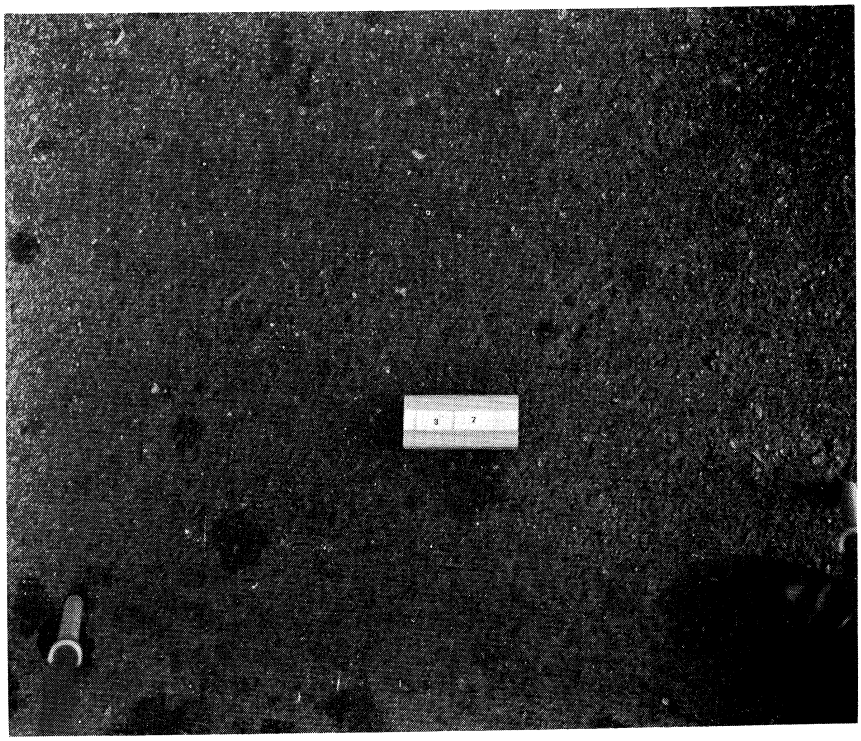
Picture 34. (1950) General view of Weber Street between Fontanerro and Jefferson Streets. Street width permits parking on both sides with double lane of traffic in central area.

Picture 35. (1950) Close-up view of Weber Street paving texture. The relatively coarse grading of the mixture prevented the roller from closing up the surface uniformly. Paving in excellent condition.

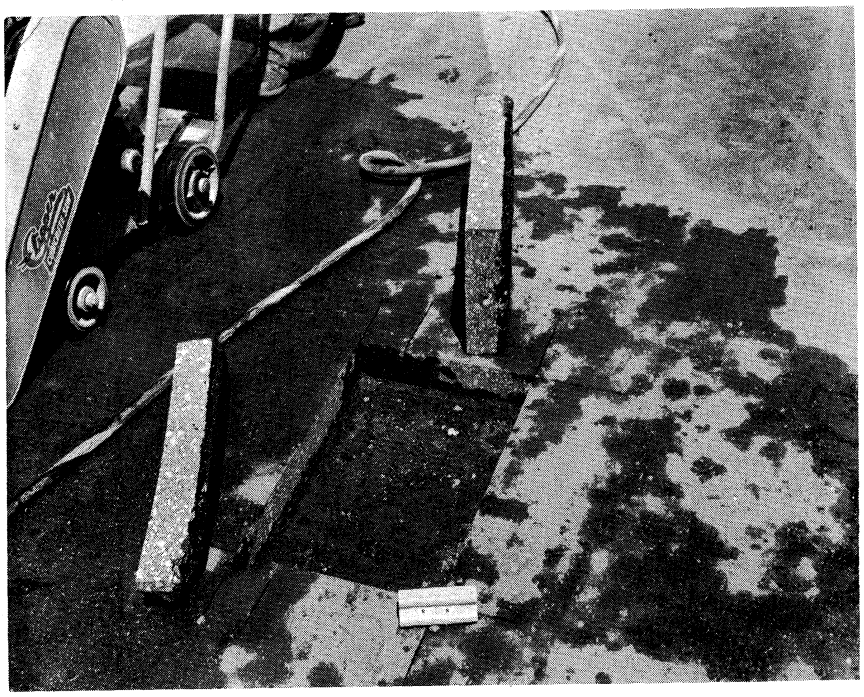


Picture 65. Weber Street, Fontanerro to Jefferson Street. View of sample cut, sample section, and gravel base. Sample taken in traffic lane. Paving thickness, 2-1/4 in.

Picture 36. (1950) General view of the paving area on Jackson Street.

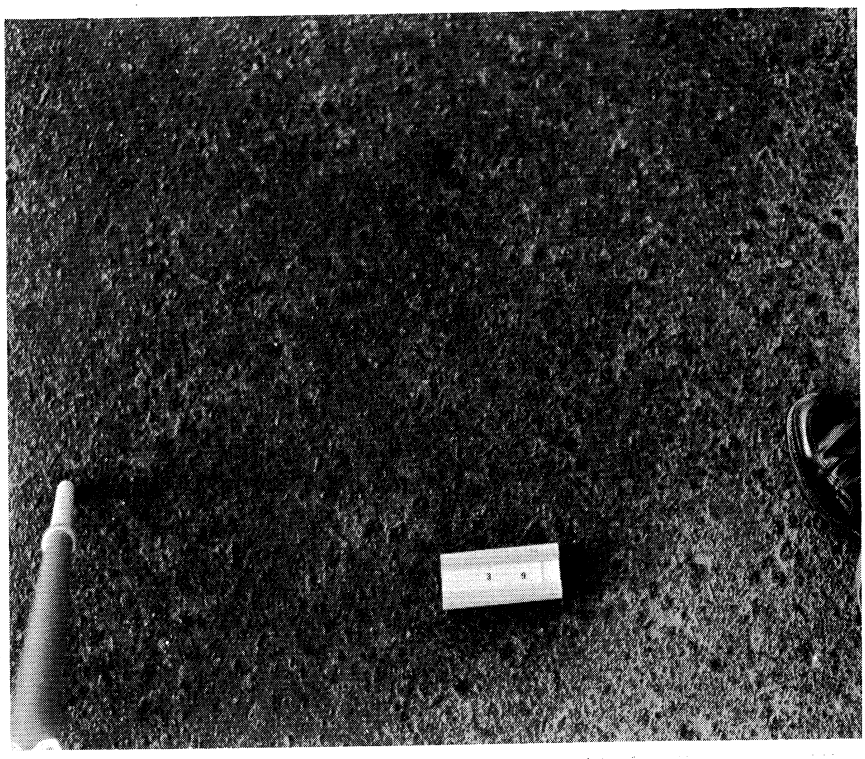


Picture 37. (1950) Close-up view of the typical paving surface on Jackson Street. Not subject to heavy traffic and there is no apparent difference between traffic lanes and parking area.

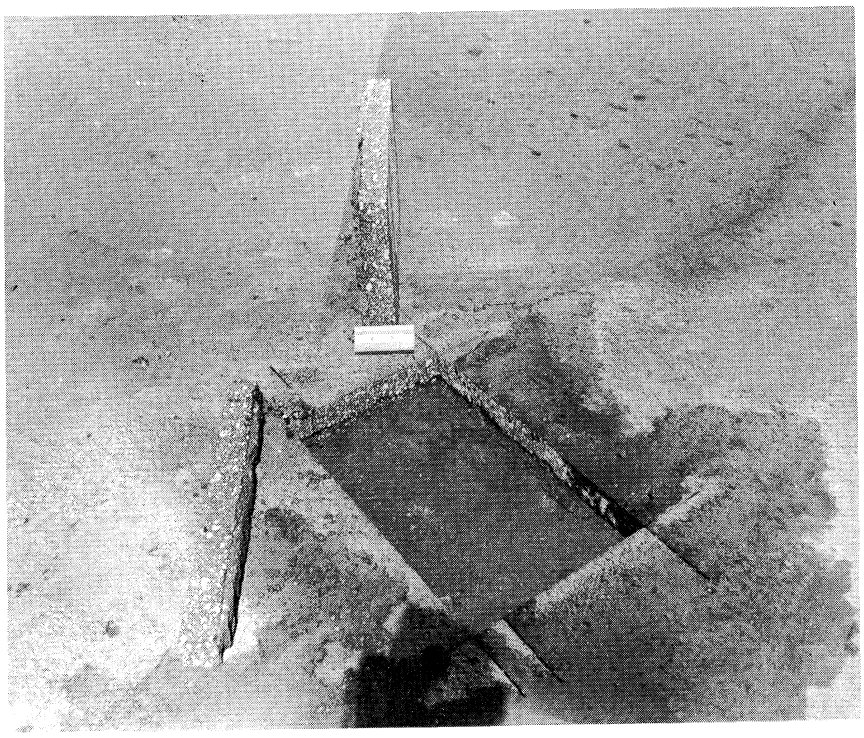


Picture 66. Jackson Street, between Cascade and Tejon Streets. Sample obtained from the westbound traffic lane. Paving thickness 3-1/4 in.

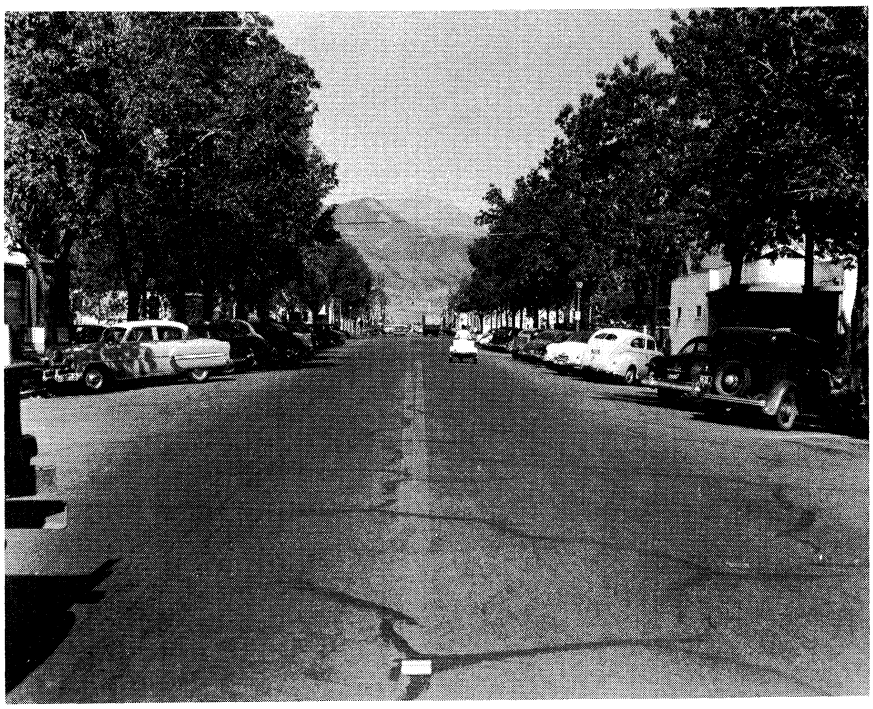
Picture 38. (1952) General view of Paseo Street from Constitution Avenue toward Van Buren Street. This street, constructed to serve the expanding residential areas of Colorado Springs, has relatively light traffic.



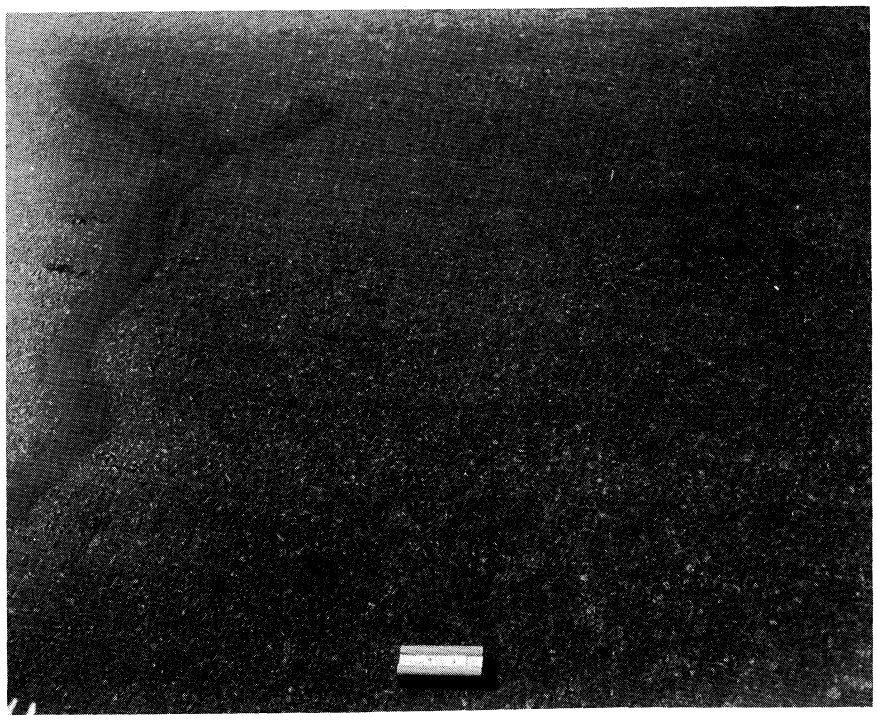
Picture 39. (1952) Close-up view of the paving texture on Paseo Street. The mixture employed produced a well-closed-up paving surface which was extremely uniform in color and texture throughout.



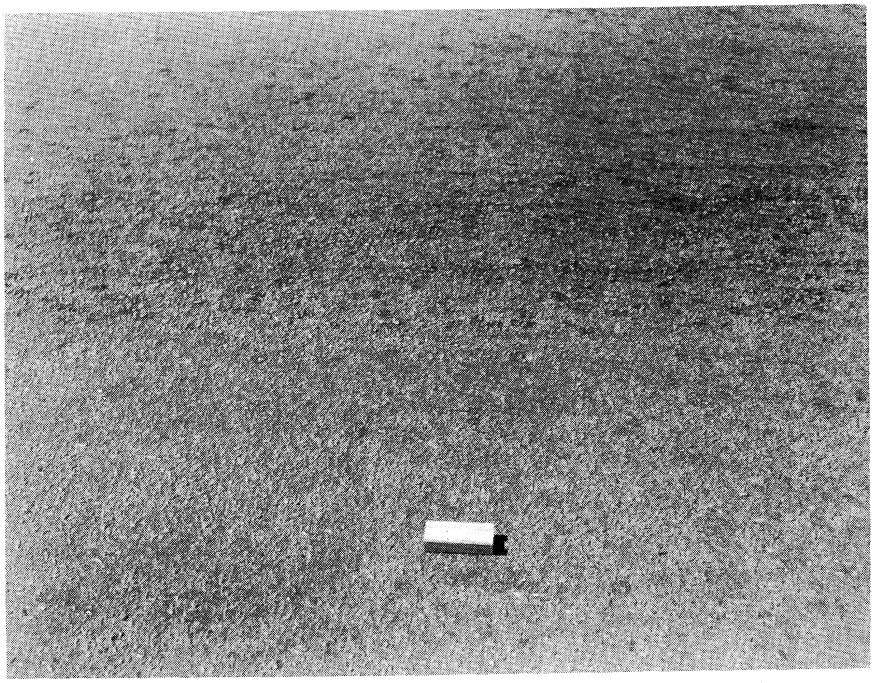
Picture 67. Paseo Street, between Constitution and Van Buren Streets. View of sample cut, sample section, and gravel base. Sample from traffic lane. Paving thickness 2-1/4 in.



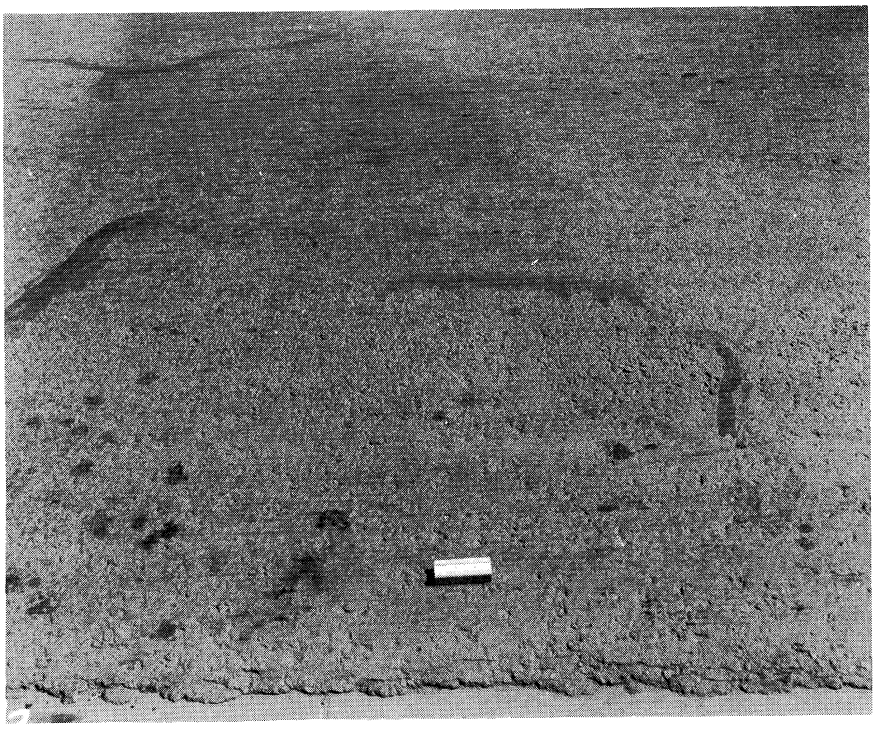
Picture 40. (1948) General view of Colorado Street taken from Wahsatch Street toward Weber Street. The traffic and parking arrangement may be noted. This is one of the heavier-traffic streets adjacent to the downtown business area.



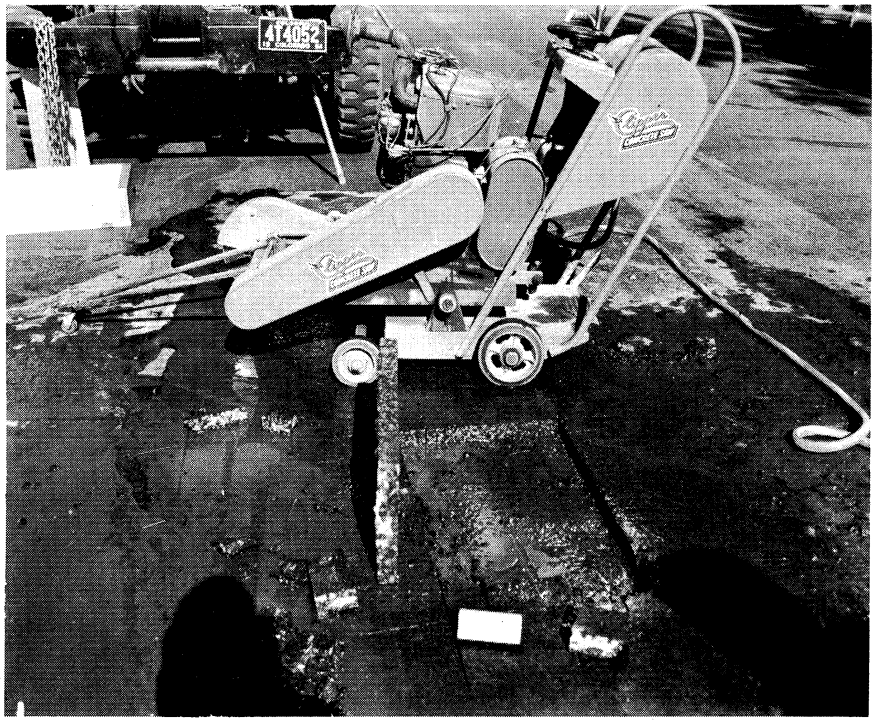
Picture 41. (1948) View of the typical paving texture of paving on Colorado Street in the traffic lanes. Its terrazzo-like appearance, well-closed surface, the cohesive, tacky condition of the mixture all indicate satisfactory service behavior.



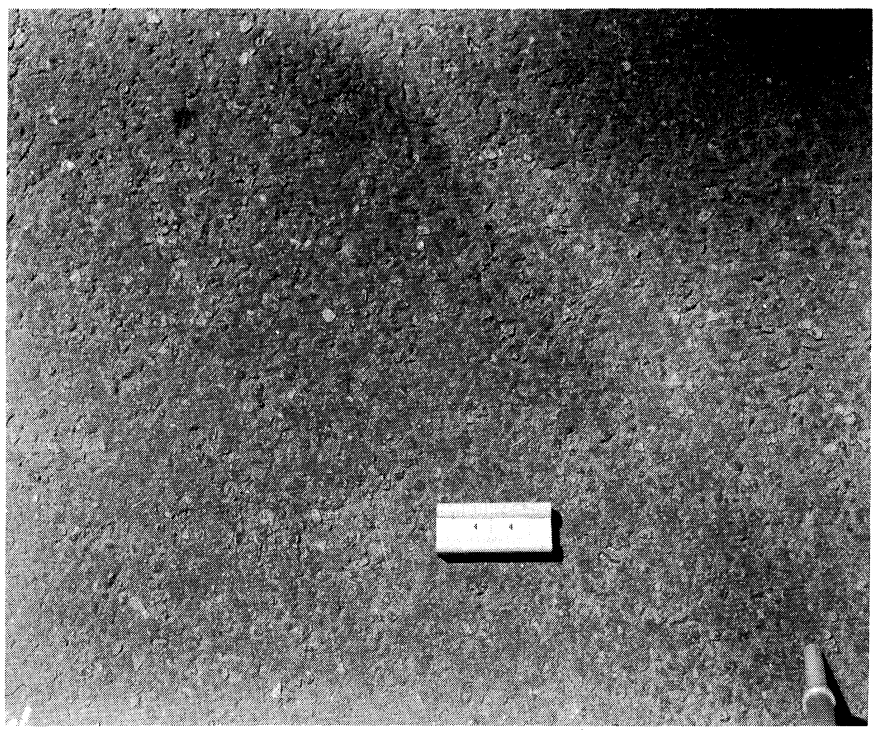
Picture 42. (1948) Close-up view of Colorado Street paving texture at stop on the east side of Nevada Street intersection. Some slight wear may be noted in the wheel paths as compared to the adjacent, relatively light-traffic areas which have maintained their original surface texture.



Picture 43. (1948) In contrast to the view shown in Picture No. 42, this picture indicates the paving surface texture in the untravelled parking areas.

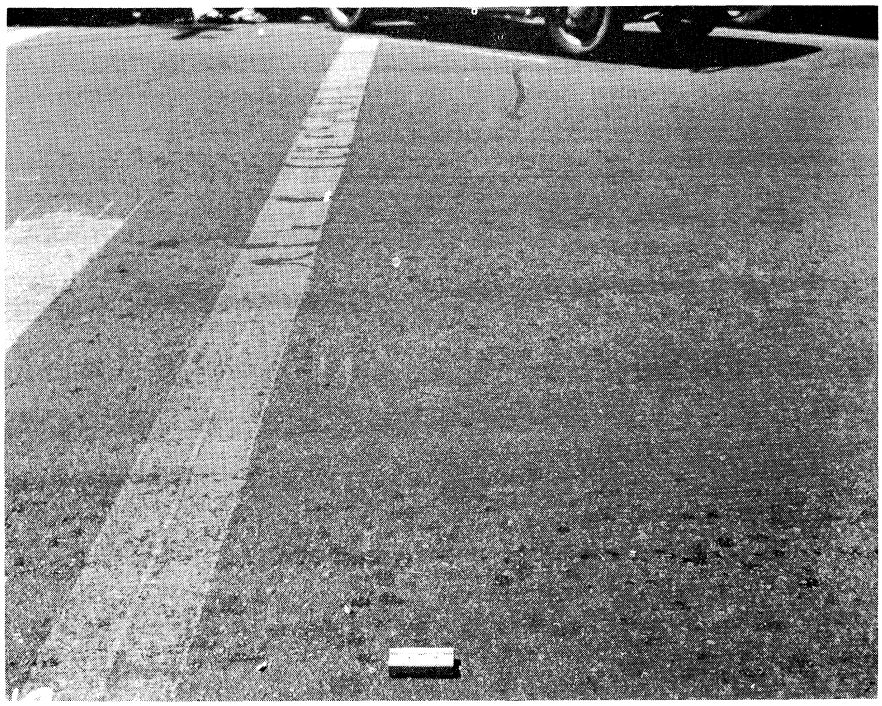


Picture 61. Colorado Street between Wahsatch and Weber Streets. View showing sample cut and sample section as removed from underlying old asphalt paving. Paving thickness 1-7/8 in.

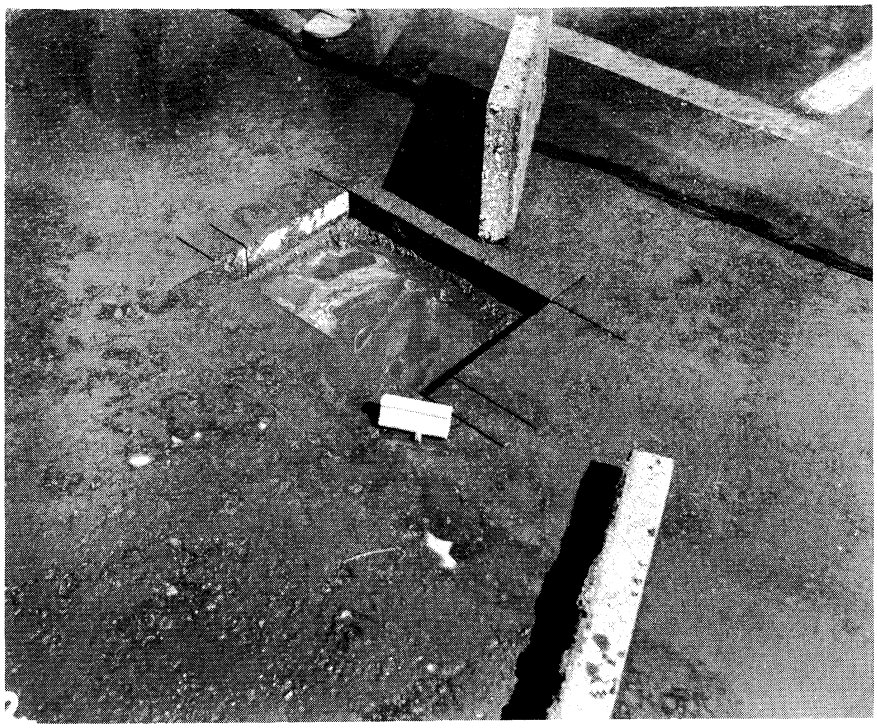


Picture 44. (1948) Vermijo Street. View of the paving surface and texture in the central parking area between Nevada and Weber Streets.

Picture 45. (1948) View of the paving surface and texture on Vermijo Street, between Nevada and Tejon Streets. It may be noted that traffic action has tended to close up the surface and remove initial roller construction marks.

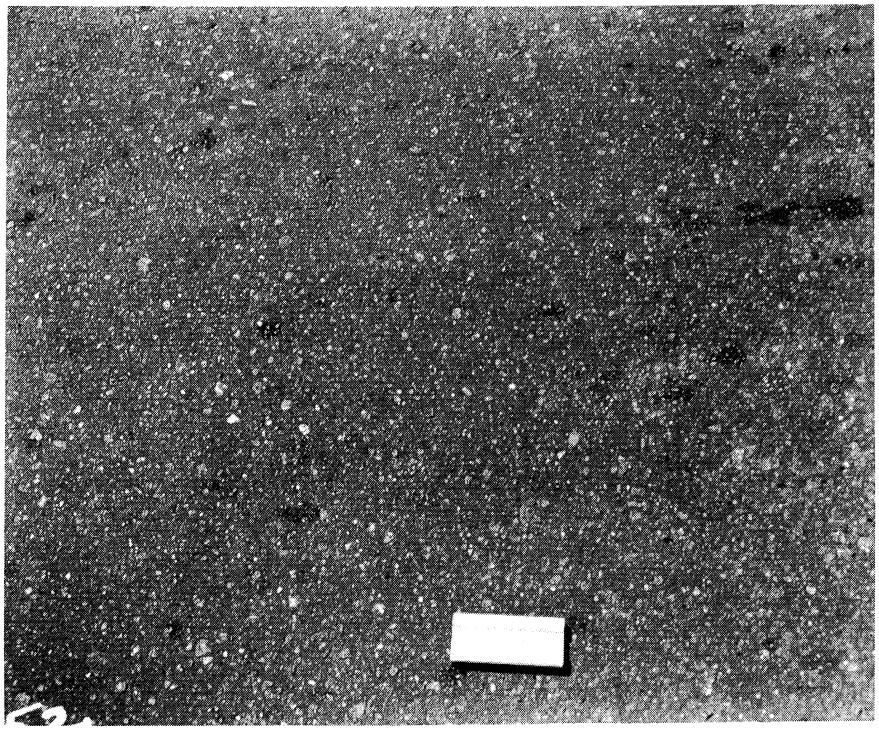


Picture 48. (1948) View of paving surface and texture on Vermijo Street at the car stop at Weber Street intersection. Some evidence of wear in the wheel paths due to abrasive action of tires resulting from braking and acceleration.

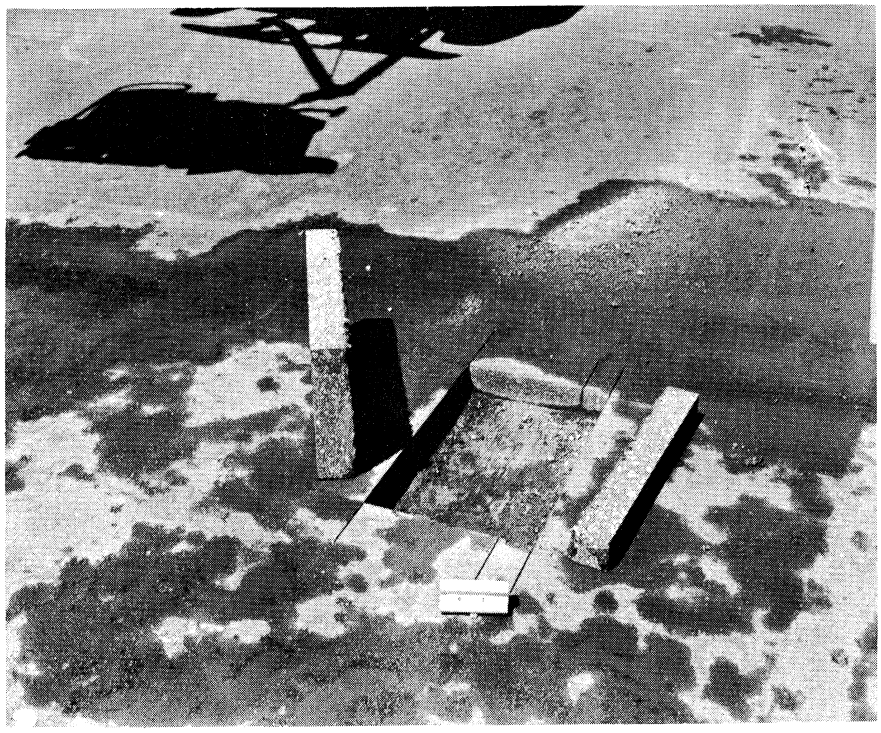


Picture 62. Vermijo Street between Weber and Nevada streets. View of sample cut, sample section, and underlying base course. Paving thickness, 2-3/4 in.

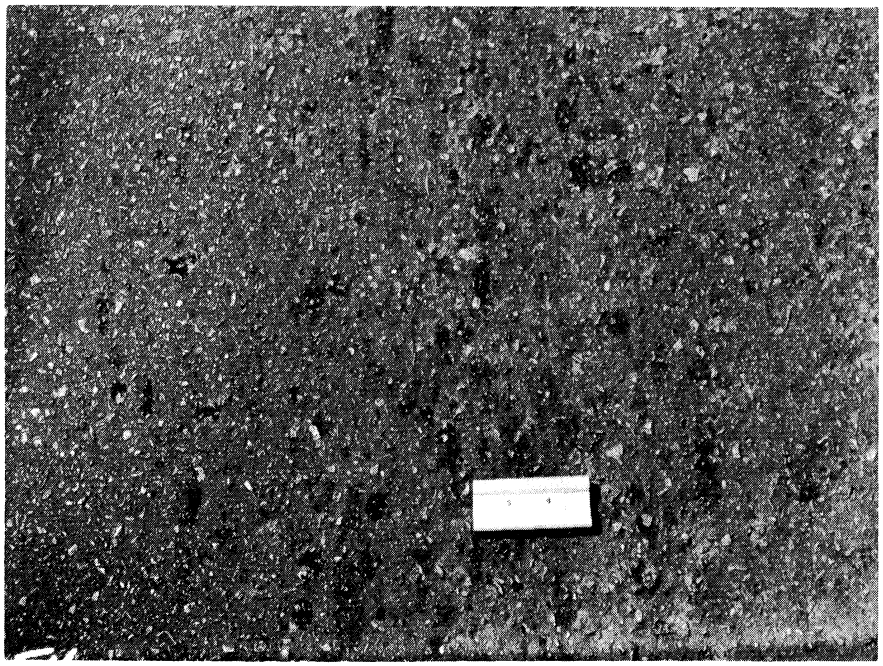
Picture 50.5. (1950) General view of Rio Grande Street between Nevada and Weber Streets. Relatively light-traffic street.



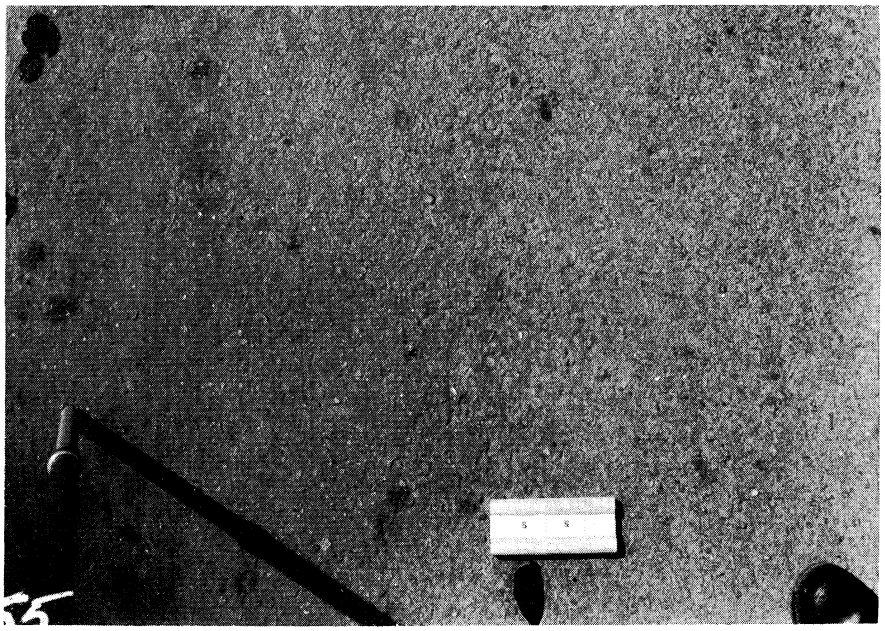
Picture 52. (1950) Close-up view of paving surface and texture in traffic lanes on Rio Grande Street.



Picture 63. Rio Grande Street between Weber and Nevada Streets. View of sample cut, sample section, and gravel base in westbound traffic lane, inner wheel path. Paving thickness 3 in.



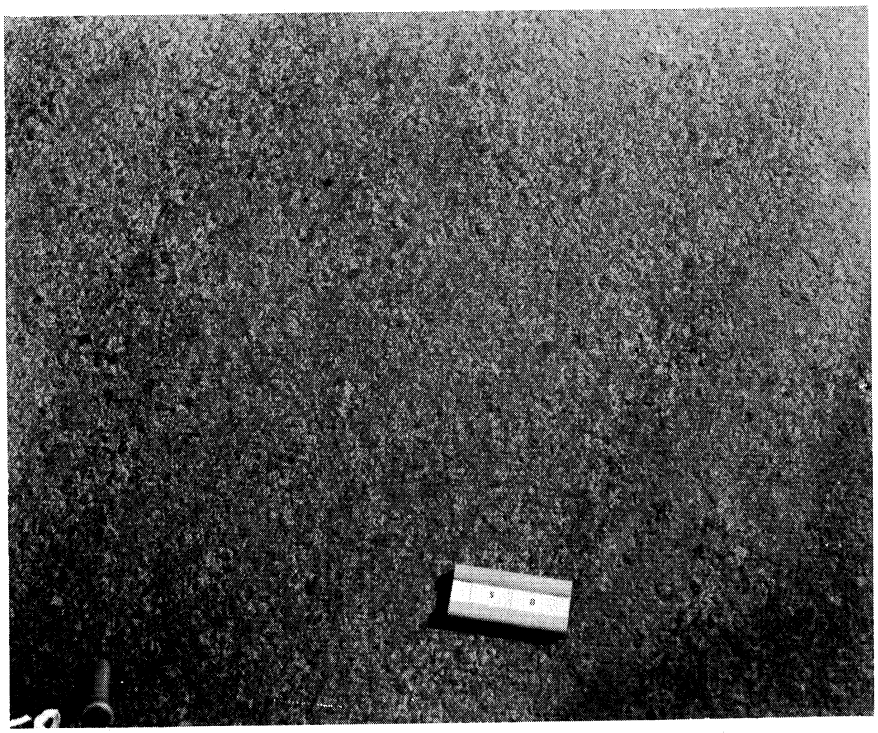
Picture 54. (1950) Colorado Avenue, City Route U.S. 24. Most heavily travelled street in Colorado Springs, handling extensive tourist traffic and service trucks to the resort areas. The views shown are typical of paving from the Viaduct to the west city limits of Colorado Springs. This picture is typical of the general wheel path condition and was taken adjacent to the point of sampling between 15th and 16th Streets.



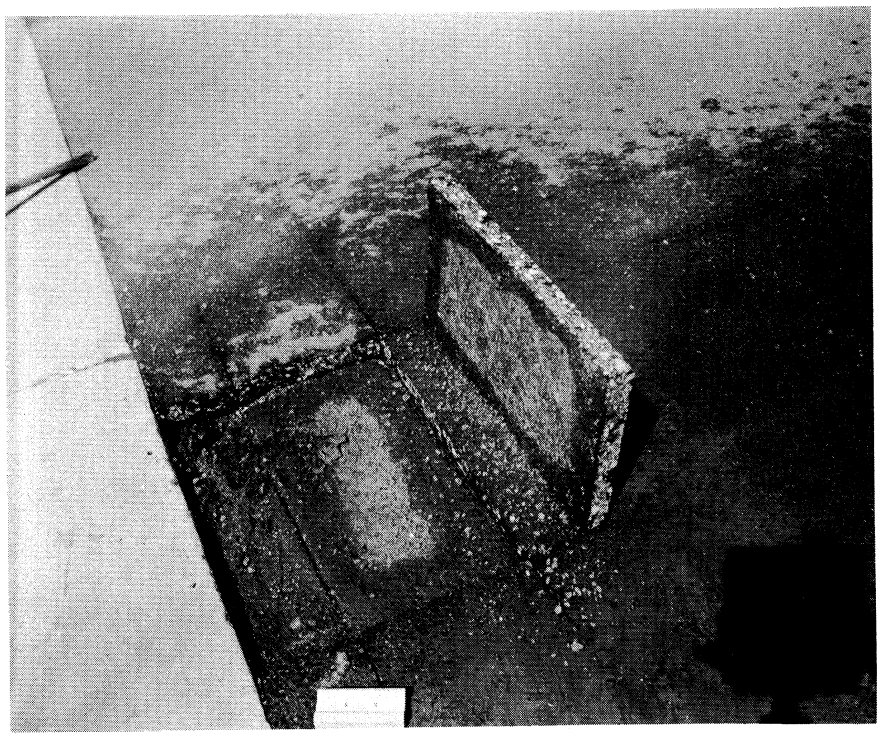
Picture 55. (1950) Colorado Avenue. In contrast to the traffic lane texture and surface shown in Picture No. 54, this view indicates the condition of the paving surface in the side traffic areas. The initial closed-up surface is undisturbed.

Picture 56. View of the equipment and personnel provided by the city to facilitate our sampling operations.

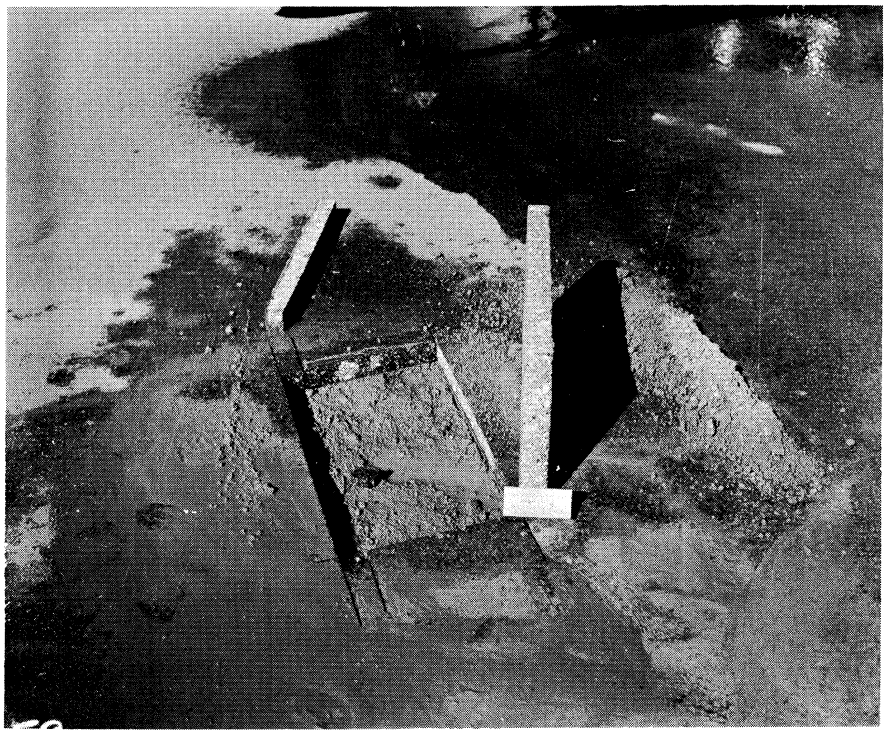
Picture 57. View of the paving cut, sample section, and paving thickness on Colorado Avenue between 15th and 16th Streets.



Picture 58. (1952) Eighteenth Street between Platte and Bijou Streets. Appearance and texture of surface shown is typical for this paving.



Picture 59. (1952) Eighteenth Street, Platte to Bijou. View of sample cut, sample section, and gravel base. Paving thickness 1-3/4 in. to 2 in.



Picture 60. (1952) Thirtieth Street, between Boulder and St. Vrain Streets. View of sample cut, paving section, and gravel base. Picture shows conditions in traffic lane. Paving thickness 2 in.

APPENDIX NO. 3

CITY OF MC COOK, NEBRASKA

ASPHALTIC CONCRETE PAVING

FIELD INSPECTION REPORT

City of McCook, Nebraska

The discussion presented herein is intended to supplement the photographs of the paving, which have been identified and explained briefly in the Picture Index.

The paving is of special interest for the reason that, although it was laid in 1926, no resurfacing or extensive maintenance has ever been done. The original construction was quite extensive, covering practically all streets in use in 1926 and entirely new roadways and extensions of existing ones to serve the contemplated expansion of the city of McCook.

Satisfactory local aggregate is not readily available in this area. A relatively fine gravel of uncertain quantity is obtainable from deposits in the Republican River valley. Coarse aggregate of better quality is shipped in from northern Kansas. This material is a relatively soft limestone. Fine sand is available in abundance, but it is of poor quality and very silty in composition. Most of the binder course aggregate on this project was shipped in from Wyoming and was dolomitic in nature. Unrecorded variations in supply, however, are indicated in the appearance of some paving areas.

Local aggregate was used entirely in the construction of the concrete base, which was built immediately prior to placing the asphaltic concrete. By present standards, the concrete is of extremely poor grade; it appears to have low cement content and is now poorly bonded. The performance of concrete paving which has been constructed of this same material is unsatisfactory, as is evidenced by the McCook airport paving, Picture No. 94, built by the Corps of Engineers for use by the Air Force during World War II.

2ND STREET EAST, FROM B TO L STREET

A preliminary inspection of the entire area involved in this operation indicated that this particular paving was representative of conditions. The other streets intersected with 2nd Street throughout its length and had been subjected to considerably less traffic. Due to the more favorable gradient between B Street and C Street, as compared to the parallel streets, 3rd and 4th East, practically all of the traffic used this section, especially during the winter, when favorable gradient was especially attractive.

Transverse and diagonal cracking of the paving surface, accompanied by pronounced buckling at these locations, was the most obvious difficulty. These cracks were reported to have formed shortly after the paving was completed and became so severe that the original contractor was required to make extensive repair prior to final payment for the work. As the asphaltic concrete paving, adjacent to and between such cracks, has remained in good structural condition, these failures may be attributed to volume change of the underlying concrete. Specific illustrations of this condition are presented in the accompanying pictures Nos. 70, 71, 74, 78, 79 and 80. Another rather remarkable condition was the live, tacky nature of the mixture. This quality was especially significant as the air temperature at the time of inspection was only about 77°.

There is little doubt that the long service life of this paving may be largely attributed to the relatively light traffic conditions. However, the absence of the ironing action of traffic, the relatively open type mixture, and the cohesive nature of the interior of the mixture, indicate that the asphalt was able to maintain its favorable properties under rather adverse conditions.

CITY OF MC COOK, NEBRASKA

SAMPLE INDEX

Sample No.	Date Const'd	Asphalt Pen	Asphalt Source	Sample Obtained From	
M37	1926	60	S.O.Co.	E. 2nd St. between F and G Sts.	traffic
M38	1926	60	S.O.Co.	" " " " " " " "	parking
M39	1926	60	S.O.Co.	" " " " H and I "	traffic
M40	1926	60	S.O.Co.	" " " " " " " "	parking
M41	1926	60	S.O.Co.	" " " " L and K "	traffic
M42	1926	60	S.O.Co.	" " " " " " " "	parking
M43	1926	60	S.O.Co.	E. 3rd St. between B and C Sts.	traffic
M44	1926	60	S.O.Co.	" " " " " " " "	parking
M45	1926	60	S.O.Co.	E. 2nd St. between B and C Sts.	traffic
M46	1926	60	S.O.Co.	" " " " " " " "	parking
M47	1926	60	S.O.Co.	E. 4th St. between B and C Sts.	traffic
M48	1926	60	S.O.Co.	" " " " " " " "	parking

PAVING MATERIAL TEST DATA

City of McCook, Nebraska
Paving of Various City Streets Constructed in 1926
Asphaltic Concrete (Warrenite Bithulithic) on Original Concrete Base
60 Pen. Asphalt (Warren Bros. Contract)—Standard Oil Co., Casper, Wyoming

INTRODUCTION

This paving was constructed in 1926. Much of it was built in advance of the actual development of the areas it now serves. As a consequence, many sections were practically unused for a number of years until the growth of the city of McCook placed them in service. Much of the paving serves residential or light commercial areas. Samples were taken from streets which had been subjected to the greatest traffic.

The most pronounced irregularities now present in the paving surface are the transverse cracks and attendent buckling of the paving at practically each crack. Previous investigations conducted by the city have established the fact that this difficulty is due to expansion of the underlying concrete slabs during the extremely hot weather experienced in this area. The concrete, serving as the base for the bituminous surface, closely resembles present-day soil-cement construction. Of special interest is the fact that, over the extensive area inspected, only a limited amount of map cracking, which could be attributed to "drying" of the asphalt, could be found. The appearance of the paving surface, supplemented by the city records, indicated that no maintenance had been done since it was originally laid. Except for the irregularities due to movements of the concrete base, the pavements still are in excellent condition.

DISCUSSION OF TEST DATA

The records covering this work were made available by Mr. Roy M. Green, now Dean of Engineering, University of Nebraska, Lincoln, Nebraska. At the time of construction he operated the Western Laboratories, Lincoln, Nebraska, and was retained to supervise this paving. His data, saved over the years, was somewhat incomplete but did include daily gradation of the aggregate, both for the asphaltic concrete and the light sand asphalt seal, always applied in Warrenite-Bithulithic construction just ahead of rolling operations. It will be observed that the original asphalt content of the sand-asphalt ranged from 11.3 to 13%, whereas that of the asphaltic concrete was 5.6 to 6.5%. From the inspection it was apparent that most of the original sand-asphalt seal had been worn off, and for that reason the percentages of asphalt reported in the ERI samples are essentially those of the asphaltic concrete.

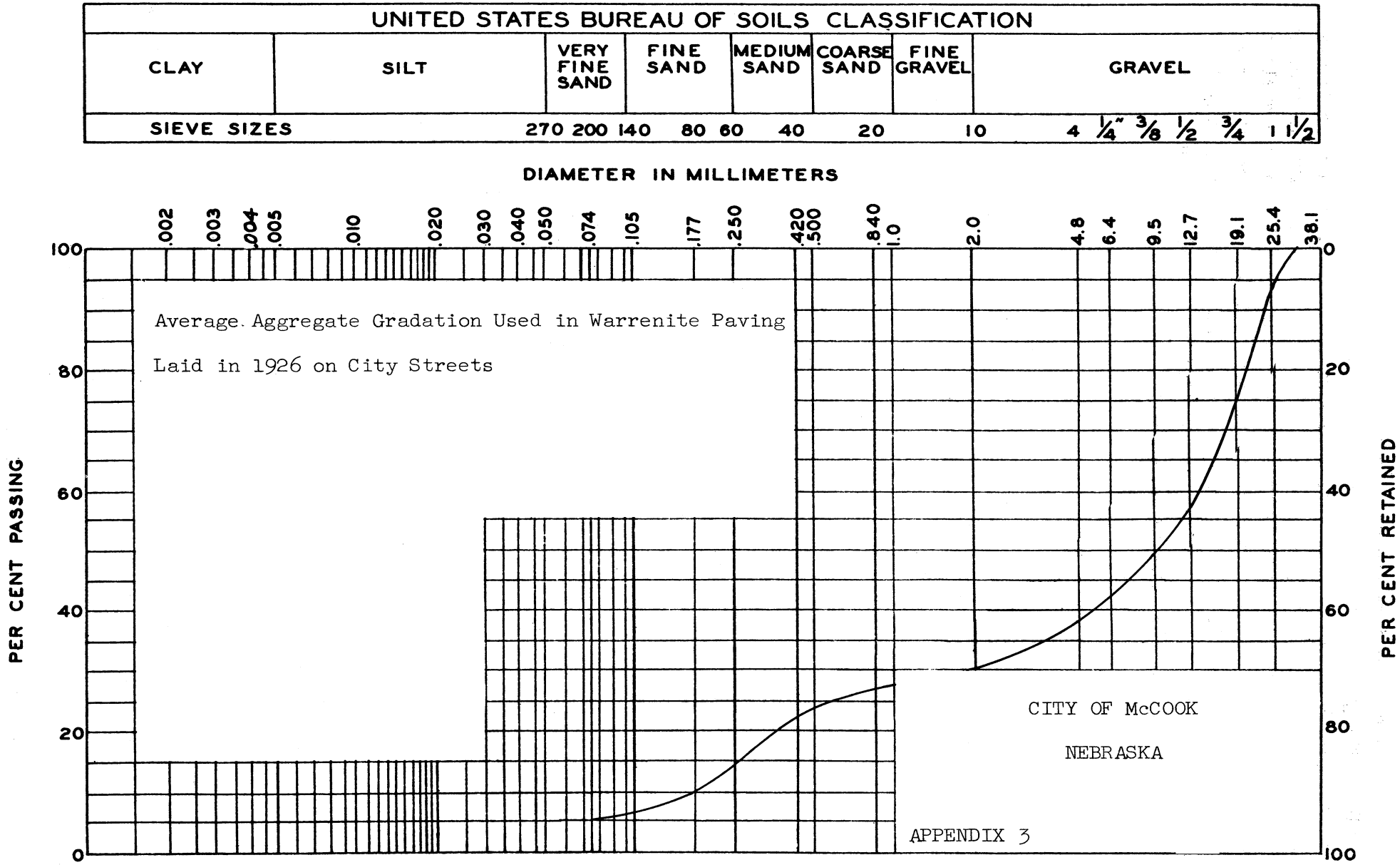
The relative coarseness of the paving mixture is shown by the gradation and confirmed by the high fineness modulus. From data in Mr. Green's records, the weight per sq yd of the paving is known and from this it is possible to compute its approximate density. Obviously good construction compaction was obtained, although exact pavement voids are not computed due to the lack of information concerning the specific gravities of the aggregates.

Records were available of the paved area in which each car of asphalt was used. This permits a direct comparison between the initial and recovered material. These data are tabulated below.

PROPERTIES OF ASPHALT—ORIGINAL AND RECOVERED

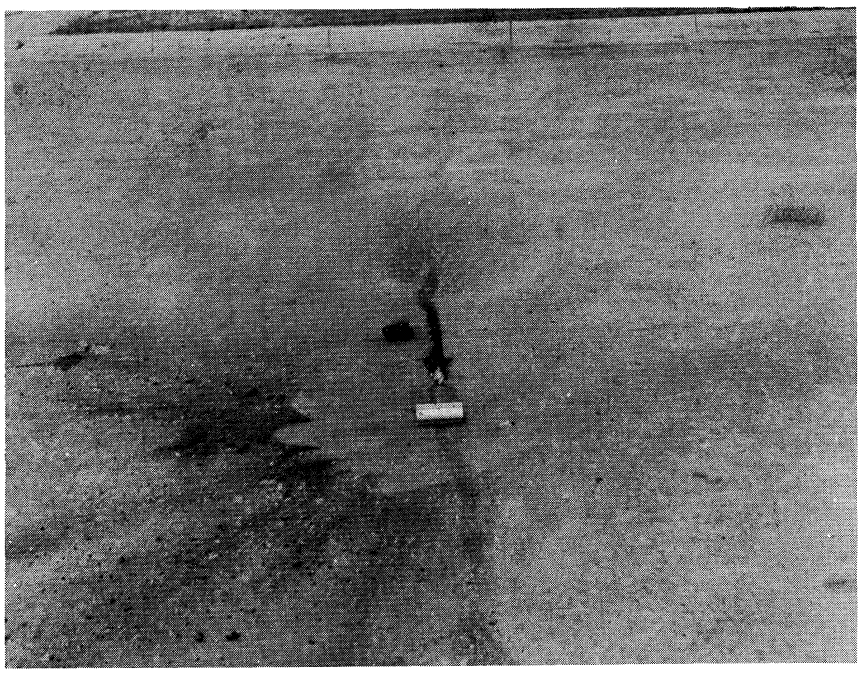
ERI No.	Sample Location	Orig Asph. pen	Orig Asph. s.pt	Recovered Asphalt pen	Recovered Asphalt s.pt	% Change pen	% Change s.pt	ERI s.pt:pen	Ratio Orig: ERI Ratio
		(s.pt:pen)							
2nd St. East									
		(2.263)							
M37	Bet.F and G	57	129	34	138	-40.4	+7.0	4.059	1.794
		(2.263)							
M38	" "	57	129	34	140	-40.4	+8.5	4.118	1.820
		(2.263)							
M39	" H and I	57	129	26	140	-54.4	+8.5	5.385	2.380
		(2.263)							
M40	" "	57	129	40	133	-29.8	+3.1	3.325	1.469
		(2.263)							
M41	" L and K	57	129	25	141	-56.1	+9.3	5.640	2.492
		(2.263)							
M42	" "	57	129	11	169	-80.7	+31.0	15.364	6.789
		(2.263)							
M45	" B and C	57	129	30	137	-47.4	+6.2	4.567	2.018
		(2.263)							
M46	" "	57	129	25	141	-56.1	+9.3	5.640	2.492
3rd St. East									
		(2.263)							
M43	Bet.B and C	57	129	25	143	-56.1	+10.9	5.720	2.528
		(2.263)							
M44	" "	57	129	35	134	-38.6	+3.9	3.829	1.692
4th St. East									
		(2.263)							
M47	Bet.B and C	57	129	27	141	-56.1	+9.3	5.222	2.308
		(2.263)							
M48	" "	57	129	32	138	-40.4	+7.0	4.313	1.906

The asphalt recovered from the paving samples M41, M42 and M44 exhibits the greatest amount of change. These samples were taken from paving lying between L and K Streets on East 2nd Street. Reference is made to the Picture Index and photographs 81, 82 and 83. These show the presence of both block- and map-cracking in the paving surface, which was prevalent over that area. The paving was practically unused for a period of approximately 10 years after construction and is now subjected to only very light residential traffic. It had been constructed on new fill and showed the effects of considerable subgrade settlement.


UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
PER CENT RETAINED
100 80 60 40 20 0
0 20 40 60 80 100
Average Aggregate Gradation Used in Warrenite Paving
Laid in 1926 on City Streets
CITY OF McCOOK
NEBRASKA
APPENDIX 3

Picture 68. General view of East 2nd Street taken from the intersection with B Street, looking northward toward C Street. Because of its favorable gradient as compared with East 3rd Street and East 4th Street, this paving receives the major portion of traffic in winter, when tires are equipped with chains.

Picture 69. Paving texture within the east-side parking area of East 2nd Street. Note that the original light sand asphalt surfacing, common to Warrenite Bithulithic paving, still remains after 28 years of service.



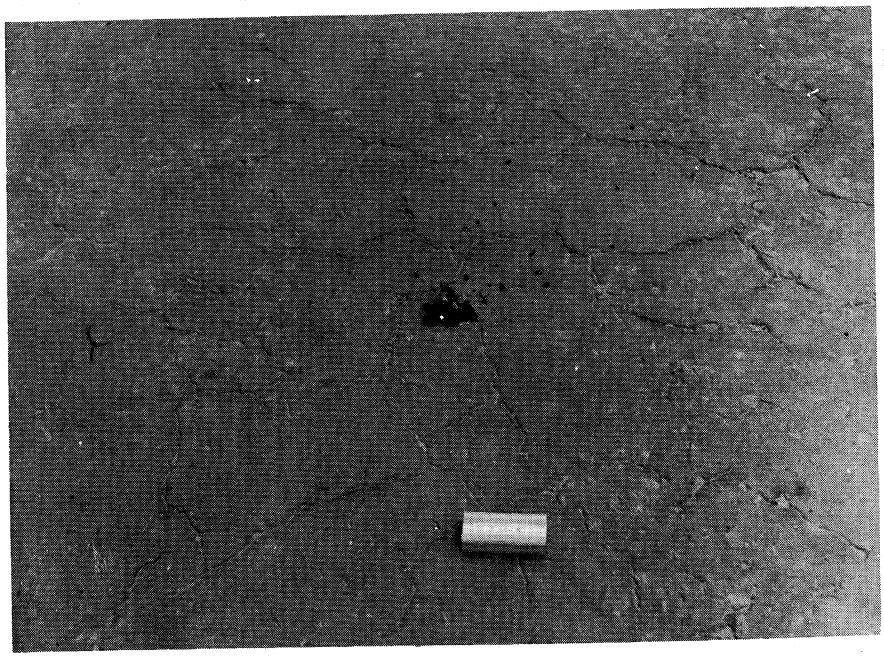
Picture 70. Transverse crack typical of those observed throughout all paved areas. These were caused by the faulting and breakup of underlying concrete base.

Picture 71. Transverse crack in paving surface at intersection of East 2nd Street and C Street. These transverse cracks were approximately 2 in. wide, dirt filled, and not maintained with seal. Asphaltic concrete paving adjacent to these cracks is still in good, serviceable condition.

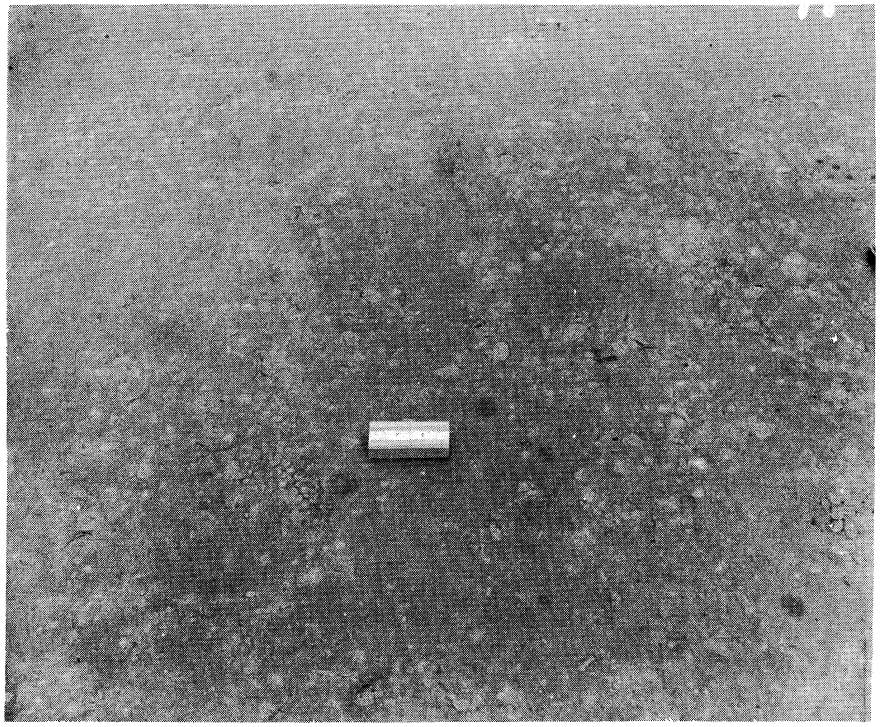
Picture 72. Between C and D Streets on East 2nd Street, showing past flow of asphalt from paving structure in the downhill direction. Thirteen transverse cracks, due to concrete base faulting, were counted between C and D Streets.

Picture 73. A limited area of map cracking. Street maintenance personnel advise that such cracking has been observed in increasing amounts during the last five years.

Picture 75. Paving texture at intersection of East 2nd and D Streets, where traffic turns. Abrasive action of tires has worn off the original light sand asphalt surface, exposing the underlying coarse aggregate. There are no loose particles in this base, however, and at air temperatures of between 80° and 100°F, asphalt in mixture was live and tacky.



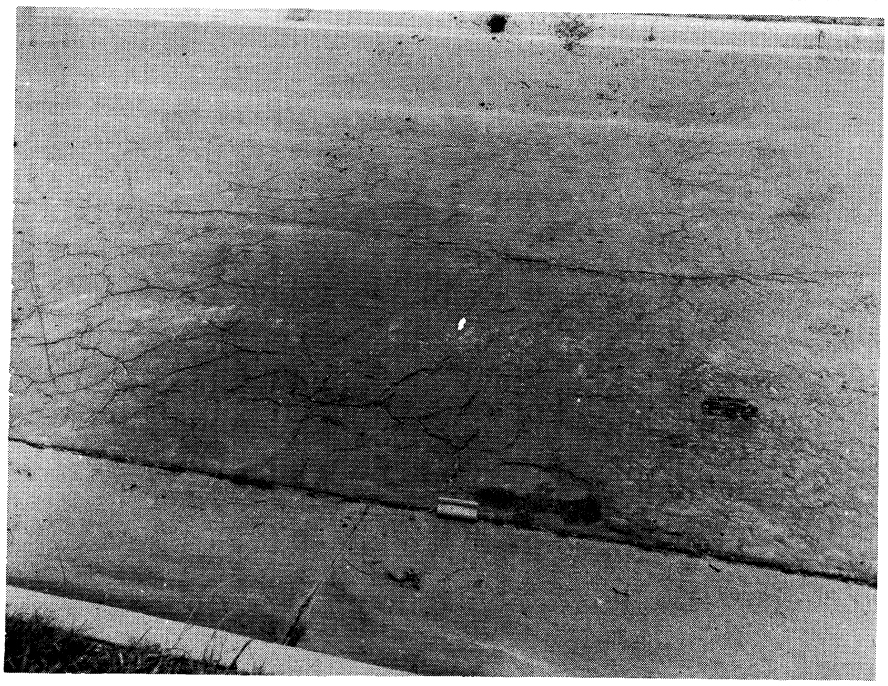
Picture 76. Typical map cracking north of D Street in lightly traveled parking area. View shows picked hole and the contrasting color of the surface and the interior of the mixture. This loosened material was rich black in color, with bituminous material live and tacky under prevailing air temperature of between 90° and 100°F.



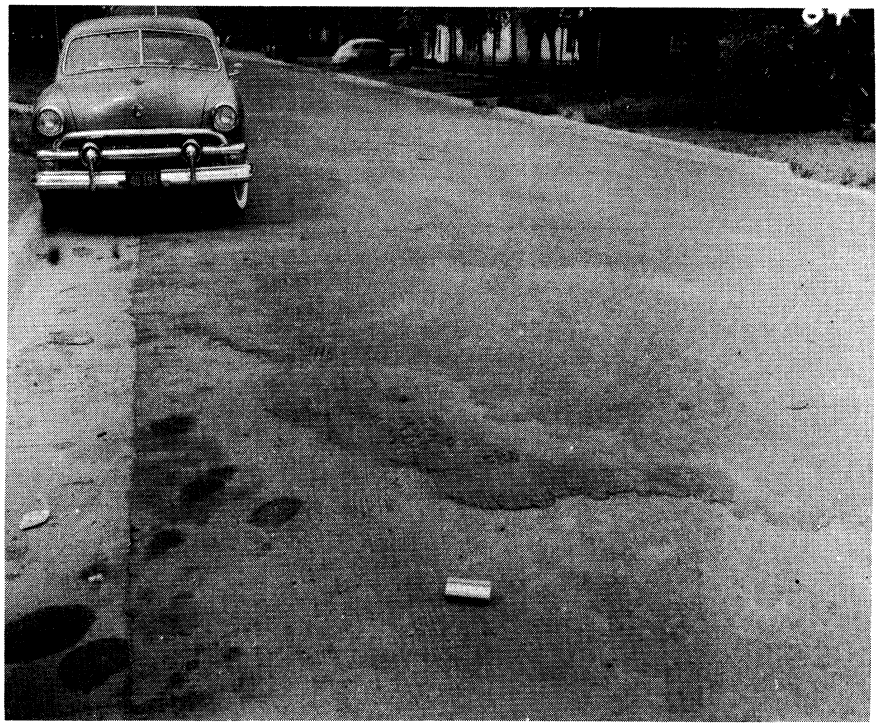
Picture 77. This is representative of typical paving surface. Coarse aggregate texture of the main body of the paving structure can be observed.

Picture 78. Vertical displacement at blow-up crack in the underlying concrete base. This extended entirely across paving width, and vertical displacement amounted to approximately 3 in.

Picture 80. Typical blow-up crack patching done by McCook city maintenance forces. Their usual procedure is to remove the failed concrete base entirely, place compacted rock aggregate, and apply bituminous seal surfacing. This type of repair constitutes practically all that has been done to this paving since it was laid in 1926.



Picture 81. Second Street between K and L Streets shows the most extensive block cracking encountered over the entire paved area. Judging from the depression of the failed area, this has been caused by base failure.



Picture 84. Between B and C Streets on East 3rd Street. The longitudinal grade in this block is approximately 3-1/2 to 4 percent. Note past flow of mixture down grade, apparently occurring during or shortly after the paving was laid.

Picture 85. Typical condition of the paving texture on East 3rd Street between B and C Streets just north of the B Street intersection, where vehicles accelerate after making turn and proceeding up the grade.

Picture 86. General view of East 3rd Street looking up ascending grade toward C Street.

Picture 88. East 4th Street between B and C Streets, showing typical paving texture. The short crinkled cracking which may be observed appeared to have been due to initial rolling of the paving.

Picture 89. Typical paving texture in the traffic lanes on East 4th Street between B and C Streets intersections. The underlying mosaic of coarse aggregate may be observed where traffic has removed the sand surfacing.

Picture 90. The original brass plate installed by Warren Brothers to identify their work.

APPENDIX NO. 4

STATE OF NEBRASKA

ASPHALTIC CONCRETE PAVING

FIELD INSPECTION REPORT

Nebraska Experimental Project S-10

The field inspection of the paving on this project was accomplished between July 30 and August 5, 1954. Air temperatures prevailing during this period ranged between 105 and 110°F. The resulting high paving temperatures contributed materially to the conditions as observed, particularly with respect to the extensive flushing and rutting of the paving surface. Traffic was exceptionally heavy during this period.

Because of the experimental nature of this project, there have been previous examinations made by the personnel of the Nebraska Highway Department. One report, submitted by Mr. W. J. Kreuscher, Senior Engineer, was made immediately after construction in the summer of 1948. It contains his observations concerning the mixtures used in the test road. The other was an inspection survey made by Mr. Harold H. Easom, District Engineer, North Platte, Nebraska, covering conditions noted as of December 1950. Excerpts from these reports are combined with our observations. When used they will be identified as Kreuscher-1948 or Easom-1950.

MIX NO. 1. (Picture Reference—No. 95, 96, 98, 99, 100, 101, 114)

Kreuscher-1948. No discussion of Mix No. 1. This mix was employed on Project 170(6).

Easom-1950. Mix No. 1. Station 90+00 to 99+30, westbound traffic lane.

Deformation—both wheel tracks—5/8 to 3/4 in.
Transverse corrugations—none
Raveling—none
Cracking—none
Bleeding—none

Note:—Section located on curve and is badly rutted throughout its entire length.

This mixture was used to resurface old concrete paving and is located on a curve between Station 90+00 and 99+30 in the westbound and 106+30 in the eastbound traffic lanes, respectively. The westbound traffic

lane paving surface, being on the inside of the curve, is in the poorest condition. Rutting, lateral displacement, longitudinal shoving with attendent chatter-bumps or corrugations, all supplemented by extensive flushing of asphalt to the paving surface, are very much in evidence. The flushed asphalt appears to contain a high percentage of an oily constituent which stained clothing readily but possesses little cohesion. Various measurements of rutting in both inner and outer wheel paths of the westbound traffic lane ranged from 3/8 in. to 2-1/4 in. in the outer wheel path (OWP) and 7/8 in. to 1-1/4 in. in the inner wheel path (IWP). Rutting of the eastbound traffic lane was materially less. The badly corrugated paving surface on the curve constituted a dangerous condition for the high-speed traffic using the highway. The nature of the rutting and shoving indicated that some might have been caused by movement or break-up of the underlying concrete slab since the surfacing had been constructed. The local maintenance personnel advised that the old concrete paving had been extensively damaged prior to the application of the asphaltic concrete surfacing.

MIX 6A. (Picture Reference—No. 97, 102)

Kreuscher-1948, has combined Mix 6A and 6B in his report. These mixtures were the same as Mix No. 1, except that limestone filler was used instead of loess. A high dust loss was observed during mixing operations, which may account for the oily appearance of both mixtures. The spreading and compaction of both were similar to that of Mix No. 1 and the resulting surface seemed to be at least equal to that mixture. The objectionable feature noted was high dust loss.

Easom-1950. Mix 6A—1-1/2 in. thick on top of base of Mix No. 1. Station 99+30 to 103+50.

Deformation—both wheel tracks—1/2 to 7/16 in.
Transverse corrugations—none
Raveling—none
Cracking—none
Bleeding—dark in color but not flushing. Appears rich in asphalt content.

Paving from this mixture connects with that from Mix No. 1 at the east end. A considerable portion of Mix 6A lies on the west end of the curve, and that portion shows pronounced rutting and corrugations. This condition is not evident on the portion located on tangent. At the junction with Mix No. 1, it was apparent that 6A paving was much darker in color, with considerable asphalt flushed to the surface, especially in the wheel paths.

MIX 6B. (Picture Reference—No. 102)

Kreuscher-1948. Comments relative to 6A are applicable to 6B.

Easom-1950. Mix 6B, Station 103+50 to 106+95, west bound traffic lane.

Deformation—both wheel paths—1/2 in.
Transverse corrugations—none
Raveling—none
Cracking—none
Bleeding—none

Flushing of asphalt over the paving surface was extensive in this section. There were no pronounced corrugations due to displacement by traffic, and the rutting in the westbound traffic lane measured 3/8 in. in the IWP and 1/2 in. in the OWP. There was a general improvement of the paving surface over the preceding section, 6A, which may be attributable to the more-directional flow of traffic on tangent, better condition of the underlying old concrete paving, or both.

MIX 1A. (Picture Reference—No. 104, 106)

Kreuscher-1948. He has combined mixes 1A, 1B, 1C and 1D in his discussion. These sections were constructed exactly like Mix No. 1, except for variations in filler and asphalt content. All sections seemed equal or better than Mix No. 1 except Mix 1B. It is believed that in this mixture the asphalt content is too high. Mix 1C seemed harder to lay than normal. This was probably due to the 2% increase in filler; however, this condition was corrected in Mix 1D. Objectionable feature—Mix 1B—asphalt content too high. Traffic lanes in 1B show some distortion at this early date.

Easom-1950. Mix 1A. Station 106+95 to 111+80, westbound traffic lane. A top course of this mix 1-1/2 in. thick was laid over 1-1/2 in. of Mix No. 1.

Deformation—both wheel tracks—1/2 to 5/8 in.
Transverse corrugations—none
Raveling—none
Cracking—one crack across roadway
Bleeding—none
Average color and appearance—slightly darker than section 6B.

The paving surface in this section was covered with excess asphalt which had flushed to the surface, especially in the wheel paths. Although the air temperature was between 100 and 105°F at the time of the inspection, there was no oily exudation from the asphalt, although it was extremely

plastic. There was only slight rutting, largely confined to the westbound traffic lane.

MIX 1B. (Picture Reference—No. 107, 109)

Kreuscher-1948. Comments included with section 1A.

Easom-1950. Mix 1B. Station 111+80 to 117+12, westbound traffic lane.

Deformation—both wheel paths—7/16 to 9/16 in.
Transverse corrugations—none
Raveling—none
Cracking—none
Bleeding—slightly

No marked contrast in texture or appearance between section 1A and 1B was noted. The rutting in 1B measured 1/4 in. in IWP and 1/2 in. in OWP, westbound lane. There were no corrugations or marked flushing, although there was a spotty occurrence of excess asphalt over the entire paving area. The surface was quite plastic without there being any visible exudation of oil at the prevailing high air temperature.

MIX 1C. (Picture Reference—No. 109, 111, 112)

Kreuscher-1948. Comments included with section 1A.

Easom-1950. Mix 1C. Station 117+12 to 123+00, westbound traffic lane.

Deformation—both wheel tracks—3/8 to 5/8 in.
Transverse corrugations—none
Raveling—none
Cracking—none
Bleeding—none

The conditions as described in section 1B are similar to those found in 1C.

MIX 1D. (Picture Reference—No. 112)

Kreuscher-1948. Comments included under Mix 1A.

Easom-1950. Mix 1D. Station 123+00 to 127+00, westbound traffic lane.

Deformation—both wheel tracks—3/8 to 5/8 in.
Transverse corrugations—none

Raveling—none
Cracking—none

Note:—Some shoving and cracking occurring at the junction between 1D and 5A seems to be due to base failure.

This section seemed to be particularly rich in asphalt content. There was considerable excess on the surface, especially in the wheel paths. Although there was only slight reported difference between Mix 1C and 1D, the latter has rutted materially more, the ruts measuring 7/8 in. in IWP and 1-1/2 in. in OWP.

MIX 5A. (Picture Reference—No. 113, 115, 116, 117)

Kreuscher-1948. This mixture consisted of locally available Nebraska blow sand with 10% loess filler and 6.0% asphalt. It was laid to a thickness of 1 in. over a 2 in. thick base made from Mix No. 1. This mixture required considerable time for cooling before rolling operations, due to the unstable character of the mixture. During the plant mixing, considerable trouble was experienced with this mixture. It proved very difficult to produce dry and hot fine sand in any quantity and the temperature control was very poor. The addition of the large amounts of filler slowed down the mixing operation materially. It is estimated that the filler loss was as high as 25%; however, the extraction tests made in the field do not indicate this. The greatest difficulty with the mix was holding it in the mixer. Dry unmixed sand leaked through the mixer gates into the batch trucks. This small quantity of unmixed sand caused thin sand streaks in the surface of the paving. The mixture is relatively easy to lay and up to the date of this report, appears to be standing up well under traffic.

Easom-1950. Mix 5A. Station 127+65 to 130+35, westbound traffic lane.

Deformation—both wheel tracks—3/8 to 1/2 in.
Raveling—none. This sand section shows wear, should have armor coat.
Transverse corrugations—none
Cracking—none
Bleeding—none

The appearance of this sand-asphalt-surfaced section was surprisingly good. Although rutting was visible and measured 3/4 in. in IWP and 1/2 in. in OWP, there was no bleeding, raveling, or corrugation and the surface was quite uniform in texture and color. An examination of the paving section where the sample was taken indicated that only 1/4 to 1/2 in. thickness of the original 1 in. sand surface remained in the wheel paths and slightly more than 1 in. was present along the edges. This appeared to be due to lateral displacement. In contrast to adjoining sections composed

of gravel aggregate, the color of this section is much darker. Only isolated cracking at random locations could be detected. There was slight pitting visible, possibly due to balls of poorly mixed sand asphalt or the breakdown of larger soft particles. The pits were normally not more than 1/4 in. in diameter and 1/8 in. in depth. Contrary to what might be expected of this type of surfacing, the appearance and performance of this section compared favorably with any other on the project.

MIX 5B. (Picture Reference—No. 113, 117)

Kreuscher-1948. Comments in 5A apply to this section.

Easom-1950. Mix 5B. Station 130+35 to 132+75, westbound traffic lane.

Deformation—both wheel tracks—1/4 in.
Transverse corrugations—none
Raveling—none
Cracking—none
Bleeding—none

Note:—This sand surface section is located on a slight curve. Some wear in the wheel paths may be noted, although this section has more of a traffic seal than section 5A.

The remarks and observations applicable to 5A are similar for this section. Although there was an increase of 5% of loess filler in this mixture, the service behavior was not effected.

MIX 4X.

No picture reference. Paving surface at the time of inspection has been covered with a road mix.

Kreuscher-1948. He has combined 4A, 4B, 4C and 4X in his remarks. These sections were made up from local materials only. In his opinion the Mix 4C has produced the best section. All sections were similar except for quantity of asphalt and filler. However, section 4X was based on section 4B for filler and asphalt content, but a larger amount of aggregate retained on No. 4 sieve was used, without changing the trap openings into the dryer. All sections are standing up well under traffic at the present time. One failure has appeared in 4X, but it is definitely due to base conditions. The higher filler content slowed plant mixing operations somewhat, and the filler loss is definitely higher than for Mix No. 1. Rolling operations are delayed for from 8 to 10 hours. The cooling-off period was extended through the night following the laydown in order to

obtain good density, as the hot mixture tended to roll and shove under roller action.

Easom-1950. Mix 4X. Station 138+00 to 133+85, eastbound traffic lane.

Deformation—both wheel tracks—7/16 to 5/8 in.
Transverse corrugations—none
Raveling—none
Cracking—one crack on edge
Bleeding—none

No report is made on this section, as the surface had been covered with road-mix material by the maintenance department. This was due to an error in starting maintenance work which had been ordered done on the paving lying to the west of the experimental section.

MIX 4C. (Picture Reference—No. 118, 113)

Kreuscher-1948. Comments included with those under Mix 4X.

Easom-1950. Mix 4C. Station 132+80 to 127+75, eastbound traffic lane.

Deformation—both wheel tracks—5/16 in.
Transverse corrugations—none
Raveling—none
Cracking—some cracks both longitudinal and transverse
Bleeding—none
Appearance—good

This is one of the better paving sections on the project. There was no visible rutting, corrugation, raveling or flushing. Aggregate texture was distinct throughout. Riding qualities were good.

MIX 4B. (Picture Reference—No. 110)

Kreuscher-1948. Comments included under Mix 4X.

Easom-1950. Mix 4B. Station 127+75 to 121+00, eastbound traffic lane.

Deformation—both wheel tracks—7/16 to 1/2 in.
Transverse corrugations—none
Raveling—none
Cracking—few transverse cracks in outer 6 in. of edge
Bleeding—none

The surface of these local aggregate mixtures contained more visible aggregate, practically no flushed asphalt on the surface, no rutting, corrugation, shoving or raveling. Riding qualities were good. There was very little difference in appearance and performance as compared with 4A.

MIX 4A. (Picture Reference—No. 110)

Kreuscher-1948. Comments included under Mix 4X.

Easom-1950. Mix 4A. Station 121+00 to 114+75, eastbound traffic lane.

Deformation—both wheel tracks—7/16 in.
Transverse corrugations—none
Raveling—none
Cracking—none
Bleeding—none
Appearance—good

The remarks appearing under Mix 4B, apply to this section.

MIX 3. (Picture Reference—No. 105, 106, 108)

Kreuscher-1948. This mixture was very similar to the No. 4 series. However, crushed sand-gravel was used in place of the regular Platte River sand-gravel. By use of the crushed material it was possible to produce a mat with density equal to that of Mix No. 1. Laying operations were very similar, except that a longer time was required for cooling so that the final rolling could be completed.

Easom-1950. Mix 3. Station 114+75 to 110+65, eastbound traffic lane.

Deformation—both wheel tracks—5/16 to 3/8 in.
Transverse corrugations—none
Raveling—none
Cracking—some transverse and longitudinal similar to those in Mix 4C
Bleeding—none
Appearance—good except for some dark-colored spots

This section had similar service behavior and appearance to that of Mix 4A. The ruts measured 1/4 in. in IWP and 1/2 in. in OWP. Riding qualities were good, with no shoving, raveling or corrugation.

MIX 2. (Picture Reference—103, 105, 106, 108)

Kreuscher-1948. This mixture very similar to that of Mix No. 1 except that Nebraska crushed gravel was used to replace the Wyoming dolomite from Guernsey, Wyoming. The material received for this section was produced by the Lyman-Ritchie Gravel Company and it tested about 30% finer than the Wyoming dolomite. This resulted in a finer mixture. The paving densities were similar to Mix No. 1, but the length of time before rolling could be completed was greater.

Easom-1950. Mix 2. Station 110+65 to 106+30, eastbound traffic lane.

Deformation—both wheel tracks—3/8 to 9/16 in.
Transverse corrugations—none
Raveling—none
Cracking—none
Bleeding—dark appearance only
Appearance—fair, darker in color than section 4X, 4C, 4B, 4A and 3. Appears to be rich in asphalt content.

There is a distinct contrast between paving texture and color at the junction between Mix 2 and 3. Mix 2 appears to be over-asphalted, with a substantial amount of excess asphalt flushed to the surface, especially in the heavily travelled wheel paths. This Mix 2 also shows definite rutting in the wheel paths, with the formation of a raised surface, due to lateral displacement, between wheel paths. The elevated section between wheel paths shows a tendency to slight superficial hair cracking. Ruts in Section 2 measured 3/8 in. in IWP and 1/2 in. in OWP.

MIX 1. (Picture Reference—103)

Kreuscher-1948. No discussion of Mix No. 1. This mix was the same as employed on Project 170(6).

Easom-1950. Mix No. 1, Station 106+30 to 90+00, eastbound traffic lane.

Deformation—both wheel tracks—1/4 to 3/8 in.
Transverse corrugations—none
Raveling—none
Cracking—none
Bleeding—none
Appearance—section on the outside of curve, very good condition.

Although this Mix No. 1 paving in the eastbound traffic lane was identical with that placed in the westbound traffic lane, its service performance at the time of the survey was markedly superior. This may be

attributed largely to its more favorable position on the outside of the curve and possibly to some better base support afforded by the underlying old concrete slab. It was much darker in color than the adjoining section from Mix 2. Rutting, while not excessive, was more pronounced but almost negligible as compared with the westbound lane in the same section.

STATE OF NEBRASKA
EXPERIMENTAL PROJECT S-10

SAMPLE INDEX

Sample No.	Date Constd	Asphalt Pen	Asphalt Source	Sample Obtained From				
M49	1948	100-120	Frontier	Mix 1,	pav edge,	ebnd	lane	untraveled
M50	1948	100-200	Frontier	" "	owp	"	"	traffic
M51	1948	100-120	Frontier	" "	pav edge,	wbnd	lane	untraveled
M52	1948	100-120	Frontier	" "	owp	"	"	traffic
M53	1948	100-120	Frontier	Mix 6B,	pav edge,	wbnd	lane	untraveled
M54	1948	100-120	Frontier	" "	owp	"	"	traffic
M55	1948	100-120	Frontier	Mix 1B,	pav edge,	wbnd	lane	untraveled
M56	1948	100-120	Frontier	" "	owp	"	"	traffic
M57	1948	100-120	Frontier	Mix 1D,	pav edge,	wbnd	lane	untraveled
M58	1948	100-120	Frontier	" "	owp	"	"	traffic
M59	1948	100-120	Frontier	Mix 2,	pav edge,	ebnd	lane	untraveled
M60	1948	100-120	Frontier	" "	owp	"	"	traffic
M61	1948	100-120	Frontier	Mix 5A,	pav edge,	wbnd	lane	untraveled
M62	1948	100-120	Frontier	" "	owp	"	"	traffic
M63	1948	100-120	Frontier	Mix 3,	pav edge,	ebnd	lane	untraveled
M64	1948	100-120	Frontier	" "	owp	"	"	traffic
M65	1948	100-120	Frontier	Mix 4B,	pav edge,	ebnd	lane	untraveled
M66	1948	100-120	Frontier	" "	owp	"	"	traffic
M67	1948	100-120	Frontier	Mix 4C,	pav edge,	ebnd	lane	untraveled
M68	1948	100-120	Frontier	" "	owp	"	"	traffic

Nebraska Experimental Project S-10
Route U.S. 30—West of North Platte
Asphaltic Concrete Resurfacing of Old Concrete
100-120 Penetration Asphalt-Frontier Refining Co., Cheyenne, Wyoming

PROJECT OBJECTIVE

The State of Nebraska initiated this project in 1948, when it became apparent that traffic conditions on its principal routes would require more stable surfacing than that provided by the road mixes then in use.

During the year of 1947, the initial major paving construction, using asphaltic concrete, had been completed east of North Platte to Maxwell, Nebraska. Experience gained during this construction indicated the desirability of additional study relative to the design of asphaltic concrete and the application of local and imported aggregates to the state's growing problem of providing resurfacing for existing concrete paving.

This project was authorized, to permit the investigation of mixture combinations employing imported Guernsey, Wyoming dolomite, Platte River local sand and gravel, crushed sand and gravel from Columbus, Nebraska, and to determine the adequacy of locally available fine sand for wearing course construction. Additional information was made available by comparison of limestone dust with locally available loess for filler in selected test sections. It was intended that a continuing study be conducted, which might indicate the most favorable and economical combination of materials, based upon their service performance, under heavy traffic conditions expected on Route U.S. 30.

In conformity with the principal objective, attention was directed to the effect of aggregate combinations. The asphalt was obtained from a single source, and the percent by weight in the several mixes was controlled to vary over a limited range. The testing and service evaluation of asphalt has been relegated to a minor role in their investigations.

This test paving afforded the opportunity of studying asphalt behavior with different aggregate combinations, under relatively heavy traffic. In addition, the paving surface was not sealed, a rarity in the west. Irregularity of subgrade support was minimized by constructing this test paving over an old concrete surface.

The project was planned to comprise the following mixtures:

Mix No.	Agg. Comp. and Type: Cr Dolo %	Sand, Grav %	Fine Sand %	Fill %	Asph Cont %	Pav. Location and Stations	Thickness
*1	49.9	34.6	11.5	4.0	5.0	wbnd lane, 90+00-99+30	3 in. on concrete
1A	49.9	34.6	11.5	4.0	4.7	ebnd " , 90+00-106+30	"
*1B	49.9	34.6	11.5	4.0	5.3	" " , 111+80-117+12	1-1/2 in. on Mix No. 1
1C	48.9	33.8	11.3	6.0	5.3	wbnd " , 117+12-123+00	"
*1D	48.9	33.8	11.3	6.0	5.6	" " , 123+00-127+00	"
6A	49.1	34.0	11.4	5.5	5.0	" " , 99+30-103+50	"
*6B	49.1	34.0	11.4	5.5	4.7	" " , 103+50-106+95	"

Mix No.	Agg. Comp. and Type: Grav %	Sandy Grav %	Fine Sand %	Fill %	Asph Cont %	Pav. Location and Stations	Thickness
4A	39.1	39.1	12.7	9.0	5.1	ebnd lane, 114+75-121+00	3 in. on concrete
*4B	38.3	38.3	12.4	11.0	5.1	" " , 121+00-127+75	"
*4C	39.1	39.1	12.8	9.0	4.8	" " , 127+75-132+80	"
4X	43.0	43.0	14.0	11.0	5.1	" " , 133+85-138+00	2 in. on concrete
*5A	---	---	90.0	10.0	6.0	wbnd " , 127+65-130+35	1 in. on Mix No. 1
5B	---	---	85.0	15.0	6.75	" " , 130+35-132+75	"

Mix No.	Agg. Comp. and Type: Cr Grav %	Sand, Grav %	Fine Sand %	Fill %	Asph Cont %	Pav. Location and Stations	Thickness
*2	49.4	34.2	11.4	5.0	5.0	ebnd lane, 106+30-110+65	1-1/2 in. on Mix No. 1
	Grav	Cr Sand, Grav	Fine Sand	Fill			
*3	40.9	40.9	13.2	5.0	5.5	ebnd lane, 110+65-114+75	3 in. on concrete

*Sampled under ERI Project No. 2249.

000 designates the percentage of limestone dust filler.

PRESENTATION OF TEST DATA

Reference is made to the tabulated test data presented in Tables 1 and 2. The data for each test section is presented in four adjacent columns. Two of these columns, in which the E.R I sample number appears, contain E R I laboratory data and computed values. The middle two columns contain information obtained from the records of the Nebraska State Highway Department, Lincoln, Nebraska. Where their information has not been completely developed, it was supplemented by computation to permit more detailed comparison with project laboratory data.

The values and notations appearing in each column are self-explanatory, with the possible exception of four items. These are: Location of Sample, Fineness Modulus of the Aggregate, Identification of Tests Applicable to Recovered Asphalt, and Ash in Recovered Asphalt. The designations have been used throughout the report and are explained in a previous section, "Test and Computation Procedures and Definition of Terms."

Routine tests were performed on each shipment of asphalt, but no record was maintained relating the different shipments to paving locations. For this reason average values have been employed to indicate the test properties of the asphalt. As considerable difference is apparent between state and refinery test values, both have been presented for comparison with results obtained in the ERI laboratory.

DISCUSSION OF TEST DATA

The several sampled mixtures will be discussed collectively. Although the asphalt in the mixtures is of major interest, the aggregate and mixture composition is a most important factor affecting the service behavior of the experimental test sections.

As shown on the data sheets and graphs, there has been a pronounced modification of the paving composition during its six years of service. The most obvious characteristics of practically all sections is the presence of excessive asphalt, variable gradation of the aggregate, and marked rutting and displacement. These conditions were accentuated during the extremely hot weather, 105 to 110°F, at the time of the inspection.

Another contributing factor was the lack of previous experience with hot plant mixes by the supervisory and construction personnel. This test section was built during the transition period between road and plant mix construction. While no inventory of the plant and equipment was available, those familiar with the project history were critical of the equipment and control provided during the mixing and laying operations.

There was no mechanical method for incorporating the filler material. Loess was used as it was delivered from its place of natural deposit. When dumped into the mixer, the contained moisture rapidly converted to steam and caused the loess to be violently expelled from the hot mixture. Evidently, the dump gates of the mixer were not in good operating condition, as indicated by many references to "loss of dust" by the plant inspector. These conditions are evidenced, in the present paving, by visible differences in color, texture, and consistency of successive batches. Fortunately, the lessons learned on this project have been helpful in developing more adequate control and supervision of subsequent hot plant-mix asphaltic concrete paving in Nebraska.

Throughout this discussion the characteristics of the original mixture and those obtained from the paving samples are compared. Certain differences may be anticipated, for the reason that the Nebraska record is based upon a limited number of tests covering the entire experimental mixture, whereas the ERI laboratory data refer solely to the material in a particular sample. The resultant information is more indicative of a trend than a demonstration of explicit differences.

The gradation of the aggregate in the mixtures is an important consideration affecting paving stability and subsequent service behavior. The mixtures under consideration would be classified as dense graded, plant mix, bituminous surface courses. Three different sources of information have been selected in order to compare recommendations relative to the permissible range of aggregate in mixtures of this nature, as follows:

The Asphalt Institute,
Construction Specifications, Construction Series No. 80,
Type V, mixture.

American Association of State Highway Officials,
Specifications for Highway Materials, Part 1, 1950,
Page 44.

Ohio Oil Company,
Fundamentals of Asphalt Paving, 1949,
Exhibit D, Class I.

When plotted on Charts 1 and 2, in this appendix, the limits suggested by the Ohio Oil Company publication permit the use of a wider range in gradation in the body of the mixture and between 5 to 11% passing 200-mesh material. The A.A.S.H.O. tends to favor a coarser mixture throughout, but especially between the 1 in. and No. 10 sieves. Their recommended percentage passing the 200-mesh sieve is closely identical to that suggested by the Ohio Oil Company. In contrast, the Asphalt Institute favors a much more restricted grading band, its limits falling within the middle third of the Ohio Oil Company range and toward the finer side of the one proposed by A.A.S.H.O.,

except that they have suggested the range of passing 200-mesh material between 8 and 15%.

The gradations of the original Nebraska mixtures are plotted on Charts 1 and 2. In general, the mixtures containing dolomite as coarse aggregate (Nos. 1, 1B, 1D, 6B) are within the A.A.S.H.O band. Those mixtures containing gravel coarse aggregate (Nos. 2, 3, 4B, 4C) tend to be somewhat finer, but are within the Ohio Oil Company limits. However, the gradation does not accurately define the compactibility of an aggregate, and a mixture, to be satisfactory, must contain a percentage of asphalt which is consistent with the available void space.

Additional appraisal of the mixture and paving properties is made possible through the inspection of Table 2 in this appendix. In this table the relationship between the asphalt content and the voids in the mixture and paving have been lifted from Table 1 and assembled for comparison. Columns 1 to 5 list the voids in the mixtures, filled and total, and the excess or deficiency of space available to take care of volume changes in the asphalt. For convenience, the respective values have been expressed in terms of the percent of asphalt by weight of the mixture. Nebraska records give densities obtained by laboratory compaction of plant-prepared mixtures, but not the densities of mixtures after construction. Also, only average daily asphalt contents are available. Thus it is not certain that these data accurately represent the original composition of the mixtures of the sampled areas. The data do indicate a tendency to fill, or overfill, the voids of the aggregate. As indicated in columns 6 to 9, the comparison between the initial volume of voids from the Nebraska laboratory tests and those found in paving samples indicates a marked increase in density. This was probably due to initial undercompaction. The vibratory action of traffic doubtless promoted further consolidation or lateral displacement of the paving surface, with the attendent expulsion of the excess asphalt from the voids in the aggregate as the particles were brought into more intimate contact. Columns 10 to 15 indicate the changes in the volume of the asphalt in the mixture during the years of service, and support the foregoing observations that inadequate void volume had been provided to accomodate the asphalt used in the mixtures.

Columns 16 to 19 contain information relative to the initial and recovered asphalt. It was unfortunate that the tests on the initial asphalt entering into each of the mixtures could not be identified. In absence of such information the average data had to be used. The apparent low loss in penetration contrasts sharply with the results obtained upon asphalts from other sources, such as the Texas Company and the Ohio Oil Company. A tabulation of selected data is shown below:

Source of Asphalt	Pen Grade	Location Used	Avg Initial Pen	Avg Pen as Recovered	% of Original
Frontier	100-120	Nebr. S-10	128	76	59.38
Ohio	120-150	Colo. Springs	132	37	28.03
Texas	120-150	Wyo. U.S. 87	128	46	35.94

It should be pointed out that the Frontier asphalt was decidedly oily, that initial rolling of the hot mixture was at times delayed in order to avoid excessive shoving and checking. The comments of engineers of the area were to the effect that mixtures containing asphalt from this source must be handled carefully and that somewhat less than the usual design percentage should be used in order to obtain satisfactory results. They also stress the oily nature of the product.

Low loss in penetration as shown by tests on recovered asphalt is generally regarded as a favorable characteristic. With respect to Frontier, this may not be the case, since its behavior in these Nebraska Sections may be due, in part at least, to the unbalance of the mixture designs.

The ductility test results seen have no significance.

The E.R.I ring-and-ball softening-point tests provide data for comparison with similar values of the original material and are tabulated below. Again it should be pointed out that Nebraska records provide only average values. The computed ratios should be studied with this limitation in mind.

PROPERTIES OF ASPHALT—ORIGINAL AND RECOVERED

Mix	ERI	Orig Asph		Recovered Asphalt		% Change		Orig Ratio	ERI Ratio
No.	No.	pen	s.pt	pen	s.pt	pen	s.pt	s.pt-pen	s.pt-pen
1-edge	M49	128	110	72	121	-43.7	+9.8	0.867	1.681
1-owp	M50	128	110	87	117	-32.0	+6.5	0.867	1.344
1-edge	M51	128	110	78	121	-39.0	+9.8	0.867	1.551
1-owp	M52	128	110	78	121	-39.0	+10.3	0.867	1.551
6B-edge	M53	128	110	48	127	-54.6	+15.2	0.867	2.646
6B-owp	M54	128	110	88	118	-31.2	+7.3	0.867	1.341
1B-edge	M55	128	110	89	118	-30.4	+7.0	0.867	1.326
1B-owp	M56	128	110	70	118	-45.2	+7.5	0.867	1.686
1D-edge	M57	128	110	86	115	-32.8	+4.9	0.867	1.337

PROPERTIES OF ASPHALT—ORIGINAL AND RECOVERED (Continued)

Mix No.	ERI No.	Orig Asph pen	Orig Asph s.pt	Recovered Asphalt pen	Recovered Asphalt s.pt	% Change pen	% Change s.pt	Orig Ratio s.pt-pen	ERI Ratio s.pt-pen
1D-owp	M58	128	110	85	116	-33.5	+5.5	0.867	1.365
2-edge	M59	128	110	86	113	-32.8	+2.9	0.867	1.314
2-owp	M60	128	110	71	118	-44.5	+7.3	0.867	1.662
3-edge	M63	128	110	67	121	-47.6	+10.1	0.867	1.806
3-owp	M64	128	110	64	125	-50.0	+13.5	0.867	1.953
4B-edge	M65	128	110	83	121	-35.1	+10.4	0.867	1.458
4B-owp	M66	128	110	76	116	-40.6	+5.7	0.867	1.526
4C-edge	M67	128	110	76	118	-40.6	+7.5	0.867	1.553
4C-owp	M68	128	110	85	118	-33.6	+7.0	0.867	1.388

	Ratio ERI s.pt-pen to Orig s.pt-pen
1-edge	1.957
1-owp	1.565
1-edge	1.806
1-owp	1.806
6B-edge	3.080
6B-owp	1.561
1B-edge	1.544
1B-owp	1.963
1D-edge	1.556
1D-owp	1.589
2-edge	1.530
2-owp	1.935
3-edge	2.102
3-owp	2.273
4B-edge	1.697
4B-owp	1.776
4C-edge	1.808
4C-owp	1.616

Attention is directed to Mix No. 5A, Table 1, this appendix. In the preceding discussion it has not been considered because of the great difference between this mixture and all others on this project. Mix 5A is a mixture of Nebraska blow sand and loess filler. It was used as surfacing, 1 in. in thickness, over a base course consisting of Mix No. 1.

As there are extensive areas in Nebraska where "blow sand" is the only material available for road construction, this mixture was tried in order to obtain some idea of its service behavior. It was fully expected to fail at an early date, and only a short section was constructed.

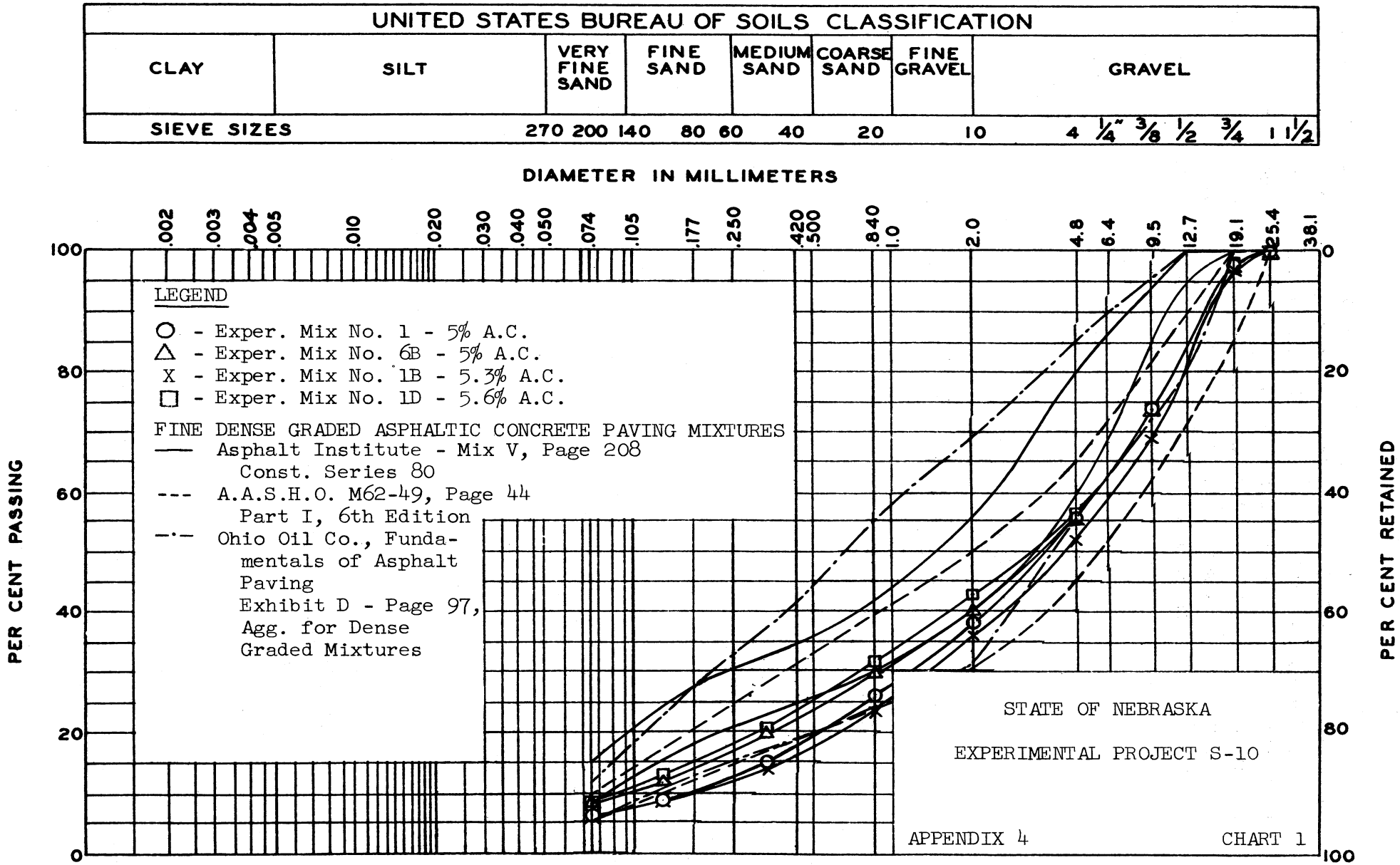
Contrary to expectations, both sand-surfaced sections, 5A and 5B, have been equal in performance to the best sand-gravel mixture, Section 4C, and markedly superior to mixtures No. 1, 6B, 1B, 1D, 2 and 3. The appearance is similar to that of sheet asphalt, as will be noted in the photographs. There has been no bleeding, corrugating or raveling. The measured rutting in 5A was 3/4 in. in the inner and 1/2 in. in the outer wheel path. An inspection of the sawed cross section of the paving samples M61 and M62, from the paving edge and outer wheel path respectively, shows that the original thickness of 1 in. has slightly increased in the edge sample, and decreased to approximately 1/2 in. in the outer wheel path. This is undoubtedly due to lateral displacement, as indicated by the increased edge thickness and slight bulging between wheel paths.

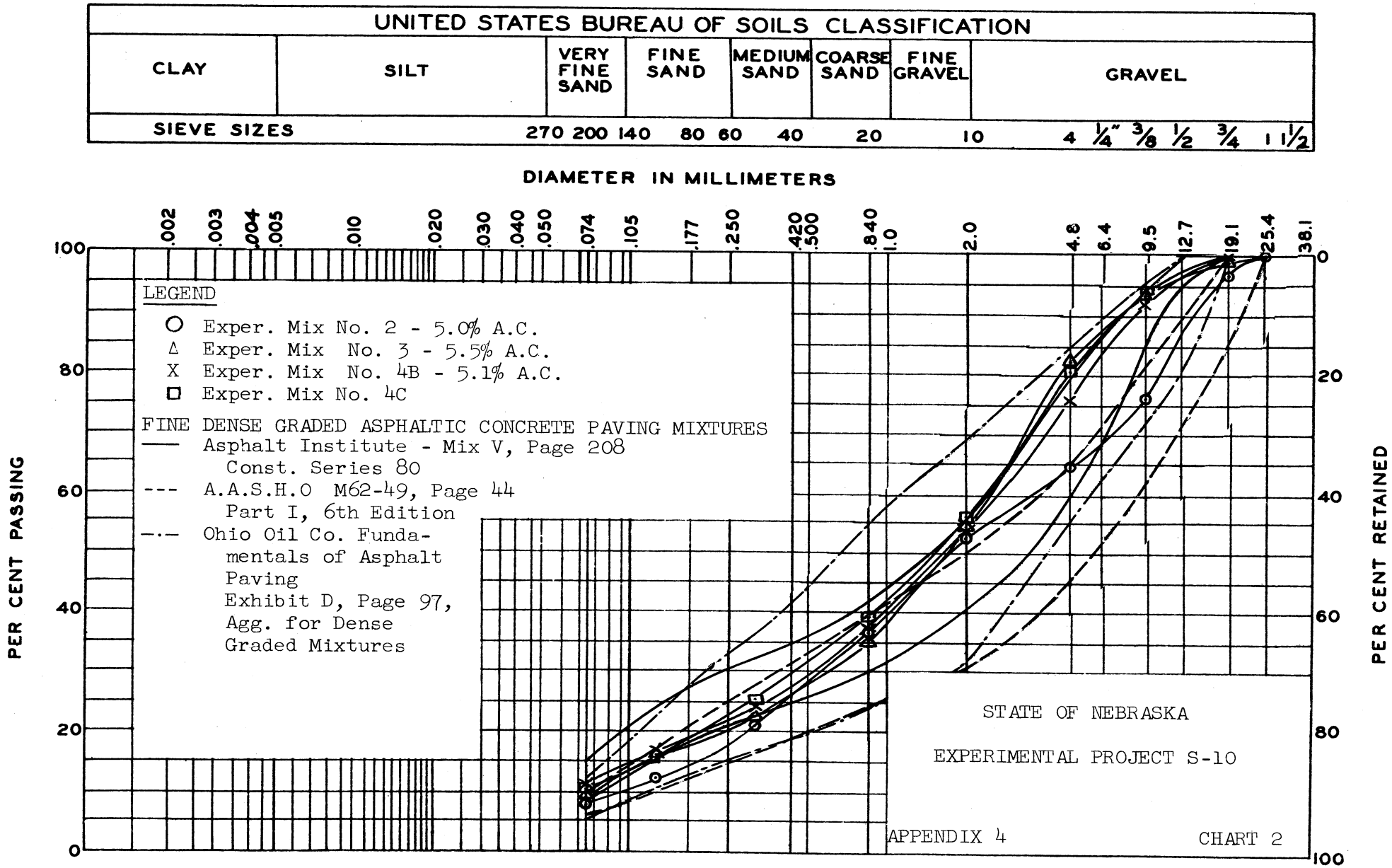
There is further conclusive evidence that the absence of flushing or bleeding of the asphalt can be attributed to the relatively large volume of voids present in the initial paving and not appreciably reduced after 6 years of service. While the volume of voids and voids filled with asphalt appears to have provided excessive space for the expansion of the bituminous material, the appearance of the paving surface indicates that it was satisfactorily closed and has a texture giving the appearance and performance of a satisfactory mixture.

The most pronounced difference between Mix 5A and others in this experimental section shows up in the recovered asphalt. These test data are shown in Table 1, this appendix, as samples M61 and M62. In common with all other mixtures, the average values for the original asphalt were used for comparative purposes. In all of the asphaltic concretes the penetration of the recovered asphalt ranged from a low of 48 to a high of 89, the average being 77. In the case of the sand-asphalt mixture, the penetration on the recovered asphalt was 30 on the sample from the untraveled edge and 26 in the heavily traveled outer wheel path. The ductility of the recovered asphalt in Mix 5A was 150+°F in the edge sample and 88°F in the sample from the outer wheel path. By comparison, all 18 samples of asphaltic concrete showed ductilities of well above 100 cm. The softening point of the recovered asphalt from the 5A mixture was 137.7°F and 139.10°F for mixture obtained from the untraveled edge and outer wheel path, respectively. For the remaining 18 samples of asphaltic concrete, the low softening point was 113.2°F, the high 126.7°F, and the average was 119°F.

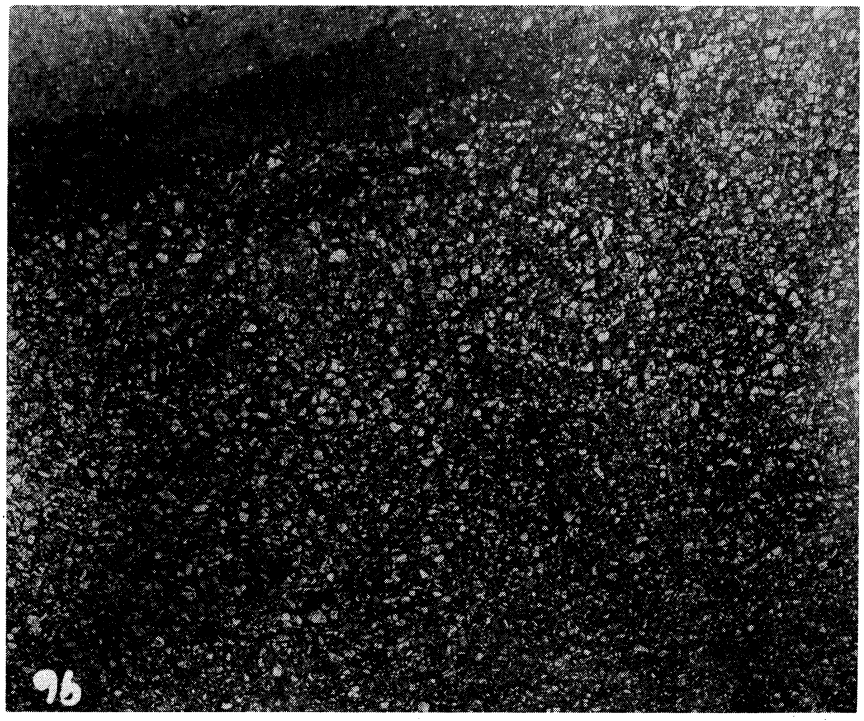
It is quite evident from the above that there was a materially greater rate of change in the same asphalt when employed in the finely graded blow sand mixture. Even though the records indicate that the sand

mixtures contained an appreciably greater amount of asphalt, it appears that the much larger surface area of the fine particles resulted in a decrease of the film thickness. This, combined with the unusually high void content of the paving mixture, served to expose the asphalt to more accelerated action of the factors tending to alter the original properties. Apparently, these factors which have materially reduced the penetration and ductility and have increased the softening point have improved the service characteristics of the resulting paving.

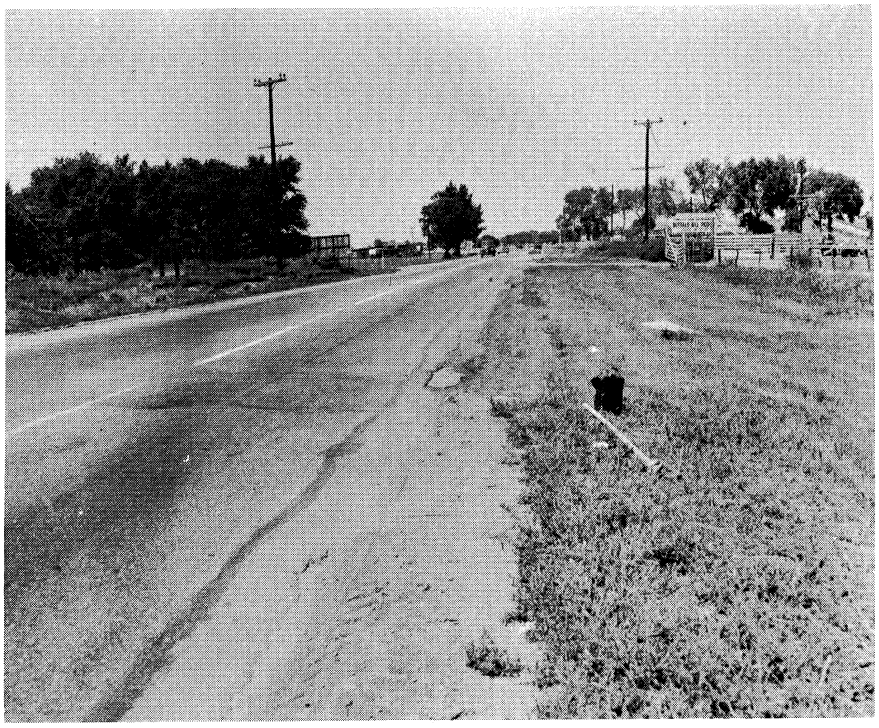

UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
PER CENT RETAINED
LEGEND
○ - Exper. Mix No. 1 - 5% A.C.
△ - Exper. Mix No. 6B - 5% A.C.
X - Exper. Mix No. 1B - 5.3% A.C.
□ - Exper. Mix No. 1D - 5.6% A.C.
FINE DENSE GRADED ASPHALTIC CONCRETE PAVING MIXTURES
—— Asphalt Institute - Mix V, Page 208 Const. Series 80
--- A.A.S.H.O. M62-49, Page 44 Part I, 6th Edition
—·— Ohio Oil Co., Fundamentals of Asphalt Paving Exhibit D - Page 97, Agg. for Dense Graded Mixtures
STATE OF NEBRASKA
EXPERIMENTAL PROJECT S-10
APPENDIX 4
CHART 1


UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
PER CENT RETAINED
LEGEND
Exper. Mix No. 2 - 5.0% A.C.
Exper. Mix No. 3 - 5.5% A.C.
Exper. Mix No. 4B - 5.1% A.C.
Exper. Mix No. 4C
FINE DENSE GRADED ASPHALTIC CONCRETE PAVING MIXTURES
Asphalt Institute - Mix V, Page 208
Const. Series 80
A.A.S.H.O M62-49, Page 44
Part I, 6th Edition
Ohio Oil Co. Fundamentals of Asphalt Paving
Exhibit D, Page 97,
Agg. for Dense
Graded Mixtures
STATE OF NEBRASKA
EXPERIMENTAL PROJECT S-10
APPENDIX 4
CHART 2

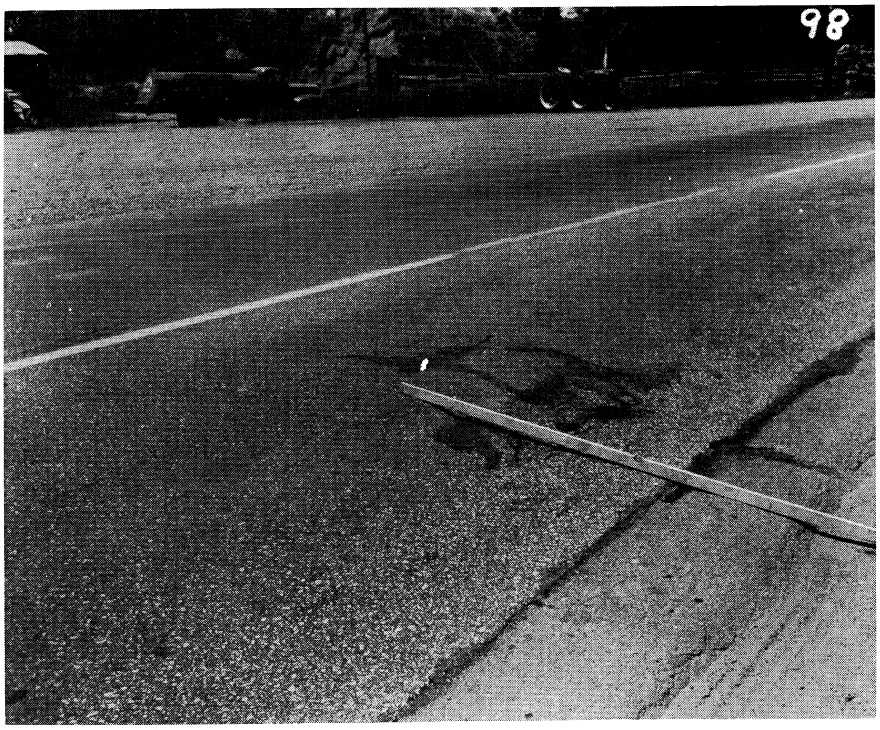
Picture 95. View of paving at junction of Mix No. 1 and Mix No. 6-A. Tendency for asphalt to flush in the wheel paths may be noted in both mix sections. Mix 6-A is considerably darker in color, with surface showing more pronounced flushing of asphalt.



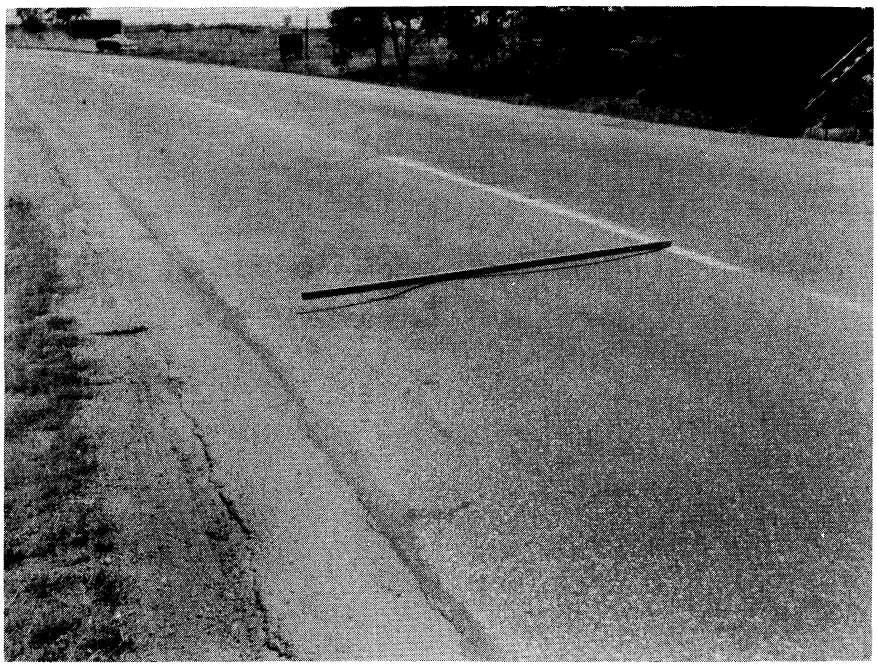
Picture 96. Close-up view of the surface texture of paving made from Mix No. 1.



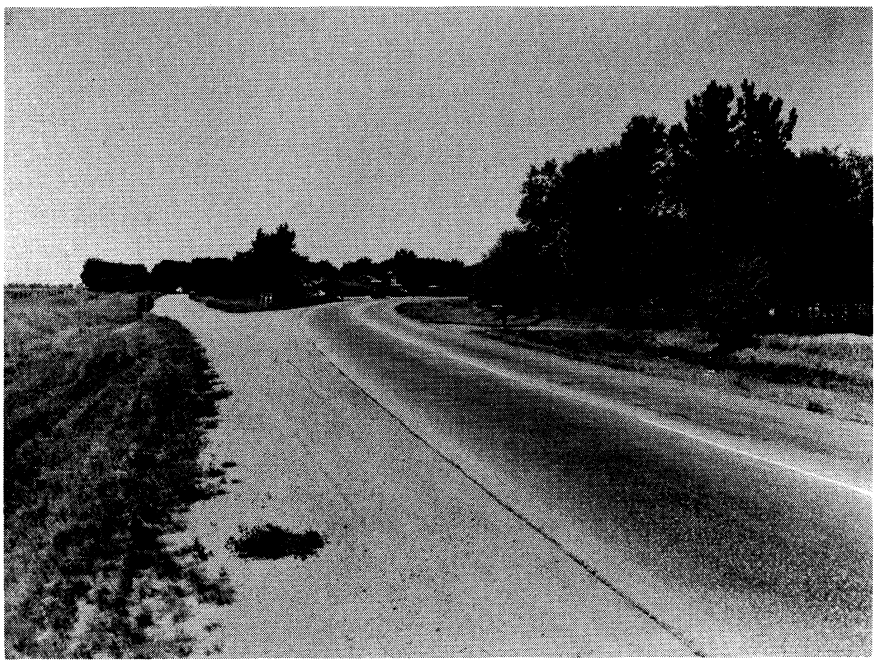
Picture 97. General view of the junction of paving made from Mixes No. 1 and No. 6-A, showing darker colored surface in No. 6-A and rutting in both wheel paths.



Picture 98. View showing the extensive rutting, 1-1/8 in., as measured from straight edge, in Mix No. 1 paving. The location shown is in the outer wheel path, westbound traffic lane, on inside of curve.



Picture 99. View of lateral displacement of paving surface and rutting in Mix No. 1. In this view the ruts measured 1-1/8 in. from straight edge. This longitudinal rutting was accompanied by shoving and chatter-bumps in the outer wheel path of the westbound lane.



Picture 100. General view of Mix No. 1 paving looking west from the point of curvature at Station 90+00, the start of the project. Excessive asphalt has been flushed to the surface, as indicated by the darker color in the general traffic area.

Picture 101. General view showing the uneven surface of paving made from Mix No. 1. The alternate light and dark transverse pattern indicates the location of longitudinal shoving and surface corrugations. These are particularly pronounced in the westbound traffic lane on the inside of the curve.

Picture 102. Close-up view of texture at the junction of Mixes No. 6-A and 6-B. In Mix No. 6-A there is pronounced rutting and corrugations on the curve, which are absent on the tangent. Rutting on section of Mix No. 6-B measured 3/8 in. in the inner wheel path and 1/2 in. in the outer wheel path, westbound lane. There were no pronounced corrugations in the 6-B paving.

Picture 103. View showing the contrast in paving texture and color at the junction of Mixes No. 1 and No. 2; Mix No. 1 is much darker in color and richer in asphalt content. Rutting in No. 1 is more pronounced on the tangent than in Mix No. 2.

Picture 104. This close-up view of paving surface made from Mix No. 1-A shows the excessive amount of asphalt flushed to the surface in the wheel paths. Although the air temperature was between 95° and 100°F at the time this picture was taken, there was no pronounced bleeding, and the surface asphalt was extremely plastic.

Picture 105. View showing the contrast in texture and color at junction of paving made from Mix No. 2 and Mix No. 3. Mix No. 2 appears to be definitely over-asphalted. Rutting in Mix No. 2 amounted to 3/8 in. in the inner wheel path and 1/2 in. in the outer wheel path. In Mix No. 3, rutting in both wheel paths was not in excess of 1/4 in.

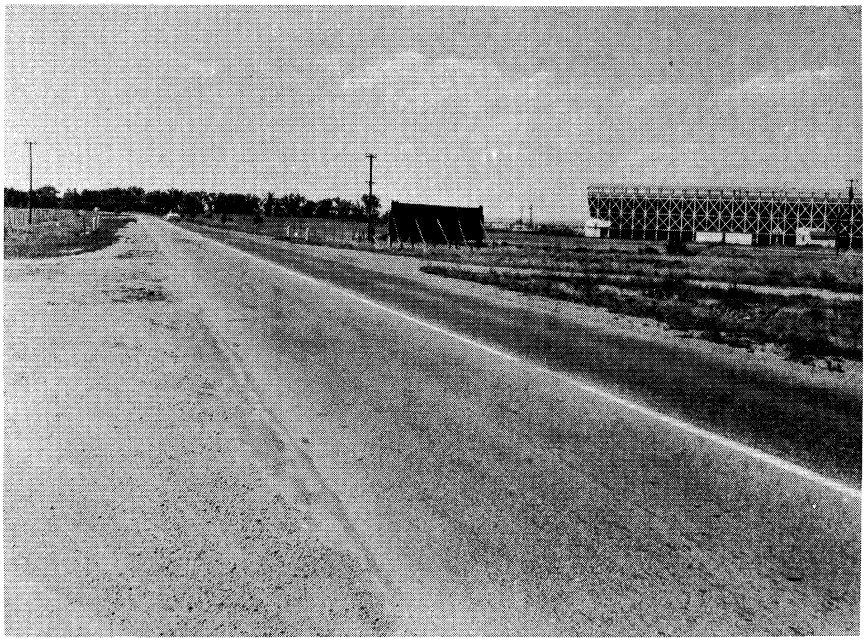
Picture 106. View showing the difference in color between Mix 1-A in foreground, westbound lane, and Mix No. 3, eastbound lane.

Picture 107. View showing the similarity in texture between Mixes No. 1-A and No. 1-B in westbound lane. Both sections of mixes have excessive amount of asphalt at surface. Rutting in Mix No. 1-B paving was 1/4 in., inner wheel path, and 1/2 in., outer wheel path.

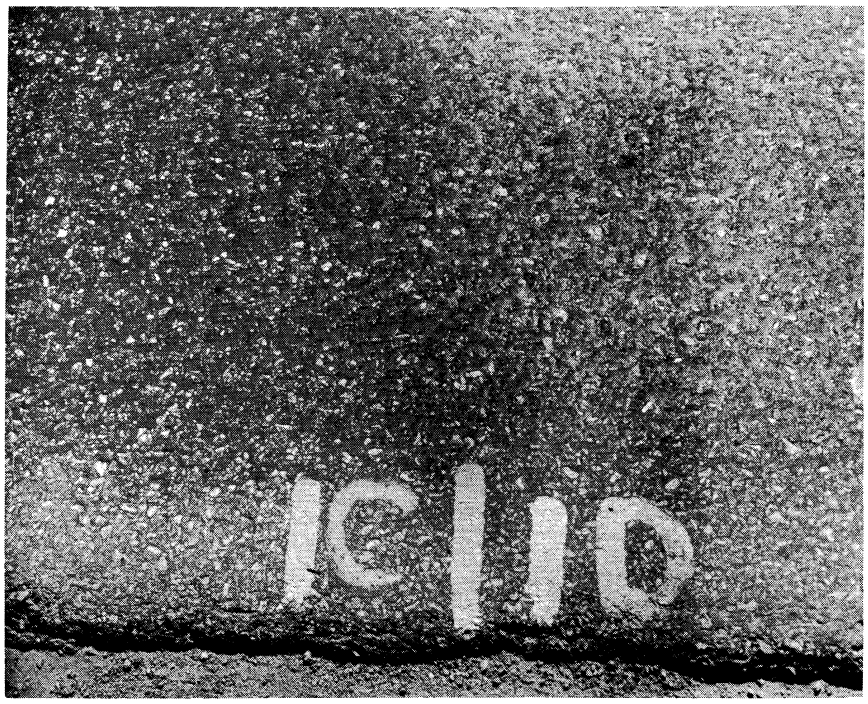
Picture 108. View showing negligible contrast in the surface texture and color of Mixes No. 3 and No. 4-A in the westbound traffic lane.

Picture 109. View taken at junction of paving as made from Mixes No. 1-B and 1-C. There were no corrugations or flushing, and rutting was negligible. At the time this picture was taken air temperature ranged between 98° and 102°F.

Picture 110. View of texture and color of paving made from Mixes No. 4-A and No. 4-B, eastbound lane. In both sections of mixes there was no apparent difference in surface performance, ruts were negligible, there were no shoving, corrugations, or ravelling.

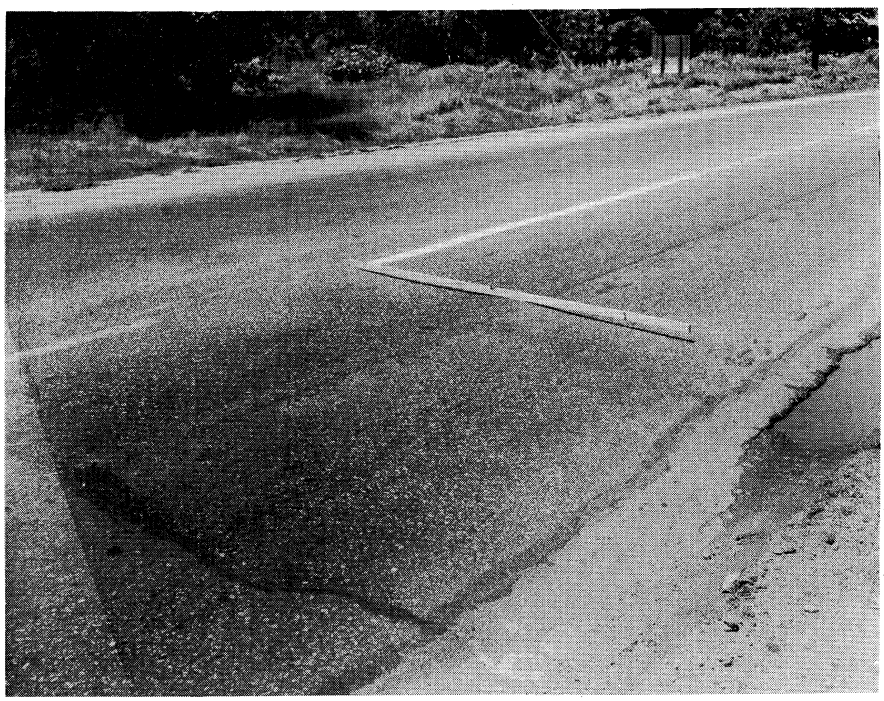


Picture 111. This view shows the contrast in color between the westbound lane (Mix No. 1-C) in the foreground, and the eastbound lane (No. 4-B). The darker color of 4-B, particularly in wheel paths, indicates flushing of asphalt to the surface.

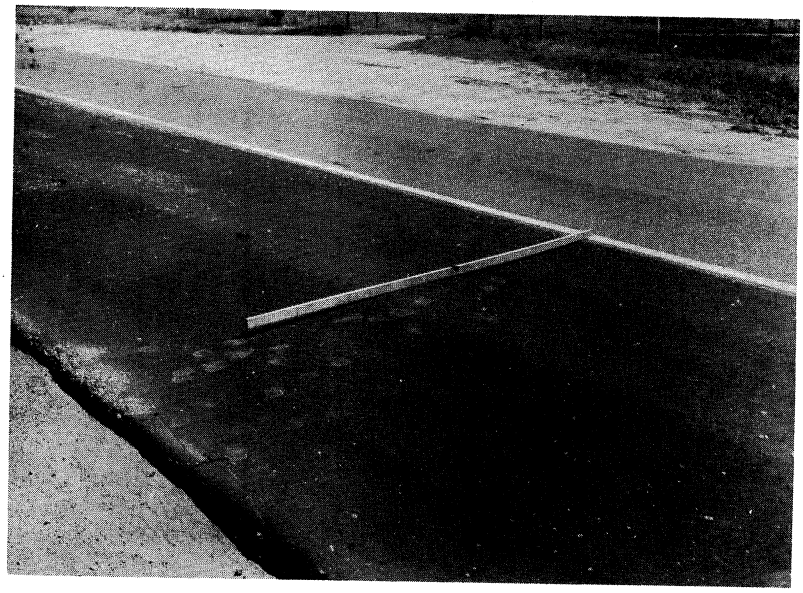


Picture 112. Close-up view showing the contrast in texture and color between paving made from Mixes No. 1-C and No. 1-D. Mix No. 1-D has a considerable amount of free asphalt on the surface, especially in the wheel paths, and has rutted materially more than No. 1-C. Ruts in the wheel paths of section made of Mix No. 1-D were 7/8 in. in inner wheel path and 1-1/2 in. in outer wheel path.

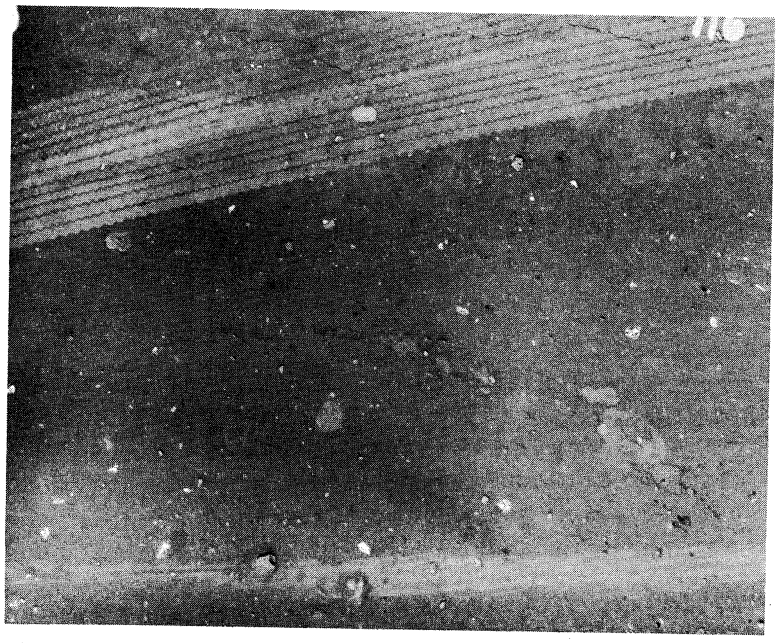
Picture 113. General view of the sand-asphalt surface made from Mixes No. 5-A and No. 5-B. This sand-asphalt was made from locally available fine blow sand with 10 to 15% loess filler and has been extremely effective from a service standpoint.



Picture 114. View showing rutting in the inner wheel path of westbound traffic lane in paving surface made from Mix No. 1. Rutting in inner wheel path, 7/8 in., in outer wheel path, 3/8 in.

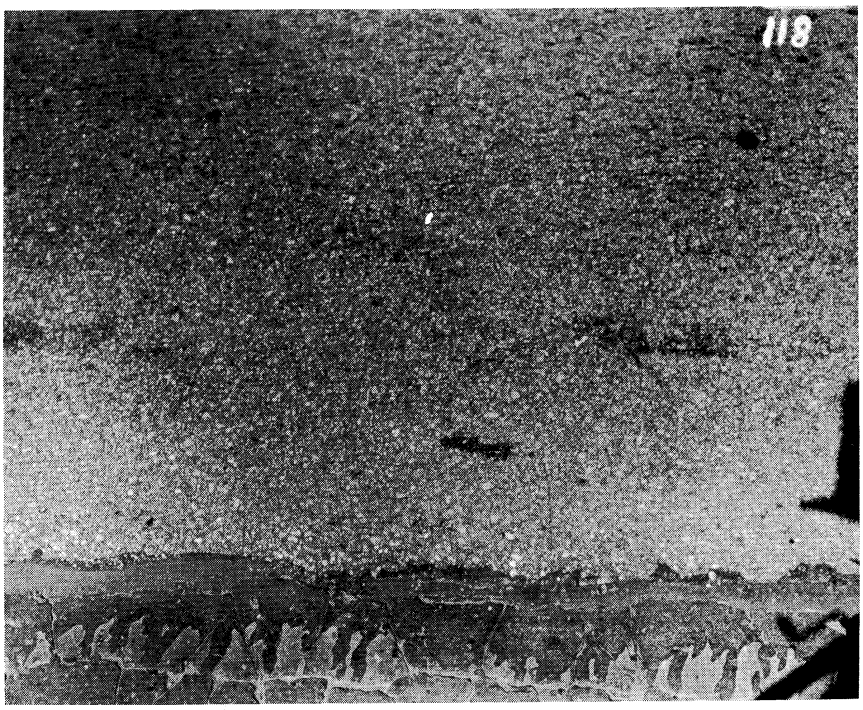


Picture 115. View of rutting in paving surface made from Mix No. 5-A, fine sand asphalt. Ruts in inner wheel path measured 3/4 in., outer wheel path, 1/2 in. There was no shoving, stripping, ravelling, or corrugation in this paving.



Picture 116. Close-up view of sand-asphalt paving texture as made from Mix No. 5-A. Slight pitting is apparent, due to balls of poorly mixed fine aggregate or the breakdown of larger soft particles. Pitting normally not more than 1/4 in. in diameter and 1/8 in. in depth. Only isolated fine hair cracking noted at random locations throughout this section.

Picture 117. Close-up view of paving texture at the junction of paving made from Mixes 5-A and 5-B. Mix 5-A contained 10% loess filler. Mix 5-B contained 15% loess filler. Such sand mixes, although considered as being low in stability, have proven equal or superior to other surfaces in this test section.



Picture 118. Typical view of texture and color of paving constructed from Mix No. 4-C, located in the eastbound traffic lane. Throughout this section there was no rutting, corrugation, ravelling, or flushing.

APPENDIX NO. 5

STATE OF NEBRASKA

ASPHALTIC CONCRETE

FIELD INSPECTION REPORT

State of Nebraska Project 170(6)
U. S. Route 30, North Platte to Maxwell
Picture Reference No. 119 to 134, inclusive

The asphaltic concrete paving on this project was constructed during the fall of 1947 and completed in the spring of 1948. Asphalt supplied by the Frontier Refining Company, Cheyenne, Wyoming, was 100-120 penetration grade. The records also indicate that four cars of the same grade of asphalt were supplied by Sinclair Oil Company of Rawlins, Wyoming. The location of the paving in which this asphalt was employed is uncertain, and, it may actually have been mixed with the material from Frontier. This paving was used for the purpose of resurfacing old concrete for a width of 24 ft and a designed thickness of 3 in. This project is reported to be the first hot plant mix paving construction undertaken by the Nebraska State Highway Department. Both mix design and construction control undoubtedly contributed to the present unsatisfactory paving condition.

Another factor was the use of coarse aggregate obtained from the Tobin Quarries, Guernsey, Wyoming. This material had not been previously used in Nebraska. It is a crushed dolomite with relatively high specific gravity and low absorption. It was combined with sand-gravel from the Platte River, fine sand from a local pit, and loess filler from a deposit on the Nebraska State Farm, adjacent to North Platte. Officials of the Nebraska State Highway Department believe that the use of excessive asphalt in this paving was partially due to their failure to recognize the characteristics of the dolomitic aggregate.

One of the most noticeable conditions observed throughout the length of this project was the excess asphalt which had been flushed to the surface. Not unusual are extensive areas over which asphalt, combined with a small amount of fine sand, cover the surface of the paving to depths of from 1/8 in. to 1/2 in. Rutting in the wheel paths, especially between mile 0.0 and mile 0.5, is abnormal and accompanied by considerable lateral displacement, shoving, and transverse corrugations or chatter-bumps. Recorded air temperatures at the time of inspection ranged from 105° to 110° F.

The balance of this section will be concerned with conditions observed at various locations throughout the project, supplemented by pictures taken at specific locations. Uniform color and texture of the paving surface may be taken as good criteria of mixture design and control. Throughout the length of this project extensive differences were found in the appearance

of adjacent traffic lanes, successive day operations, and in many cases between what appeared to be successive truck loads.

Attention is directed to picture No. 120 showing the contrast between the paving surface in this project and the adjoining pavement. Picture No. 123 shows the difference between the eastbound and westbound traffic lanes at mile 0.5. Picture No. 127 is a visual example of excessive asphalt flushing. Asphalt with low sand content is present on the surface to a thickness of at least 3/8 in. and has a plastic, unstable consistency. A typical variation between the paving color and texture in eastbound and westbound lanes is shown in picture No. 130. The eastbound lane in the foreground, while somewhat over-asphalted, is of such composition as to permit viewing the aggregate texture, while the surface in the westbound lane is uniformly covered with flushed asphalt.

The instability of the paving surface is manifested through extensive rutting. Pictures No. 121 and 122 show visual evidence of this condition. The view in picture No. 121 is taken of the westbound lane at mile 0.0, in which measured rutting in the inner wheel path is 1/2 in. and in the outer wheel path is 3/4 in. Picture No. 122 is a view of the eastbound lane. Ruts measure 1/2 in. in the inner wheel path and 5/8 in. in the outer wheel path. The view in picture No. 123 indicates the texture and color contrast between the eastbound and westbound lanes. The eastbound lane is in the foreground. At this location, rutting in the eastbound lane measures 3/8 in. in the inner wheel path and 5.8 in. in the outer wheel path. Picture No. 124, taken at mile 0.5, is a view showing pronounced shoving and rutting, where the depression below a straight edge laid on the paving surface measures 2-1/2 in. This extreme condition appears to be due to a corner failure of an underlying concrete slab. At mile 1.0 rutting in the westbound traffic lane measures 7/8 in. in the inner wheel path and 1 in. in the outer wheel path, with a similar condition existing in the eastbound lane in this area. Between mile 1.0 and mile 2.0 there are very severe transverse corrugations or chatter-bumps in both traffic lanes. Excessive asphalt has been flushed to the paving surface, and a "Slippery When Wet" sign has been erected as a warning to traffic. A member of the Nebraska State Police advised that this particular section of Route U. S. 30 has been the scene of numerous accidents, which police investigation had revealed were caused principally by vehicles going out of control under heavy brake application on the greasy, over-asphalted paving surface. The same oily exudation as that observed on Experiment Project S-10 (Appendix 4), in which Frontier asphalt was also used, was very noticeable on this project.

The Nebraska State Highway Department was at that time negotiating a contract for the resurfacing of this paving for the purpose of correcting these adverse conditions. This operation was scheduled for completion before November, 1954.

SAMPLE INDEX

Sample No.	Date Constd	Asphalt Pen	Asphalt Source	Sample Obtained From
M69	1947	100-120	Frontier	Sta. 165+20, Edge pvg. westbnd lane-untrav.
M70	1947	100-120	Frontier	" " OWP " -traffic
M71	1947	100-120	Frontier	Sta. 204+81, Edge pvg. eastbnd " -untrav.
M72	1947	100-120	Frontier	" " OWP " -traffic
M73	1947	100-120	Frontier	Sta. 331+52, Edge pvg. westbnd " -untrav.
M74	1947	100-120	Frontier	" " OWP " -traffic

PAVING MATERIAL TEST DATA

State of Nebraska Project 170(6)
Route U. S. 30-4.0 Mi. East North Platte City Limits a Distance of 7.54 Miles to Maxwell, Nebraska
Asphaltic Concrete Re-surfacing over Old Concrete Paving
100-120 Pen. Asphalt, Frontier Refining Co., Cheyenne, Wyoming

INTRODUCTION

This project was initiated in the fall of 1947 and completed in the early summer of 1948. Since very few of the original construction and laboratory test records are available in the files, a comparison of original and present mixtures and composition is of uncertain value.

The design thickness of the paving was to have been three in. However, due to the pronounced amount of rutting and shoving in the locations where the samples were obtained, there is considerable difference in the thickness.

The mixture design from Nebraska records is given in Table 1 of this appendix. However, the test results on E.R.I. samples do not check with that composition, and it seems apparent that the original design was not followed at the paving plant.

DISCUSSION OF TEST DATA

With respect to the aggregate gradation of the mixture as obtained from the samples and the mixture design for the project, there is only a slight

difference between fractions retained on the No. 10 sieve. Pass No. 10 and retained on No. 200 are closely identical. However, the fines, the percent passing the No. 200 sieve, vary widely. Occasional notations on the records indicate a large loss of loess filler during plant mixing operations and this loss is definitely reflected in the comparative gradations.

Irregularities in the surface began to develop almost immediately after the paving was constructed. The conditions noted at the time of inspection are the worst encountered on any bituminous paving surveyed in connection with this project.

The comparison between the averaged test values of the original asphalt and of those recovered from the E R I samples may be taken as an indication of the change in the test properties of the material while in service. The comparative data are tabulated below:

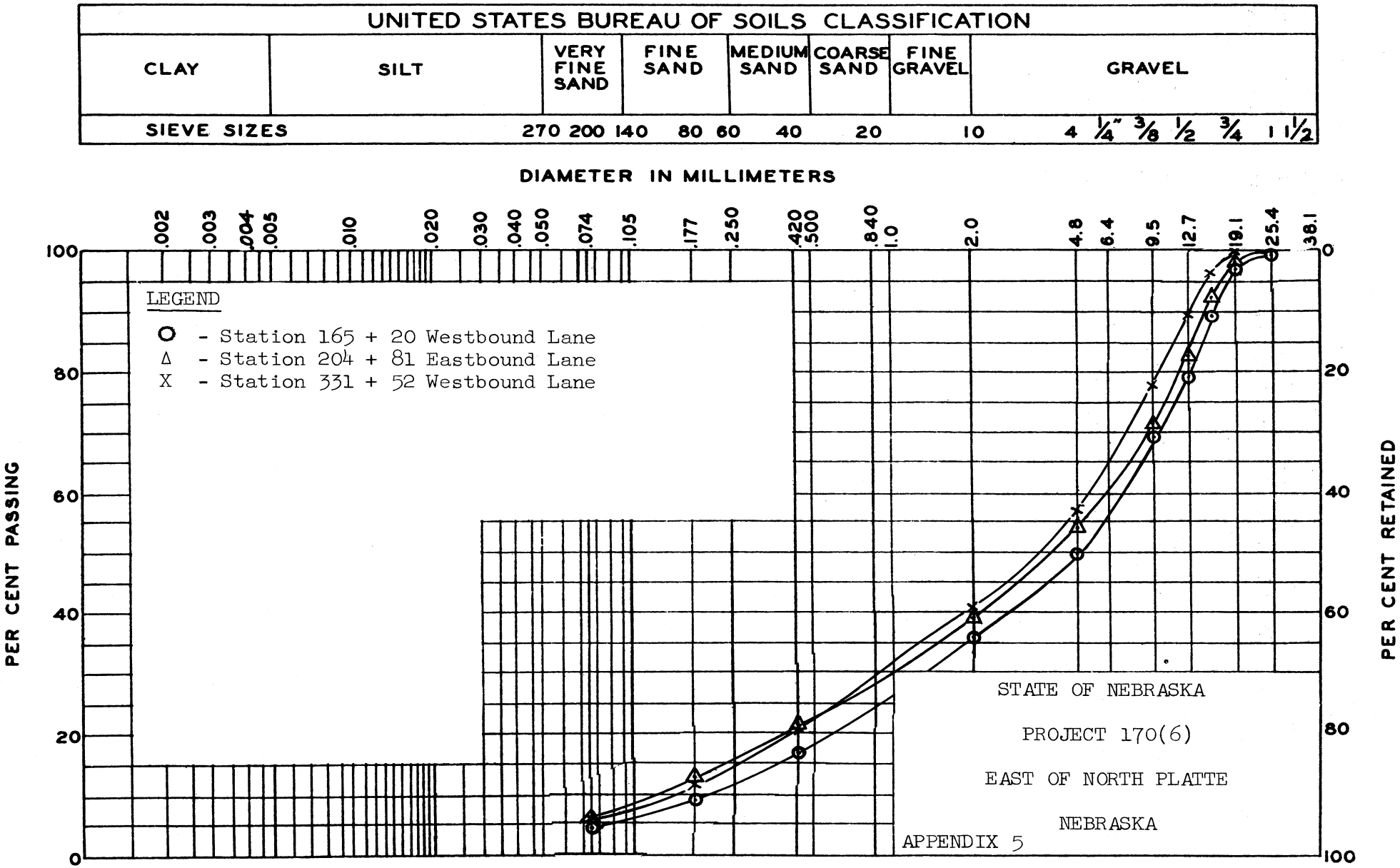
PROPERTIES OF ASPHALT—ORIGINAL AND RECOVERED

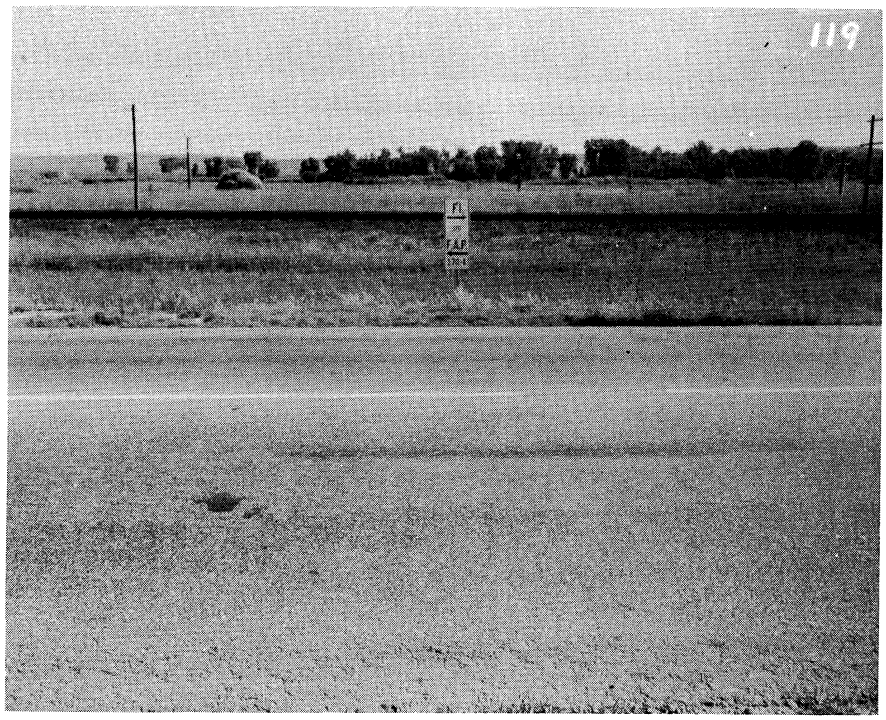
ERI No.	Sample Location	Orig Asphalt Pen	Orig Asphalt S.Pt	Rcvd Asphalt Pen	Rcvd Asphalt S.Pt	%Chng. Pen	%Chng. S.Pt	Ratio Orig S.Pt–Pen	Ratio ERI S.Pt–Pen
M69	Sta.165+2 Edge	115	110	50	124	-56.5	+12.2	0.957	2.480
M70	Sta.165+2 OWP	115	110	59	124	-48.7	+12.2	0.957	2.102
M71	Sta.204+8 Edge	115	110	64	120	-44.3	+ 9.1	0.957	1.875
M72	Sta.204+8 OWP	115	110	71	117	-38.3	+ 6.4	0.957	1.648
M73	Sta.331+5 Edge	115	110	69	121	-40.0	+10.0	0.957	1.754
M74	Sta.331+5 OWP	115	110	77	120	-33.0	+ 9.1	0.957	1.558

	Ratio of ERI to Orig Ratio
M69	2.591
M70	2.196
M71	1.959
M72	1.722
M73	1.833
M74	1.628

It is interesting to observe that in all cases the penetration of the recovered asphalt in samples taken from the paving edge is lower than for that taken from the wheel paths. Although the mix was uniformly over-asphalted, it appears that traffic manipulation in the wheel paths has been effective in maintaining the asphalt at a softer consistency.

The foregoing relationships are applicable to the conditions as developed on this particular project. When these data are included with similar information obtained from other locations, it may be possible to indicate certain characteristics of Frontier asphalt. A comparison will be made in the body of this report.

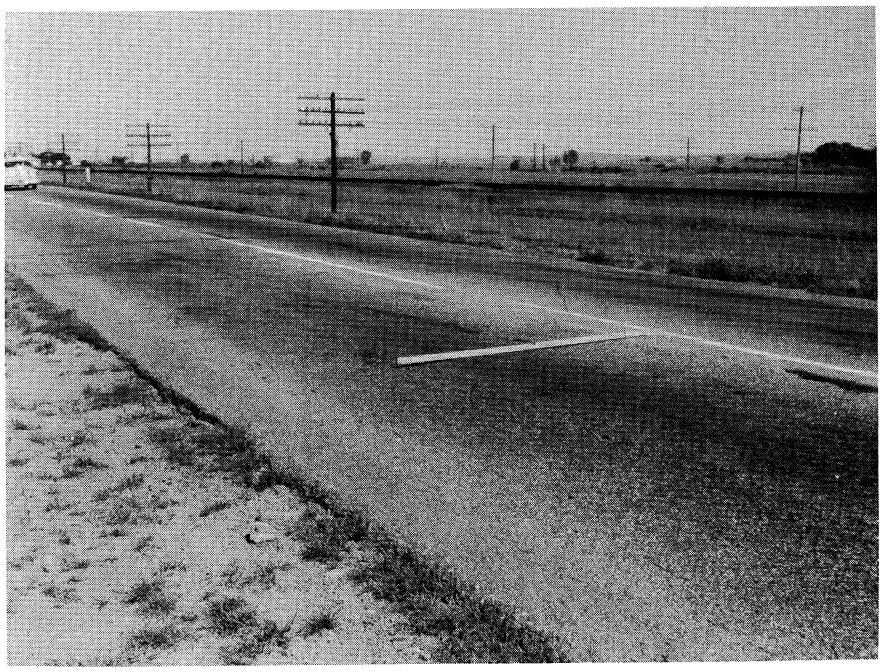

UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
PER CENT RETAINED
0 20 40 60 80 100
LEGEND
O - Station 165 + 20 Westbound Lane
Δ - Station 204 + 81 Eastbound Lane
X - Station 331 + 52 Westbound Lane
STATE OF NEBRASKA
PROJECT 170(6)
EAST OF NORTH PLATTE
NEBRASKA
APPENDIX 5



Picture 119. View of the start of the project at Nebraska Station 80+72.3, which equals Mile 0.0 on car speedometer. A difference between wheel path color and texture may be noted in both lanes as contrasted to untravelled or light-traffic areas. This is due to asphalt flushed to surface.

Picture 120. Taken at start of job, Mile 0.0, showing the junction between paving in this project, 170(6), at right, and connecting project. The difference in color of paving is due to excess asphalt in Project 170(6).

Picture 121. View of rutting at start of job, Mile 0.0. The asphalt flushed to the surface is particularly apparent in the more heavily travelled wheel paths. In the westbound lane the ruts in the inner wheel path (IWP) are 1/2 in., and are 3/4 in. in the outer wheel path (OWP).

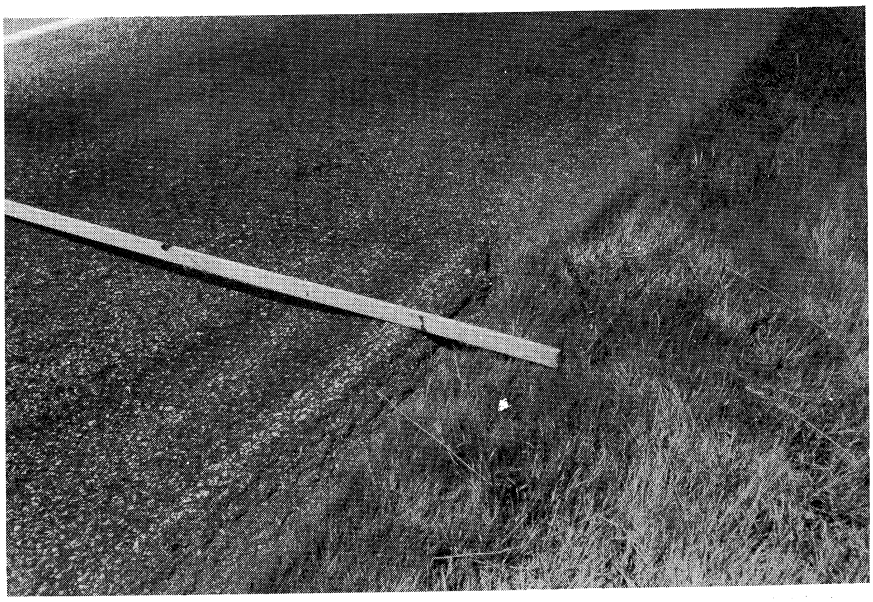


Picture 122. View of rutting at start of job, Mile 0.0, in the eastbound traffic lane. The rut in the IWP is 1/2 in., in the OWP, 5/8 in. At the junction of this project, 170(6), and the adjoining one toward the west, there is a pronounced bump, apparently caused by a moving paving joint in the underlying old concrete paving. This condition produces marked impact effect from passing wheels.

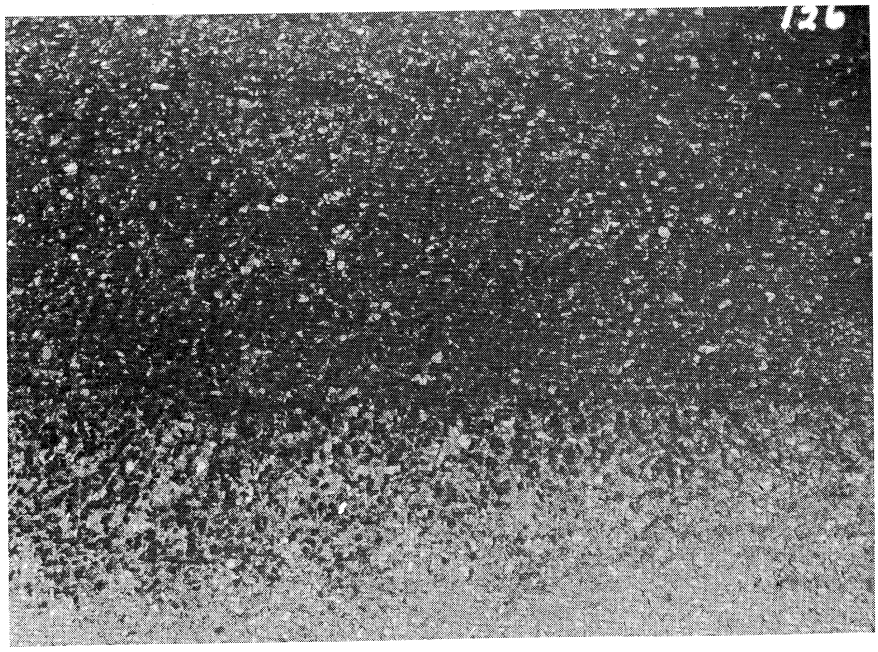
Picture 123. View of paving at Mile 0.5 showing the contrast in color of the paving surface between the east- and westbound lanes. Such difference in color is most significant as a criterion of construction control, indicating variation in mixture composition and asphalt content.

Ruts in the westbound traffic lane, background in this picture, are: IWP, 3/8 in.; OWP, 5/8 in. In the eastbound lane, ruts measured: IWP, 3/8 in.; OWP, 5/8 in.

Between Mile 0.0 and 0.5 the westbound traffic lane, south side of the roadway, is very black in color, with considerable free asphalt on the surface. This initial half-mile contains numerous transverse cracks which have been carried through from the resurfaced old concrete paving. Crack intervals are approximately 40 ft from the centers.

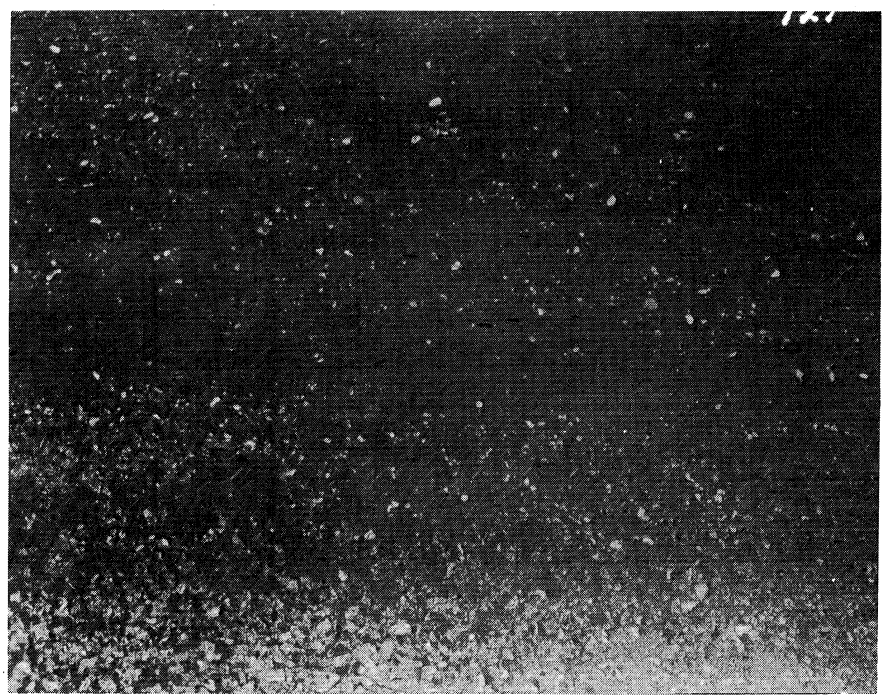


Picture 124. At Mile 0.5, marked rutting and displacement of the asphaltic concrete surfacing is apparent at the outer edge of the westbound traffic lane. The vertical displacement of the surface is 2-1/4 in. and appears to be largely due to the breaking of the corner of one of the underlying old concrete slabs.



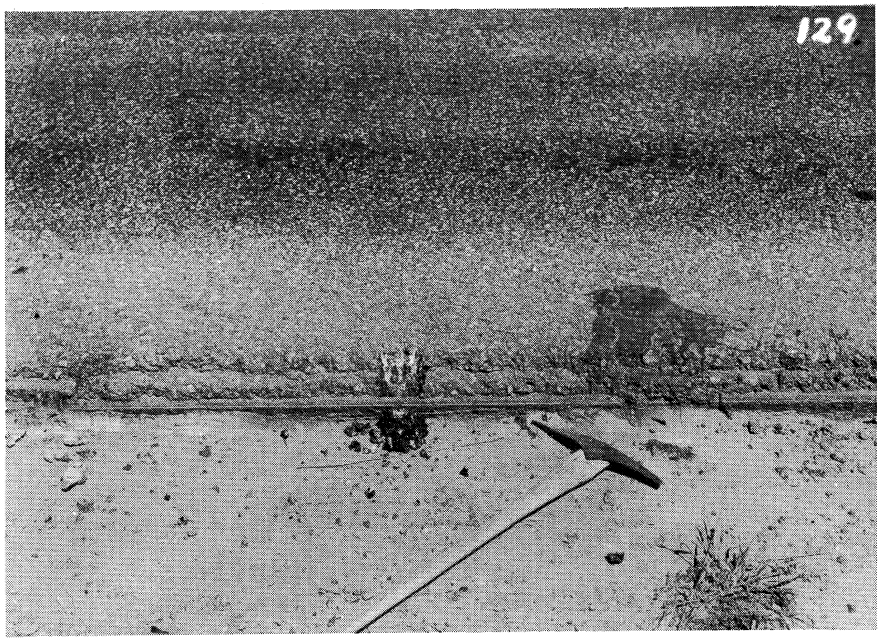
Picture 126. At Mile 1.5 the corrugations are very pronounced in the westbound traffic lane. The surface of both lanes is very black in color from excess asphalt flushed to the surface. In this section, free asphalt was removed from the surface with a spatula to a depth of 3/8 to 1/2 in.

Ruts in the westbound lane IWP were 7/8 in. and in the OWP, 1 in. In the eastbound lane ruts were 5/8 in. in the IWP and 5/8 in. in the OWP. This picture shows the overasphalted texture of the paving surface.

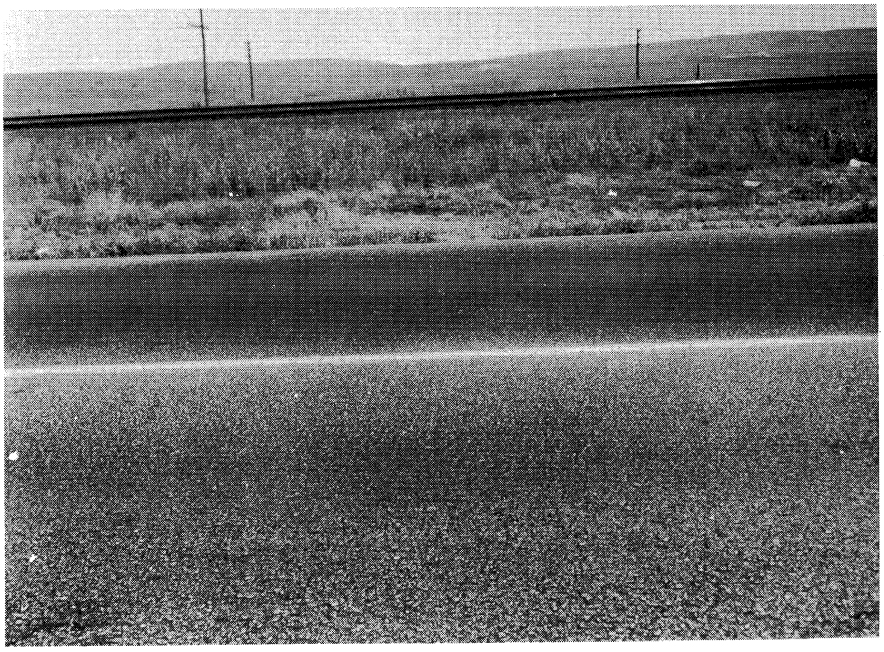


Picture 127. At Mile 2.5 there are extreme flushing conditions in the travelled wheel paths of both eastbound and westbound traffic lanes. At this location, free asphalt with slight amount of entrapped sand was 3/8 in. thick. Rutting in the westbound lane was 1/2 in. in both the IWP and the OWP. In the eastbound lane it was 5/8 in. in the IWP and 1 in. in the OWP.

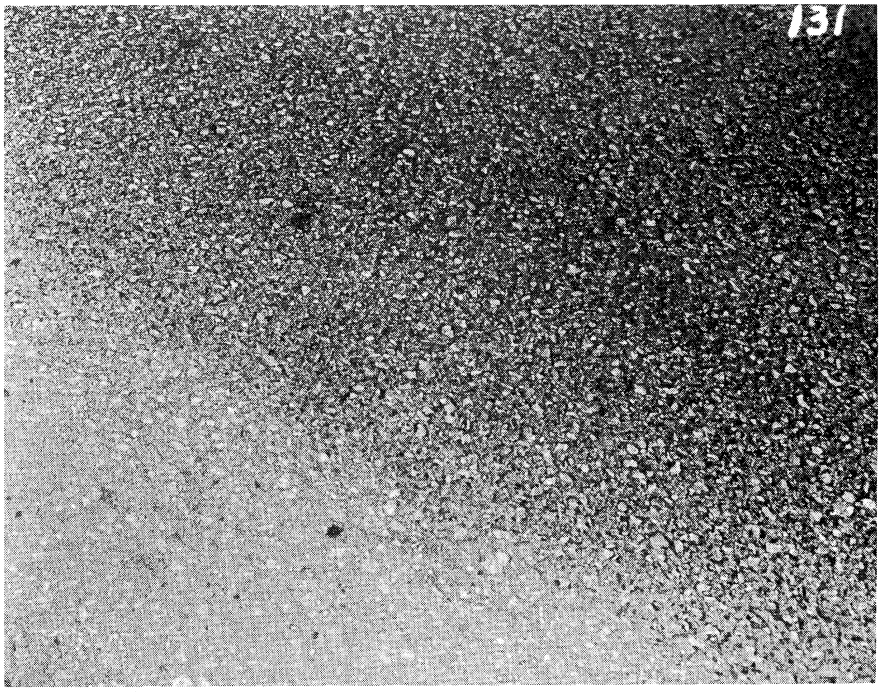
Picture 128. This picture, taken at Mile 3.0, shows the contrast between the untravelled edge and the wheel path in the eastbound lane. There was less asphalt flushed to the surface than previously encountered, but the voids in the aggregate seemed filled to capacity. Rutting in the westbound traffic lane was 5/8 in. in the IWP and 7/8 in. in the OWP, and was 1/2 in. in the IWP and 5/8 in. in the OWP of the eastbound traffic lane.



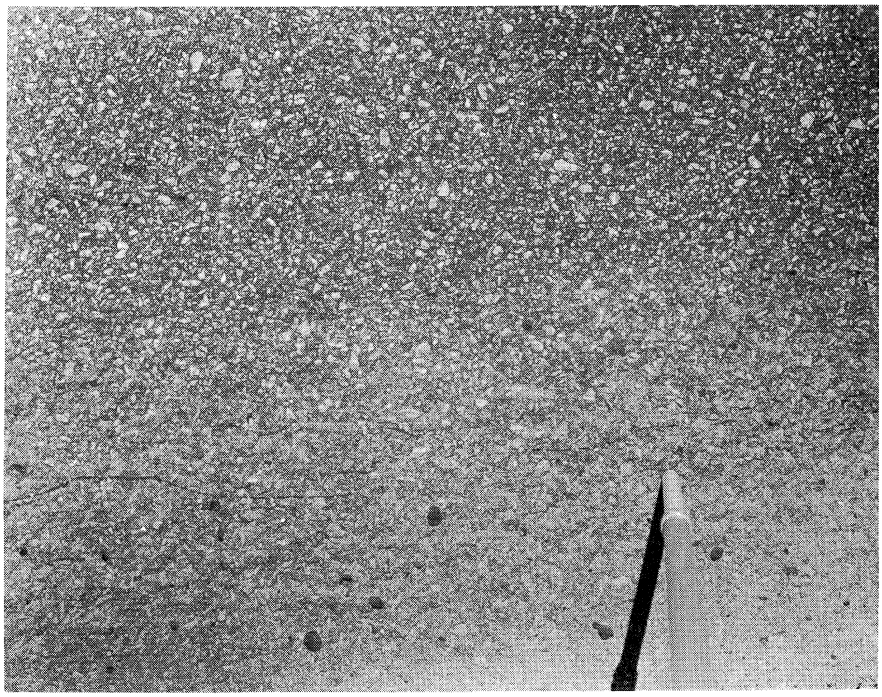
Picture 129. The view at Mile 3.0 shows the thickness of the asphalt concrete surfacing above the old concrete at the exposed edge of the eastbound traffic lane. The sample removed with a pick shows the contrast in color between the surface and the interior of the paving mixture. Flushing and spotty color in the wheel path in this picture is typical.



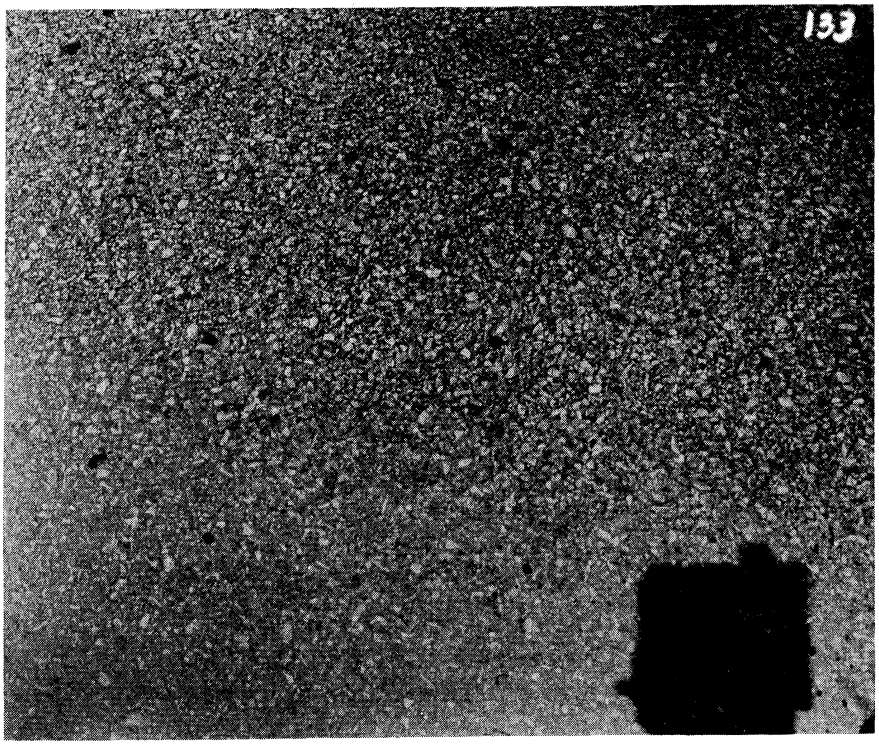
Picture 130. At Mile 4.0, the flushing of the asphalt in the westbound traffic lane, background, covered the texture of the aggregate, while the eastbound traffic lane, having lower asphalt content, had limited flushing and improved surface texture. Ruts in the westbound lane were 3/8 in. in the IWP and 1/2 in. in the OWP, and in the eastbound lane were 1/2 in. in both IWP and OWP.



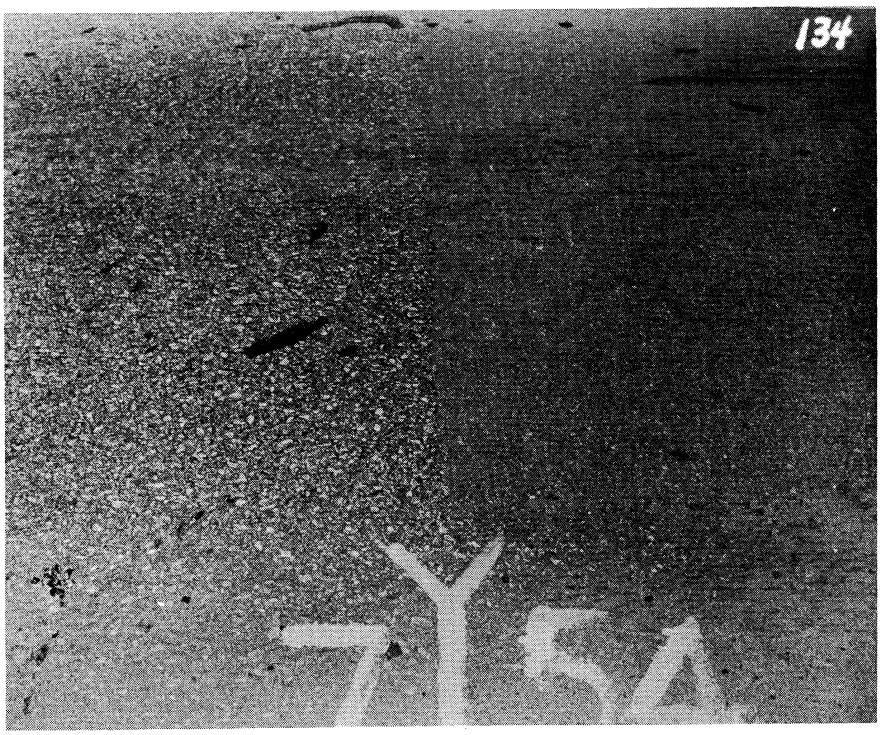
Picture 131. At Mile 4.5, there is a contrast between the outer edge of the eastbound lane and the adjacent outer wheel path. Rutting in the westbound lane was 1/2 in. in both IWP and OWP, and in the eastbound lane was 3/8 in. in IWP and 5/8 in. in OWP.



Picture 132. This view was taken at Mile 5.0. From this point on to Mile 7.54, the end of the project, the character of the paving surface was much improved, as is shown by the picture. Flushing and surface irregularities became very limited.



Picture 133. At Mile 6.0 the view shows the contrast between the untravelled edge and the outer wheel path in the eastbound traffic lane. The texture in the wheel path in this picture seems to be deficient in fines surrounding the larger aggregate particles. The paving is more stable and shows markedly less rutting than for previous sections inspected. Ruts in the westbound lane were 3/8 in. in the IWP and 5/8 in. in the OWP. In the eastbound lane they were 5/8 in. in the IWP and 3/8 in. in the OWP.



Picture 134. This view taken at Mile 7.54, the end of the project, shows the contrast between paving in Project 170(6) and that paving east of it. Project 170(6) is on the left and adjacent paving, a sealed road-mix type, on the right in the picture. Measurement of rutting in both types indicates the following:

Project 170(6)	Paving East of End of Project
Westbound IWP-1/4 in., OWP-3/4 in.	Westbound IWP-5/16 in., OWP-1/4 in.
Eastbound IWP-5/8 in., OWP-1/2 in.	Eastbound IWP-none, OWP-1/4 in.

APPENDIX NO. 6

WESTERN ASSOCIATION OF STATE HIGHWAY OFFICIALS
TEST ROAD AT MALAD, IDAHO

ASPHALTIC CONCRETE PAVING

FIELD INSPECTION REPORT

The information in this section will be very briefly presented. This experimental project was under the jurisdiction of the Highway Research Board. Mr. W. N. Carey, Jr., was the project engineer and is now engaged in preparing a report covering complete operations and results. Whether this report will be made public, in whole or in part, is probably the prerogative of the Western Association of State Highway Officials, who sponsored and contributed materially in the financing of operations.

Mr. W. M. Aldous, who made all the field investigations of this ERI project, served between September, 1953, and May, 1954, as Research Engineer on the W.A.S.H.O. Test Road. Any engineering interpretations relative to the detailed performance of the several test sections will not be discussed in advance of the publication of the report by the Highway Research Board or W.A.S.H.O. A condensed summary will, however, be presented for the reason that it will facilitate the interpretation of the data assembled in Table 1 of this appendix. These data were obtained from paving samples supplied through the courtesy of the W.A.S.H.O. organization.

This test installation was initiated to determine the relative merit and adequacy of several flexible paving designs employed by the member organizations of W.A.S.H.O., with particular reference to the service behavior of flexible paving under heavy truck and trailer traffic. Two identical test sections, joined by an access road and representing wide differences in design, were completed in the fall of 1952. Traffic was started immediately thereafter and continued until approximately December, 1952. No operations, except for intermittent 10,000-lb axle-load conditioning traffic, were maintained during the winter months. In 1953, traffic began in mid-June and was continued until late fall. It was again discontinued during the winter and resumed in the spring of 1954 until about June 1, when the test was completed.

The physical layout for the various test sections is presented in tabular form together with comments relative to their service behavior and condition as of April 30,1954.

NORTH TEST LOOP

Lane 1 — 18,000-lb single-axle-loading with dual tires on drive axle and trailer

Lane 2 — 22,400-lb single-axle-loading with dual tires on drive axle and trailer
O.W.P. — designates outer wheel path of lane referred to
I.W.P. — designates inner wheel path of lane referred to
Paving width — 24 ft or 12 ft per lane, throughout
All surfacing was asphaltic concrete—120-150 pen. asphalt, supplied by Phillips Petroleum Company, Pocatello, Idaho, refinery.
All test sections herein considered were 300 ft in length, with a 100-ft transition section between them.

Sect.	A.C. Pav. in.	Grav. Base in.	Gravel Sub-base in.	Axle Load Lane 1 lb	Axle Load Lane 2 lb	Vehicle Trips Lane 1	Vehicle Trips Lane 2	Paving Condition
A	4	2	16	18,000	22,400	103,460	103,302	No failures
B	4	2	12	18,000	22,400	103,460	103,302	No failures
C	4	2	8	18,000	22,400	103,460	103,302	No failures
D	4	2	4	18,000	22,400	103,460	103,302	Sl.crk.OWP only
E	4	2	0	18,000	22,400	103,460	103,302	OWP fail, IWP OK
F	2	4	16	18,000	22,400	103,460	103,302	No failures
G	2	4	12	18,000	22,400	103,460	103,302	Sl.crk.OWP and pch.
H	2	4	8	18,000	22,400	103,460	103,302	Crk.OWP, IWP OK
J	2	4	4	18,000	22,400	103,460	103,302	Fail.OWP,crk.IWP
K	2	4	0	18,000	22,400	103,460	103,302	Complete failure

Note: None of the samples investigated in the project laboratory for our operation were obtained from the above sections.

SOUTH TEST LOOP

Lane 1 — 32,000-lb tandem-axle-loading with dual tires on drive axle and trailer
Lane 2 — 40,000-lb tandem-axle-loading with dual tires on drive axle and trailer
O.W.P. — designates outer wheel path of lane referred to
I.W.P. — designates inner wheel path of lane referred to
Paving width — 24 ft or 12 ft per lane, throughout
All surfacing was asphaltic concrete, 120-150 pen. asphalt, supplied by Phillips Petroleum Company, Pocatello, Idaho, refinery.
All test sections herein considered were 300 ft in length, with a 100-ft transition section between them.

Sect.	A.C. Pav. in.	Grav. Base in.	Gravel Sub-base in.	Axle Load Lane 1 lb	Axle Load Lane 2 lb	Vehicle Trips Lane 1	Vehicle Trips Lane 2	Paving Condition
L*	2	4	16	32,000	40,000	103,587	103,360	Sl.crk.OWP,IWP OK
M	2	4	12	32,000	40,000	103,587	103,360	Crk.OWP,IWP OK
N*	2	4	8	32,000	40,000	103,587	103,360	OWP fail,IWP OK
O	2	4	4	32,000	40,000	103,587	103,360	OWP fail,IWP crk.
P	2	4	0	32,000	40,000	103,587	103,360	Entirely failed
Q*	4	2	16	32,000	40,000	103,587	103,360	No failures
R	4	2	12	32,000	40,000	103,587	103,360	No failures
S	4	2	8	32,000	40,000	103,587	103,360	Sl. failures
T*	4	2	4	32,000	40,000	103,587	103,360	Crk.OWP,IWP OK
U	4	2	0	32,000	40,000	103,587	103,360	Failed entirely

Note: Sections sampled for this project study were obtained from areas marked with (*).

The specimens obtained for our laboratory examination were taken from sections which had performed creditably. This was purposely done in order that we could evaluate the properties of the mixture and the asphalt under conditions not caused by failure in subgrade or inadequacy of thickness. Actually, the composition of the asphaltic concrete was the same throughout the project. The surfacing gave uniformly good service, the failures on the project being due to the inadequate structural design of certain sections.

PAVING MATERIAL TEST DATA

W.A.S.H.O. Test Road, Malad, Idaho
Asphaltic Concrete Surface on Gravel Base and Sub-base
120-150 Pen. Asphalt—Phillips Petroleum Company, Pocatello, Idaho

INTRODUCTION

The information in this report will include that from the ERI samples and W.A.S.H.O. tests. The data are included in Table 1 of this appendix.

PRESENTATION OF TEST DATA

The six paving samples represent the test sections employed on the project which have been subjected to the heaviest wheel loads. Three columns

in Table 1 have been assigned to each paving sample to facilitate ready comparison of test results from the three sources.

DISCUSSION OF TEST DATA

There is considerable difference between the gradation of the aggregate as reported for the original mixture and that obtained from the various paving samples. With respect to the aggregate retained on the no. 10 sieve, the percentage for the original material is uniformly less than that in samples M28, M32, and M29. Samples M30 and M33 contained less of such aggregate than reported in the original material, while the composition of sample M31 and the original paving are practically the same.

As compared to the original mixture, the pass 10 retained 200 material in the ERI samples M28, M32, and M29 is materially less, is closely similar in sample M31, and is definitely more in samples M30 and M33. In all cases, however, the pass 200 mesh material reported in the ERI samples is materially greater than reported in the original mixtures. This difference in the pass 200 mesh material is from 2.1 to 3.5 percent greater, which may be an indication of some degradation of the original aggregate or an appreciable dust coating on the larger particles of the original material, which had not been separated during the original analysis.

The relationships between asphalt, aggregate, and mixture properties, together with the data on asphalt recovery tests, are presented in Table 2, this appendix.

SAMPLE INDEX

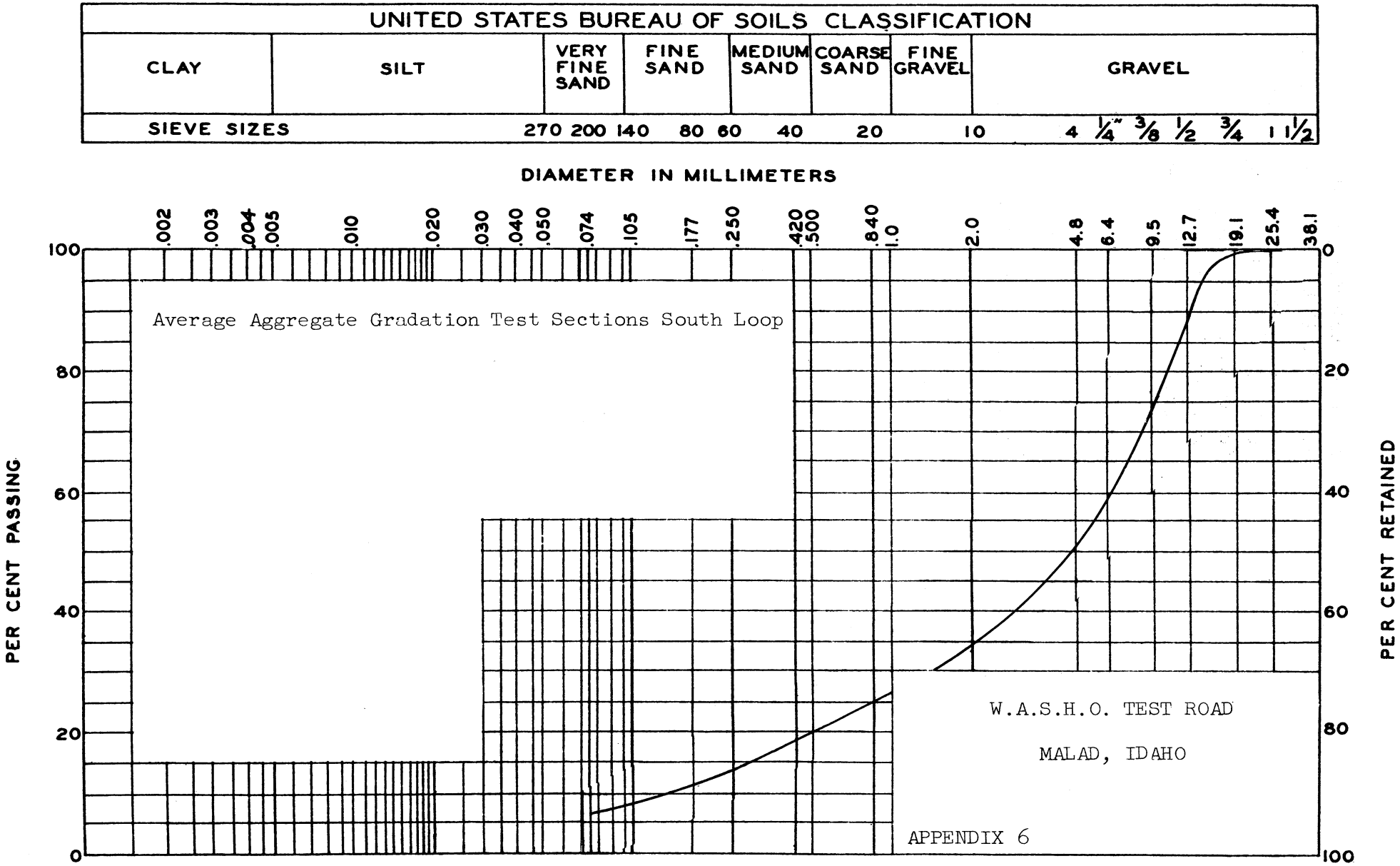
Sample No.	Date Constd	Asphalt Pen	Asphalt Source	Sample Obtained From
M-28	1952	120-150	Phillips	The South Turnaround at a point where an angle of 30° taken from center of the 150-ft-radius curve intersects the center line of this paving. The test track is shaped like a modified figure 8. This south turnaround provides the facility for trucks to move from the west to the east test sections. The test loads used on the south track imposed total tandem, dual-tired axle loads of 32,000 and 40,000 lb. While carried on individual test areas on the respective test

Sample No.	Date Constd	Asphalt Pen	Asphalt Source	Sample Obtained From
M-28 continued				sections they were both applied to the turn-around paving. As of April 30, 1954, this paving had been subjected to 103,360 vehicle coverages or 206,720 40,000-lb tendem axle loads plue 103,587 vehicle coverages, 207,174 32,000-lb tandem axle loads. The asphaltic concrete paving was approximately 4 in. thick, laid upon 2-in. gravel base and 16 in. of gravel sub-base. The location from which the sample was taken is on a super-elevated curve section. The heavy wheel loads with the addition of centrifugal force developed at the paving surface by the approximate test vehicle speed of 30 mph, imposed adverse service conditions. Personal observation by the author of this report, who was stationed at W.A.S.H.O. Test Road over a period between September, 1953, and May, 1954, indicates that this paving surface suffered no adverse effects from this concentrated traffic and is in excellent condition.
M-32	1952	120-150	Phillips	The South Turnaround in the end zone, at which location the trucks were normally accelerating prior to entering the straight-away section of the test track or were braking to reduce speed upon entering the curve. The same conditions reported under sample M-28 apply also.
M-29	1952	120-150	Phillips	Test section "Q", 200 ft from the start of section in Lane No. 2, which carried the 40,000-lb axle loads. This particular sample was obtained from the inner wheel path. The asphaltic concrete paving was approximately 4 in. thick, on 2-in. gravel base and 16-in. gravel sub-base. This paving test section had been subjected to 103,360 vehicle loadings—206,720 tandem axle loads of 40,000 lb each. In addition, there were 103,360 unrecorded loads applied by the front tractor, amounting to approximately 5,000 lb per wheel. This wheel was equipped with a single tire only. As of April 30, 1954, only slight rut-

M-29 continued				ting in the wheel paths were noticeable, with no apparent shoving, raveling, cracking, or irregularities. Aggregate texture was visible throughout, with no flushing apparent.
M-30	1952	120-150	Phillips	Test section "T", 200 ft from the start of section in Lane No. 2, which carried the 40,000-lb axle loads. This particular sample was obtained from the inner wheel path. The asphaltic concrete paving was approximately 4 in. thick, on 2-in. gravel base and 4-in. gravel sub-base. The difference between this 10-in. total thickness of paving and the 22-in. as reported in M-29 was the presence of spotty longitudinal cracking in the outer wheel path, approximately 2 ft from the edge of the paving. The balance of the paving surface in this section was satisfactory.
M-31	1952	120-150	Phillips	Test section "N", 200 ft from the start of the section in Lane No. 2, which carried the 40,000-lb axle loads. This particular sample was obtained from the inner wheel path. The asphaltic concrete paving was approximately 2-in. thick, on 4-in. gravel base and 8-in. gravel sub-base. Total thickness of paving section was 14 in. In common with all test sections under the 40,000-lb axle loading, this paving had been subjected to 103,360 vehicle loadings: 206,720 tandem axle loadings of 40,000 lb each, plus 103,360 5,000-lb applications from the single tire on the front axle of the tractor. In this section the entire outer wheel path area had entirely broken up and was replaced with patching material. The inner wheel path from which this sample was taken, while showing some rutting, was still serviceable, of good appearance, texture, and stability.
M-33	1952	120-150	Phillips	Test section "L", 200 ft from the start of the section in Lane No. 2, which carried the 40,000-lb axle loads. This particular sample was obtained from the inner wheel path. The asphaltic concrete was approximately 2 in. thick, on 4 in. of gravel base, and 16 in. of gravel sub-base. This paving test section

M-33 continued

had been subjected to 103,360 vehicle loadings, 206,720 tandem axle loads of 40,000 lb each. In addition, there were 103,360 unrecorded loads applied by the front axle of the tractor. The single tire loading per trip in this lane was approximately 5,000 lb. In this section on April 30, 1954, there was moderate longitudinal and map cracking in the outer wheel path adjacent to the gravel shoulder. In the inner wheel path, from which this sample was taken, despite slight rutting, the paving surface was normal in texture and appearance, showing little distress due to the extensive loadings which had been imposed.


UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
PER CENT RETAINED
100 80 60 40 20 0
Average Aggregate Gradation Test Sections South Loop
W.A.S.H.O. TEST ROAD
MALAD, IDAHO
APPENDIX 6

APPENDIX NO. 7

STATE OF IOWA

Project P-1028

ROUTE 64, MARSHALL AND STORY COUNTIES

ASPHALTIC CONCRETE PAVING

FIELD INSPECTION REPORT

Iowa State Project P-1028

Asphaltic concrete construction is relatively limited in Iowa. Concrete has been used extensively on the major routes, with the secondary highways usually surfaced with road mix. There is an increasing amount of interest in the use of asphaltic concrete for resurfacing the concrete paving.

A survey of the constructions accessible to inspection disclosed that only this project and one on Route 65 south of Mason City, reported in Appendix 8, were constructed solely from Wyoming asphalt. There were several other asphaltic concrete areas, but asphalt from several sources had been used without recording the exact locations in which each was used.

This project was constructed in 1952, using 85-100 penetration asphalt obtained from Husky Oil Company, Cody, Wyoming. The work included Route 64 from the Jasper County line to the junction with U.S. 30, and that portion of Iowa Route 330 from the junction of U.S. 30 to the west city limits of Marshalltown, but only the paving on Route 64 was inspected. This paving was laid as resurfacing over old concrete, which was in relatively good condition at the time of resurfacing, as is evidenced by the negligible amount of repair work and leveling course used prior to placing the bituminous surfacing.

The paving had not been in service long enough to have developed many indications of its probable service life. The color and texture was especially uniform. Except for the transverse cracking carried through from the old concrete paving, no irregularities could be observed. There was no rutting, showing, raveling, bleeding or chatter bumps over the entire area, and the riding qualities of the paving surface were excellent.

The field inspection was made during a period of cool, rainy weather, when the temperatures averaged between 70 and 85°F. Samples were picked from random locations and indicated that the bituminous mixture was live and tacky and that the asphalt adequately covered both the fine and large particles.

The pictures shows the condition of this paving. A review of the material test data indicates a high degree of uniformity of the mixture.

STATE OF IOWA
PROJECT P1028

Sample Index

Sample No.	Date Constd	Asphalt Pen.	Asphalt Source	Sample Obtained From
M75	1952	85-100	Husky	Sta. 300+00-nbnd lane-outer wheel path
M76	1952	85-100	Husky	" " " " -bet. wheel paths
M77	1952	85-100	Husky	" 700+00 nbnd lane-outer wheel path
M78	1952	85-100	Husky	" " " " -bet. wheel paths
M79	1952	85-100	Husky	" 1000+00 nbnd lane-outer wheel path
M80	1952	85-100	Husky	" " " lane-bet. wheel paths

PAVING MATERIAL TEST DATA

State of Iowa Project P-1028.
Route 64, Jasper County Line to Junction With U.S. 30
Asphaltic Concrete Resurfacing of Old Concrete Paving
85-100 Pen. Asphalt--Husky Oil Company, Cody, Wyoming

INTRODUCTION

This was the first project since Colorado Springs in which good control of aggregate proportioning was observed. Throughout Nebraska, with the exception of McCook, well-graded aggregates had not been available and careful attention to proportioning had not been exercised. The appearance of the paving texture and its uniformity are specially significant. The records indicate that all material used in this construction was processed commercially, with the exception of the fine sand, which was obtained from a wayside pit.

DISCUSSION OF TEST DATA

Reference is made to Table I of this appendix. The control of aggregate gradation and proportioning was especially good. Fifty individual tests covering this entire job operation are listed in State records. Using the fineness modulus of the aggregate as a criteria of uniformity, the maximum, representative of the coarse mixture, was 5.57; the minimum, applicable

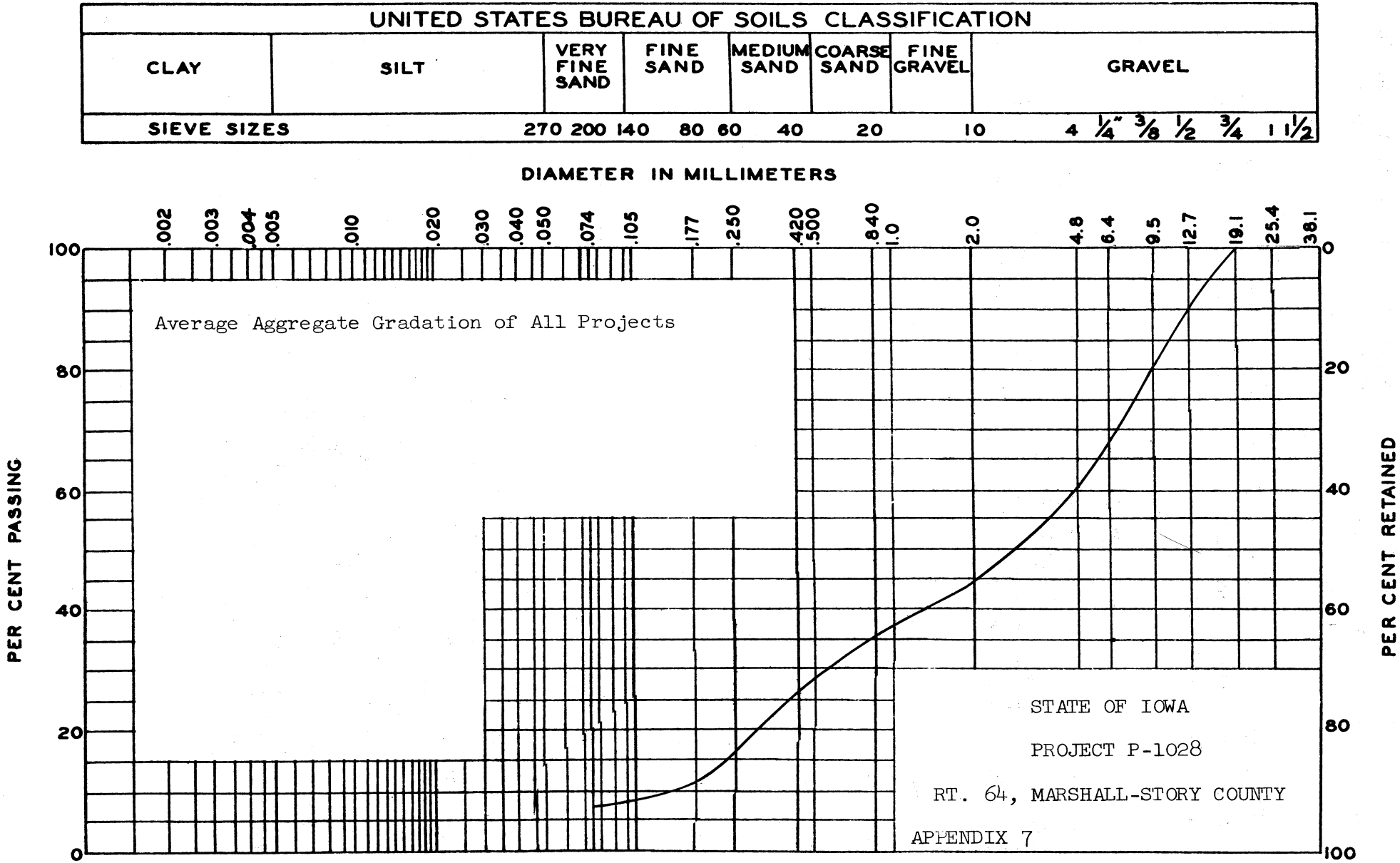
to the fine mixture, was 4.99, with the average being 5.25. Within the insignificant limits of plus-or-minus 0.10 of the average fineness modulus are 38 gradings, representing 76% of the mixtures.

Information on the asphalt used at the locations sampled was very satisfactory. It was possible to pin-point the asphalt used on each day's run and correlate the original tests with those made on the recovered asphalt. The results are tabulated below:

PROPERTIES OF ASPHALT—ORIGINAL AND RECOVERED

ERI No.	Sample Location	Orig Asph		Recovered Asphalt		% Change		Orig Ratio	ERI Ratio	Ratio to Orig
		pen	s.pt	pen	s.pt	pen	s.pt	s.pt-pen	s.pt-pen	
M75	Sta.300 OWP	92	114	44	129	-52.2	+14.1	1.239	2.932	2.366
M76	Sta.300 Bet.W.P.	92	114	30	134	-67.4	+17.5	1.239	4.467	3.605
M77	Sta.700 OWP	93	114	47	125	-49.5	+9.65	1.225	2.660	2.171
M78	Sta.700 Bet.W.P.	93	114	30	135	-67.8	+18.4	1.225	4.500	3.673
M79	Sta.1000 OWP	88	114	54	125	-38.6	+9.65	1.295	2.315	1.788
M80	Sta.1000 Bet.W.P.	88	114	32	132	-63.6	+15.8	1.295	4.125	3.185

A very pronounced pattern is developed through the comparison between the original asphalt and that recovered from the paving samples. In all cases the asphalt recovered from samples taken from the wheel paths, has appreciably less drop in penetration and lower increase in softening point than that contained in the samples taken from between wheel paths, the lightly traveled area. While these facts have been noted in other locations, the differences were not as consistent or as great as those observed here. An examination of the values for density of the aggregate, voids filled with asphalt, asphalt by volume, and the paving density, all confirm that such values were less for the untraveled area as compared with the traveled sections in the wheel paths. It appears that the properties of the asphalt may be definitely influenced by the degree of compaction and of service.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PER CENT PASSING
PER CENT RETAINED
100 80 60 40 20 0
Average Aggregate Gradation of All Projects
STATE OF IOWA
PROJECT P-1028
RT. 64, MARSHALL-STORY COUNTY
APPENDIX 7

STATE OF IOWA PROJECT P-1028, ROUTE NO. 64

APPENDIX 7
TABLE 1

PAVING MATERIAL TEST DATA. ASPHALTIC CONCRETE RESURFACING OVER OLD CONCRETE

Asphalt 85-100 Penetration - Husky Oil Company, Cody, Wyoming. 1952 Construction

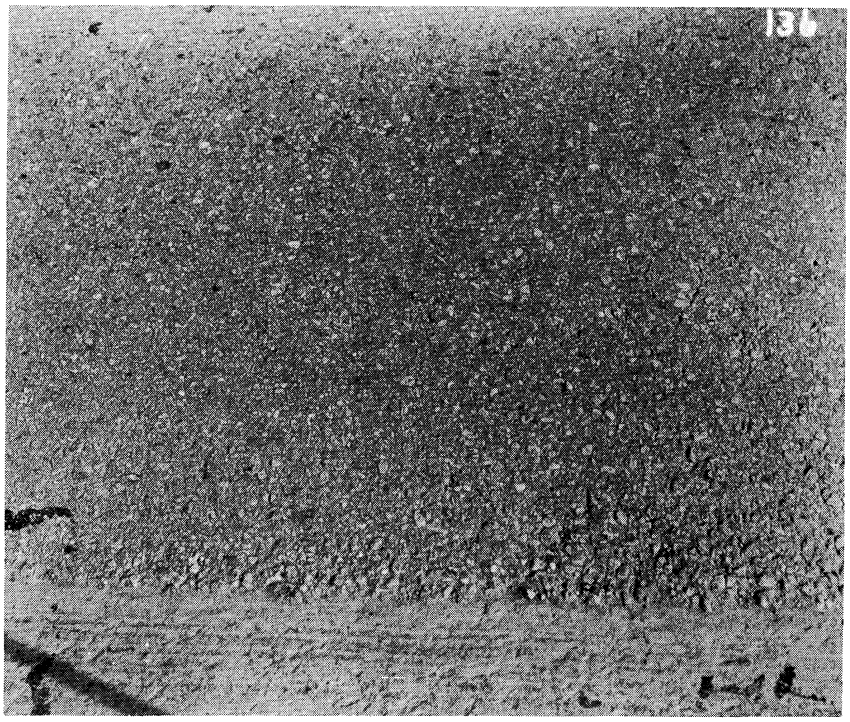
Control Items	E.R.I. Sample Mix	Iowa Paving Mix	E.R.I. Sample Mix	E.R.I. Sample Mix	Iowa Paving Mix	E.R.I. Sample Mix	E.R.I. Sample Mix	Iowa Paving Mix	E.R.I. Sample Mix
Year of construction		1952			1952			1952	
Extent of operations	14.928 mi. - 20.0' wide - 3" thick			14.928 mi. - 20.0' wide - 3" thick			14.928 mi. - 20.0' wide - 3" thick		
E.R.I sample number	M75-OWP	Sta 300	M76-bet WP	M77-OWP	Sta 700	M78-bet WP	M79-OWP	Sta 1000	M80-bet WP
Location of sample	Sta 300+00 - Nbnd Lane			Sta 700+00 - Nbnd Lane			Sta 1000+00 - Nbnd Lane		
Paving thickness - in.	2.875	3±	3.0	2.750	3±	2.625	2.750	3±	2.875
Weight - lb/sq yd									
Ret'd No. 10 sieve %	52.0	52.5	51.4	50.3	56.0	53.5	52.8	56.0	54.4
Pass 10 - ret'd 200 %	37.1	36.6	37.6	35.6	30.7	32.6	33.3	30.0	32.0
Pass No. 200 %	5.3	5.7	5.4	8.1	7.5	8.4	8.1	8.2	8.1
Asphalt content %	5.6	5.75	5.6	6.6	5.75	5.5	5.8	5.75	5.5
Percent crushed on No. 4	100.0	---	100.0	100.0	---	100.0	100.0	---	100.0
Fineness modulus	5.02	5.25	5.08	4.91	5.28	5.06	5.05	5.25	5.12
Approx. s.g. of aggregate	2.716		2.710	2.726		2.683	2.711		2.690
Density agg. - lb/cu ft	137.72	Project	134.54	137.26	Project	134.97	139.02	Project	137.16
Voids in aggregate %	18.75		20.44	19.31		19.38	17.83		18.29
Voids in agg. filled with A.C. %	67.48	Data	60.47	70.27	Data	62.75	74.43	Data	67.63
Asphalt by volume %	12.65		12.36	13.57		12.16	13.27		12.37
Solids in mixture %	93.90	Not	91.92	94.28	Not	92.78	95.44	Not	93.08
Solids in aggregate only %	81.25		79.56	80.69		80.62	82.17		81.71
Max. theor. density - paving	2.490	Available	2.485	2.482	Available	2.467	2.478	Available	2.499
Actual s.g. of paving	2.448	*	2.284	2.340	*	2.289	2.365	*	2.326
Paving density - lb/cu ft	145.89		142.52	146.02		142.83	147.58		145.14
Voids in paving %	6.10		8.09	5.72		7.22	4.56		6.92
Total voids filled with A.C. %	67.47		60.44	70.34		62.76	74.40		64.11
Air temp during opns. °F	---	85	---	---	70	---	---	60	---
Asphalt temperature °F	---	270	---	---	270	---	---	260	---
Aggregate temperature °F	---	305	---	---	300	---	---	300	---
Mix temperature °F	---	255	---	---	260	---	---	260	---
Laying temperature °F	---	240	---	---	245	---	---	250	---
Pen. 100 g - 5 sec - 77°F	R 44	92	R 30	R 47	93	R 30	R 54	88	R 32
Flash C.O.C. °F	---	530	---	---	530	---	---	590	---
Specific gravity at 60°F	---	1.035	---	---	1.035	---	---	1.034	---
Ductility - 77°F cm	R150+	100+	R150+	R150+	100+	R150+	R150+	100+	R150+
Loss on heating %	---	0.10	---	---	0.08	---	---	0.05	---
Pen. after 1. on h.	---	78	---	---	80	---	---	76	---
Sol. CCl_4 %	---	99.9	---	---	99.9	---	---	99.9	---
Soft point R and B °F	R129	**114	R134	R125	**114	R135	R125	**114	R132
Spot test	R pos	Olen neg	R pos	R pos	Olen neg	R pos	R pos	Olen neg	R pos
Ash in recovered asphalt %	R 1.31	---	R 1.22	R 1.39	---	R 2.95	R 0.35	---	R 2.02
Spot-15% xylene-85% Skelly S	neg		neg	neg		sl pos	neg		sl pos

*NOTE: No project record of maximum theoretical paving or actual paving specific gravity. No data in files on the specific gravity of aggregates.

**NOTE: Data from tests on 2-gallon sample.

E.R.I. Sample	Percent by Weight of Asphalt: To Fill Voids in Sample	In E.R.I. Sample	Excess Voids in Sample	Iowa Pvg Mix	Excess Voids in Iowa Pvg
M75	8.08	5.6	2.48	5.75	2.33
M76	8.94	5.6	3.34	5.75	3.19
M77	8.33	6.0	2.33	5.75	2.58
M78	8.49	5.5	2.99	5.75	2.74
M79	7.65	5.8	1.85	5.75	1.90
M80	7.92	5.5	2.42	5.75	2.17

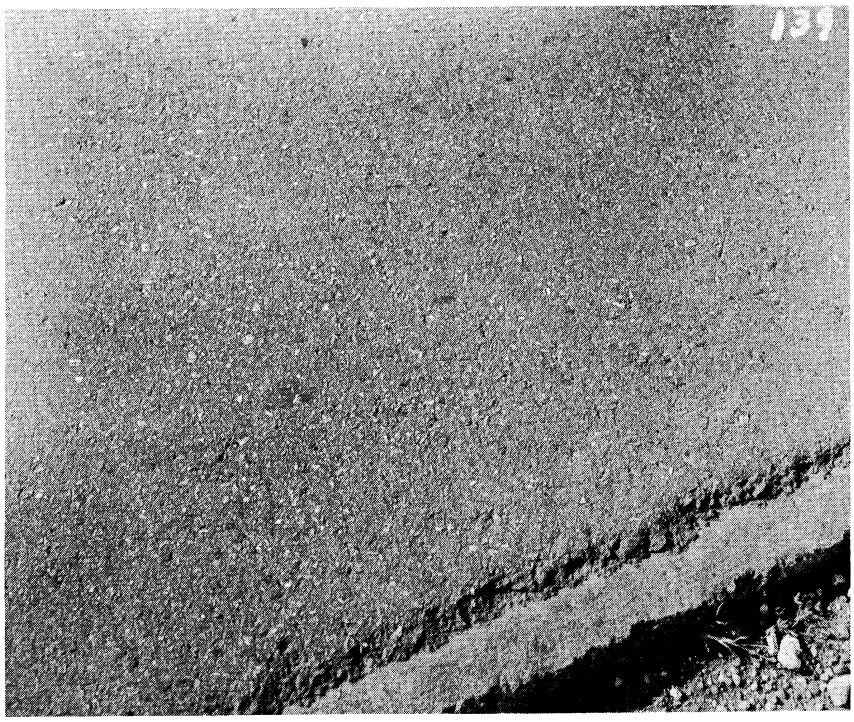
Picture 135. Start of project at Station 292+46. View of the highway showing the junction between the asphaltic concrete and Portland cement concrete at the Marshall-Jasper County line.



Picture 136. Close-up view of the asphaltic concrete paving texture. This granular texture is typical for the entire paving.

Picture 137. Transverse crack carried through from the old concrete paving. Such cracking was observed throughout the length of the project.

Picture 138. General view of highway looking north from Station 295+60. Route marker No. 64 and Marshall County sign appear on the right of the highway.



Picture 139. Close-up view of paving surface taken in the north-bound traffic lane, showing the east edge and outer wheel path. Old concrete paving is visible in the foreground of the picture.

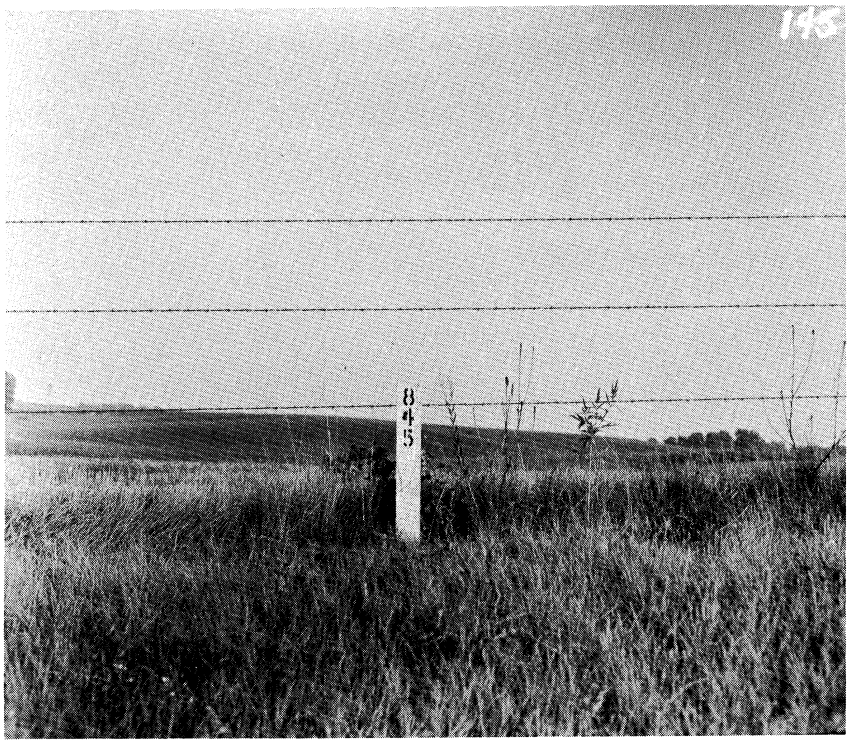
Picture 140. Typical transverse cracking carried through from underlying old concrete paving. Maintenance of these cracks was good, as only four were found unsealed over the entire project.

Picture 141. View of the east edge of the paving at Station 495+00, showing the edge thickness of asphaltic concrete over the old concrete.

Picture 142. View of typical texture at Station 495+00.

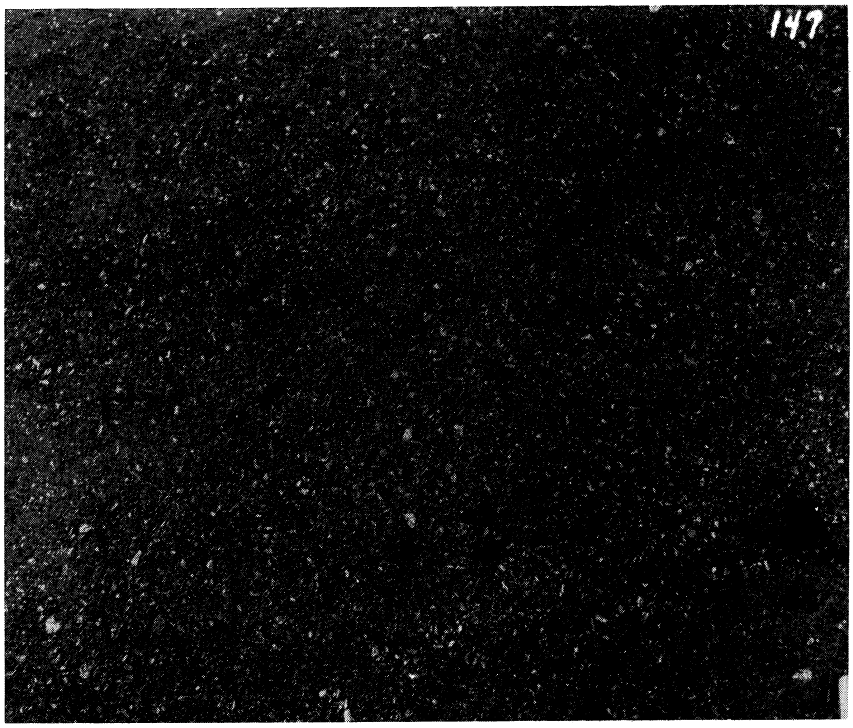
Picture 143. Another view of typical transverse cracking.

Picture 144. The worst transverse crack observed throughout the length of the project. Some minor breaking may be noted at the edges of the crack. This broken-edge section was in the southbound traffic lane, between wheel paths.



Picture 145. View of an Iowa standard right-of-way and stationing marker. These are spaced at 500-feet intervals and provide a ready location check.

Picture 146. Taken at Station 1080+00, which is just south of the junction of Route 64 and U.S. 30. The asphaltic concrete varied from full thickness to zero in the approach area serving the junction.



Picture 147. Close-up view of the paving texture at Station 1080+00.

Picture 148. View of the few longitudinal cracks occurring throughout the project. This was located along a line where the normal asphalt paving thickness was beveled from 3 to 0 inches in approximately 2 feet. This might have been eliminated had a longer bevel been employed.

APPENDIX NO. 8

STATE OF IOWA

PROJECT 115(4)

ROUTE 65, CERRO GORDO COUNTY

ASPHALTIC CONCRETE PAVING

FIELD INSPECTION REPORT

Iowa State Project 115(4)

This asphaltic concrete was used for resurfacing and widening of existing concrete paving on Route 65, south of Mason City, Iowa. The work was done in the fall of 1948 and spring of 1949. The paved width is 22 ft—18 ft over concrete and 2 ft of widening over crushed-limestone macadam at each edge. The paving thickness is 1-1/2-in. at center and 1-7/8-in. at the edge of the concrete, with 5 in. of asphaltic concrete over the 6-in. crushed-stone base widening.

The asphalt was supplied by the Standard Oil Company and was of 70-85 penetration grade. The records indicate that this material was shipped from the refineries at Casper, Wyoming, Sugar Creek, Missouri, and Wood River, Illinois. Job records are extremely sketchy and do not clearly indicate where cars of material from the different sources were used. By the process of elimination, using the unloading dates of the cars, it appears that samples M81 and M82, Station 170+00, contain Sugar Creek asphalt in the binder and Wyoming asphalt in the surface. At Station 250+00, samples M83 and M84, Wyoming asphalt was used in both top and bottom courses. At Station 375+00 Wyoming asphalt was used in the binder, with Wood River asphalt in the surface course.

Throughout the length of the project, the appearance of the surface, with respect to color and texture, was uniform. The stability of the paving was good, there being no evidence of rutting, shoving, raveling, bleeding, or corrugations. Such transverse cracking as was observed had been caused by failures in the underlying concrete and were not of recent origin, as evidenced by the appearance of the sealing material. The riding qualities of the paving were excellent. While some longitudinal cracks were noted, especially at the old centerline joint in the concrete paving and along the edges at the junction of the old concrete and the widening, these were relatively few. Although the records indicated the use of asphalt from three sources, there was nothing in the appearance of the paving or its performance to indicate any difference which could be attributed to variations in the bituminous material. Certain sections had been constructed with aggregate from different sources. The change in this material was reflected by a minor variation in color.

SAMPLE INDEX

Sample No.	Date Constd	Asphalt Pen	Asphalt Source	Sample Obtained From
M81 *	1949	70-85	S.O.Co.	Sta. 170+00, nbnd lane, between wheel paths
M82 *	1949	70-85	S.O.Co.	" " " " inner wheel path
M83 **	1949	70-85	S.O.Co.	Sta. 250+00, nbnd lane, between wheel paths
M84 **	1949	70-85	S.O.Co.	" " " " inner wheel path
M85 ***	1949	70-85	S.O.Co.	Sta. 375+00, nbnd lane, between wheel paths
M86 ***	1949	70-85	S.O.Co.	" " " " inner wheel path

*Quimby Quarry Stone in both binder and surface. Sugar Creek, Missouri, refinery asphalt in binder—5.5%, 5.75% Wyoming in surface.

**Quimby Quarry Stone in both binder and surface. Greybull, Wyoming, asphalt—5.5% in binder, 5.75% in surface.

***Quimby Quarry Stone in binder, Alden Quarry Stone in surface. Wyoming asphalt in binder—5.5%, Wood River asphalt in surface—5.75%.

PAVING MATERIAL TEST DATA

State of Iowa, Project 115(4)
Route 65, Cerro Gordo County, South of Mason City, Iowa
Asphaltic Concrete Resurfacing of Old Concrete Paving
70-85 Pen. Asphalt—Standard Oil Company, Casper, Sugar Creek, and Wood River

INTRODUCTION

This paving was laid in 1948-1949 and was one of the earliest of this type in Iowa. The paving mixture was processed with a Barber-Greene continuous mixer equipped with three aggregate bins. The complete daily construction record was not available so it was difficult to determine the disposition of the mixed material. Another complicating factor was the use of asphalt from three sources. The work was set up to employ Standard Oil Company asphalt from Casper but, due to delays in transit or other factors, several cars were supplied from the Sugar Creek and Wood River refineries. It is reasonably certain that the asphalt at Station 170+00 and 250+00 was Wyoming material. Also, it is probable that the surfacing at Station 375+00 was from Wood River asphalt, with Wyoming asphalt in the lower of the two-course construction.

There were two sources of the aggregate used. One was obtained from the Quimby Quarry, located 2 miles north of Mason City, Iowa. Between Stations 246+30 and 344+55 in the right, northbound lane and Stations 246+30 to 344+95 in the left, southbound traffic lane, the aggregate for the surface course came from the Alden Quarry, located east of Alden, Iowa, in Hardin County. The difference in the physical properties of these two materials is tabulated below:

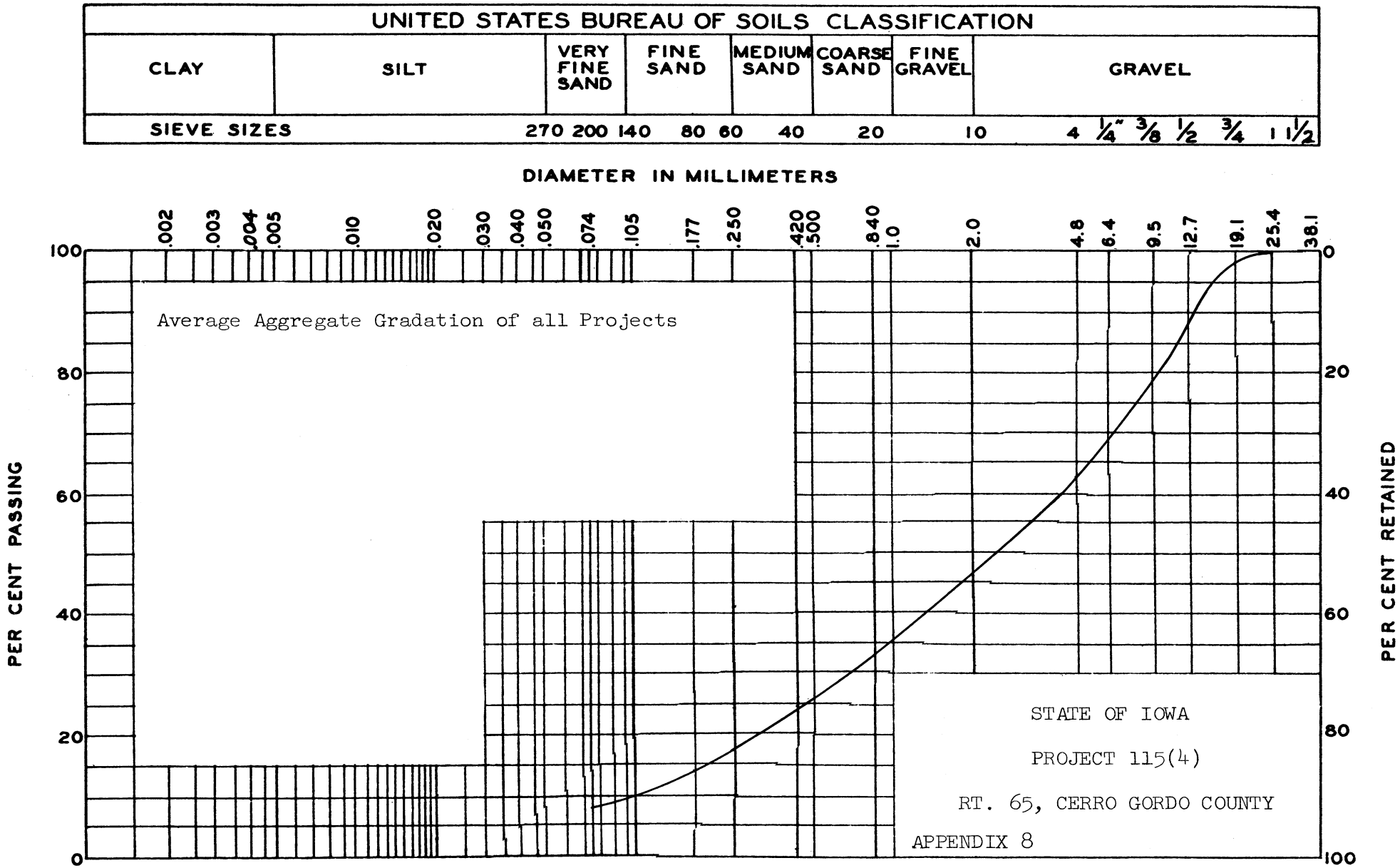
Aggregate Source	Spec. Grav.	Loss by Abrasion	Loss F and T 16 Cyc.	Absorption
Quimby	2.728	30.9%	1.75%	0.51%
Alden	2.597	37.2%	1.89%	1.33%

DISCUSSION OF TEST DATA

Except for the gradation of the aggregate in the mixtures and test data on the asphalt, the State Highway Department has no information relative to the properties of the paving mixture as laid. This prevents a comparison between the original between the original paving and the paving samples.

Comparison of the original and recovered asphalt is limited to their respective penetrations. This available data is tabulated below:

ERI No.	Sample Location	Orig Asphalt		Rcvd Asphalt		% Change		Ratio Orig	Ratio ERI
		pen	s.pt	pen	s.pt	pen	s.pt	s.pt-pen	s.pt-pen
M81	Sta.170+0 Bet. W.P.	76		36	135	-52.6			3.750
M82	Sta.170+0 IWP	76		26	140	-65.8			5.385
M83	Sta.250+0 Bet. W.P.	78		26	139	-65.8			5.346
M84	Sta.250+0 IWP	78		30	138	-60.5			4.600
M85	Sta.375+0 Bet. W.P.	80		25	140	-68.8			5.600
M86	Sta.375+0 IWP	80		23	135	-71.3			5.870


UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
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GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
PER CENT RETAINED
100 80 60 40 20 0
Average Aggregate Gradation of all Projects
STATE OF IOWA
PROJECT 115(4)
RT. 65, CERRO GORDO COUNTY
APPENDIX 8

STATE OF IOWA, PROJECT 115(4) ROUTE 65, CERRO GORDO COUNTY

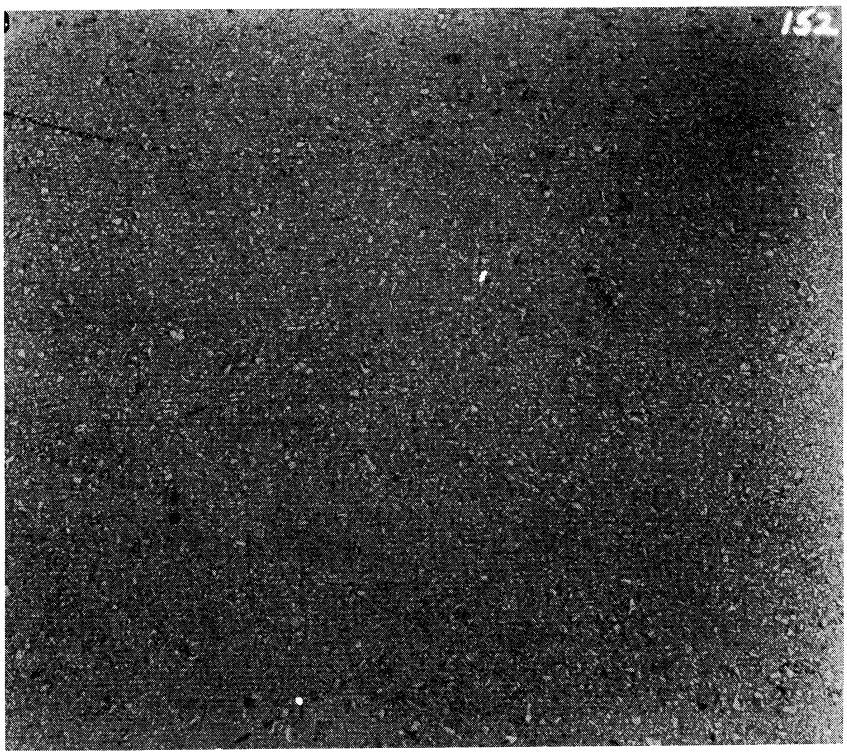
APPENDIX 8
TABLE 1

ASPHALTIC CONCRETE PAVING TEST DATA

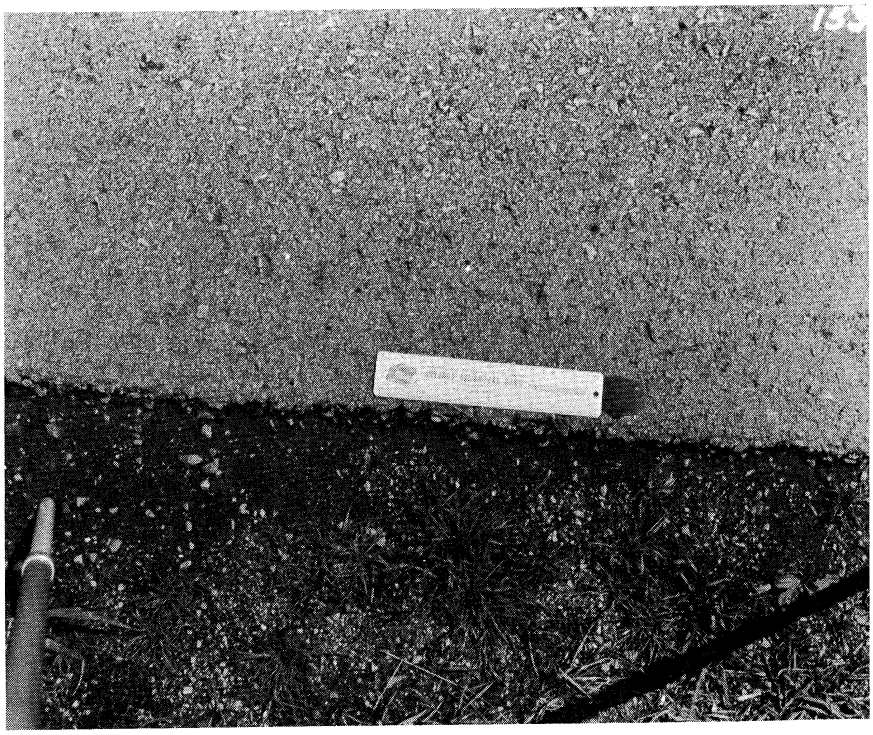
Asphalt - 70-85 Penetration - Standard Oil Co., Casper, Sugar Creek, Wood River Refineries

CONTROL ITEMS	ERI Lab. Data	Iowa Proj. Data	ERI Lab. Data	ERI Lab. Data	Iowa Proj. Data	ERI Lab. Data	ERI Lab. Data	Iowa Proj. Data	ERI Lab. Data
Date constructed		1949			1949			1949	
ERI sample number	M81	Base Top	M82	M83	Base Top	M84	M85	Base Top	M86
Location of sample	Bet WP	Sta 170 nbnd	IWP	Bet WP	Sta 250 nbnd	IWP	Bet WP	Sta 375 nbnd	IWP
Paving thickness, in.	2.500		3.250	3.125		3.125	2.000		2.000
Weight - lb sq yd									
Agg. ret'd No. 10 sieve %	54.1	57.0	53.8	55.8	57.5 56.0	47.4	47.1	57.0	49.0
Pass No. 10 - ret'd 200 %	33.1	31.8	33.6	31.3	31.5 31.75	38.6	40.6	32.25	38.2
Pass No. 200 %	7.4	5.2	7.3	7.5	5.5 6.5	8.5	7.2	5.0	7.7
Asphalt in mix %	5.4	6.0	5.3	5.4	5.5 5.75	5.5	5.1	5.75	5.1
% Crushed on No. 4 sieve	100		100	100		100	100		100
Fineness modulus	5.31	5.15	5.15	5.24	5.12 4.83	4.75	4.93	5.45	5.04
Approx. s.g. of agg.	2.708	2.728	2.735	2.675	2.663	2.673	2.735	2.728	2.709
Density of aggregate-lb cu ft	142.09		142.48	136.83		137.10	139.82		140.58
Voids in aggregate %	15.91	no	16.51	18.01	no	17.79	18.06	no	16.83
Voids filled with asphalt %	79.32		75.17	67.52		69.81	64.67		69.82
Asphalt by volume %	12.62		12.41	12.16		12.42	11.68		11.75
Solids in mixture %	96.71	data	95.90	94.15	data	94.63	93.62	data	94.92
Solids in agg. only %	84.09		83.49	81.99		82.21	81.94		83.17
Max. theor. s.g. of pvg.	2.489		2.514	2.462		2.457	2.522		2.501
Actual s.g. of paving	2.407	available	2.411	2.318	available	2.325	2.361	available	2.374
Paving density - lb cu ft	150.20		150.45	144.64		145.08	147.33		148.14
Voids in paving %	3.29		4.10	5.85		5.37	6.38		5.08
Total voids filled with a.c. %	79.32		75.18	67.53		69.81	64.66		69.80
Pen. 100g-5 sec-25°C	R 36	76	R 26	R 26	79 76	R 30	R 25	80	R 23
Flash - C.O.C.-°F		590			590 590			590	
Spec. gravity		1.0298			1.0298			1.031	
Ductility - 77°F - cm	R150+	100+	R136	R150+	100+ 100+	R150+	R142	100+	R150+
Sol. CCl_4 %		99.9			99.9 99.9			99.9	
Loss on htg. 50g-5 hr-325°F %		0.0			0.0 0.0			0.0	
Pen. after l. on h.		67.0			69.0 66.0			70.0	
Spot test - Oliensis		neg			neg neg			neg	
Soft point R and B °F	R134.60	- -	R138.46	R138.74	- - - -	R138.38	R139.82	- -	R134.78
Ash in rcv. asphalt %	R 0.33	- -	R 1.50	R 1.43	- - - -	R 0.50	R 1.64	- -	R 0.46
Spot-15% xylene-85% Skelly S	neg		neg	neg		neg	neg		neg

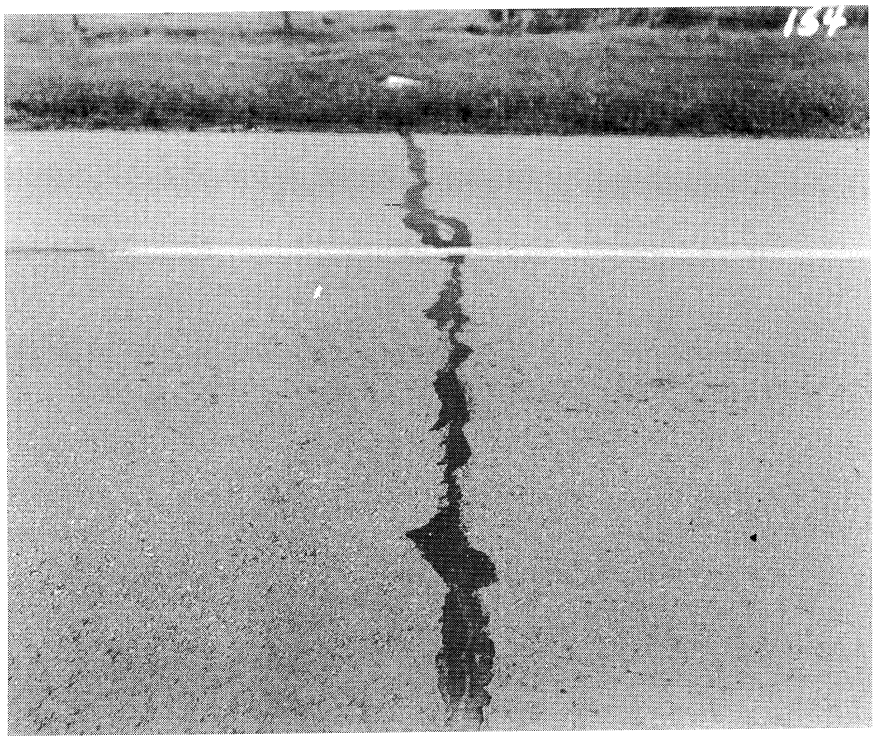
Picture 151. General view of the project roadway, looking south from Station 164+44.



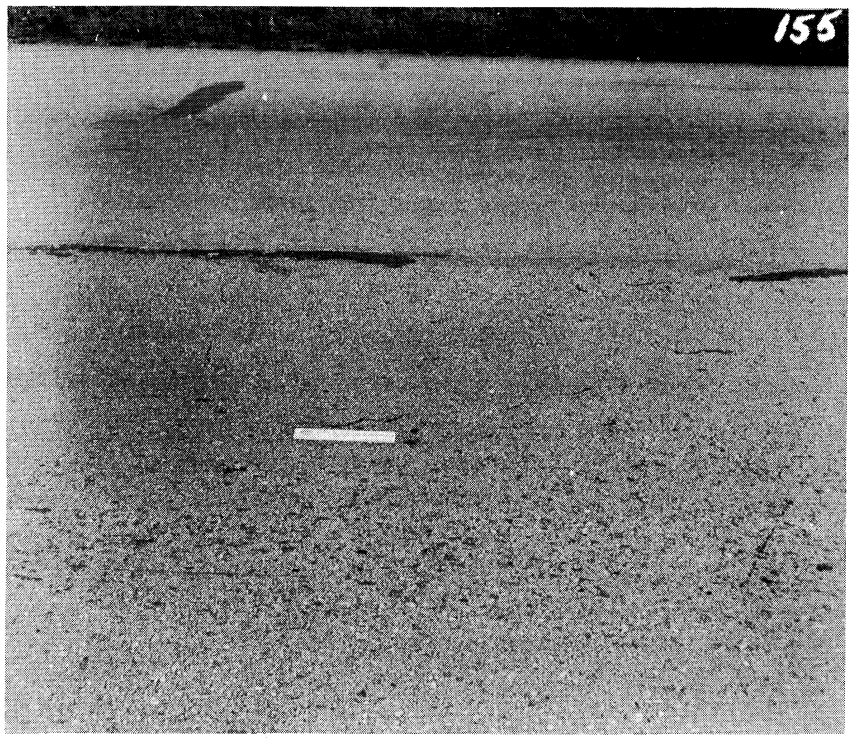
Picture 152. View of paving texture and color in OWP, northbound traffic lane. The appearance of the paving surface is typical.



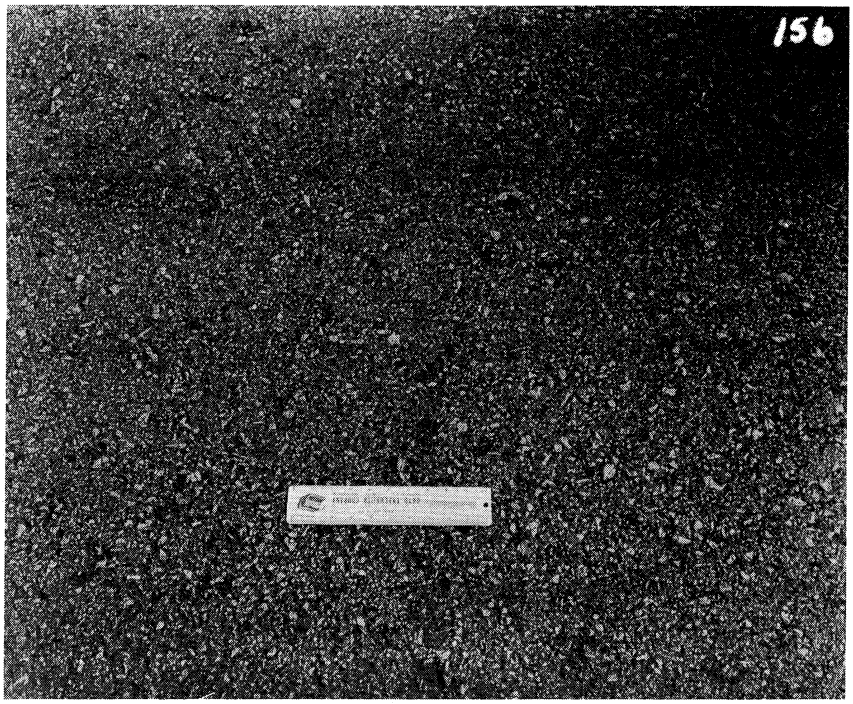
Picture 153. Paving texture and color at west edge of the paving at Station 164+44.



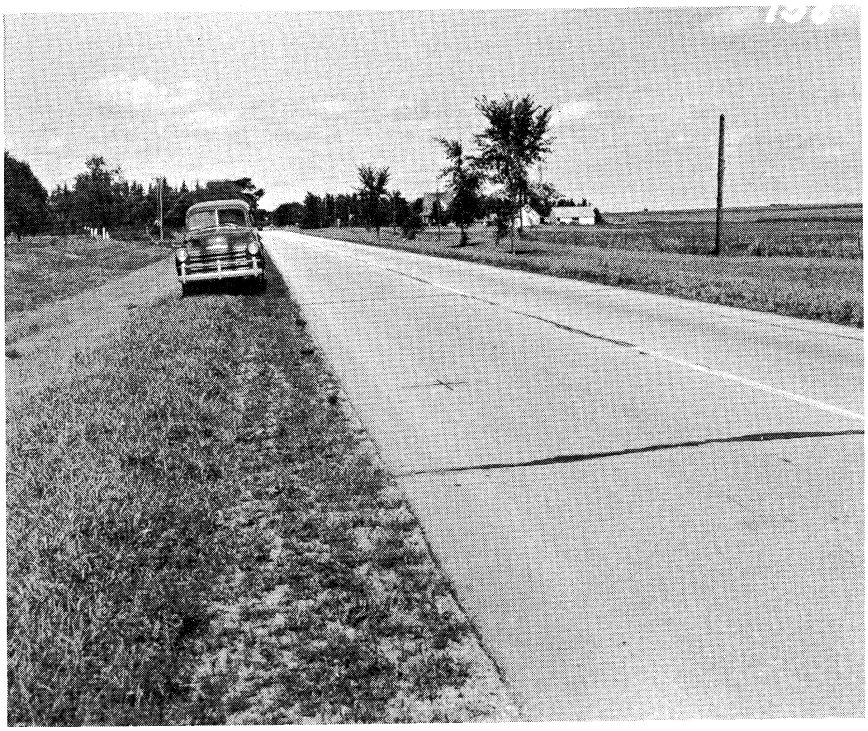
Picture 154. Typical transverse crack carried through the asphalt surfacing from the underlying concrete paving. All such cracks throughout the job are well-maintained and sealed.



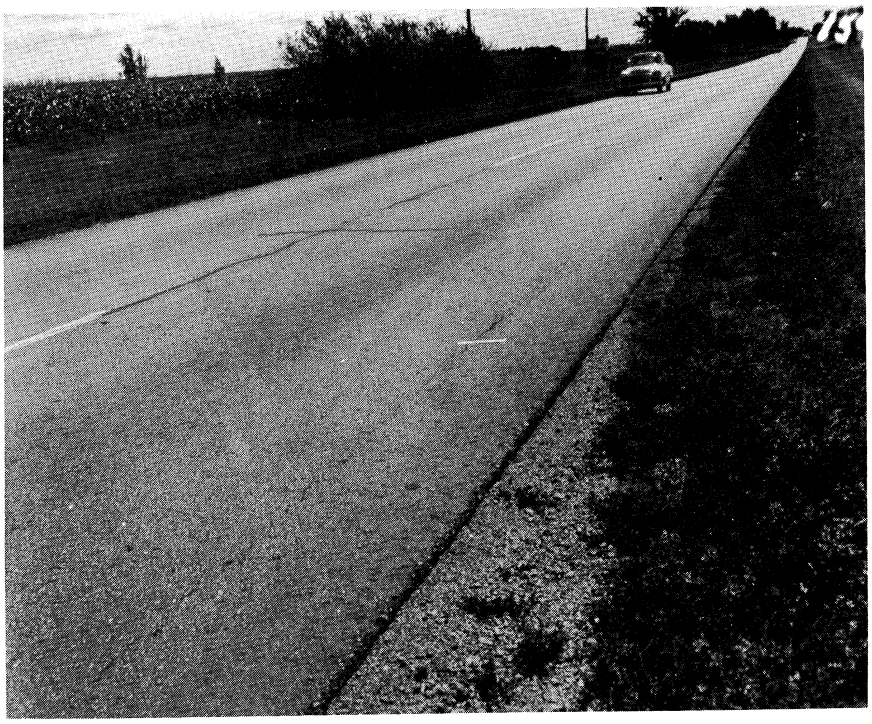
Picture 155. Typical short, random cracks, longitudinal and transverse at Station 215+00, which occur between 3 and 4 ft each side of the centerline of the highway.



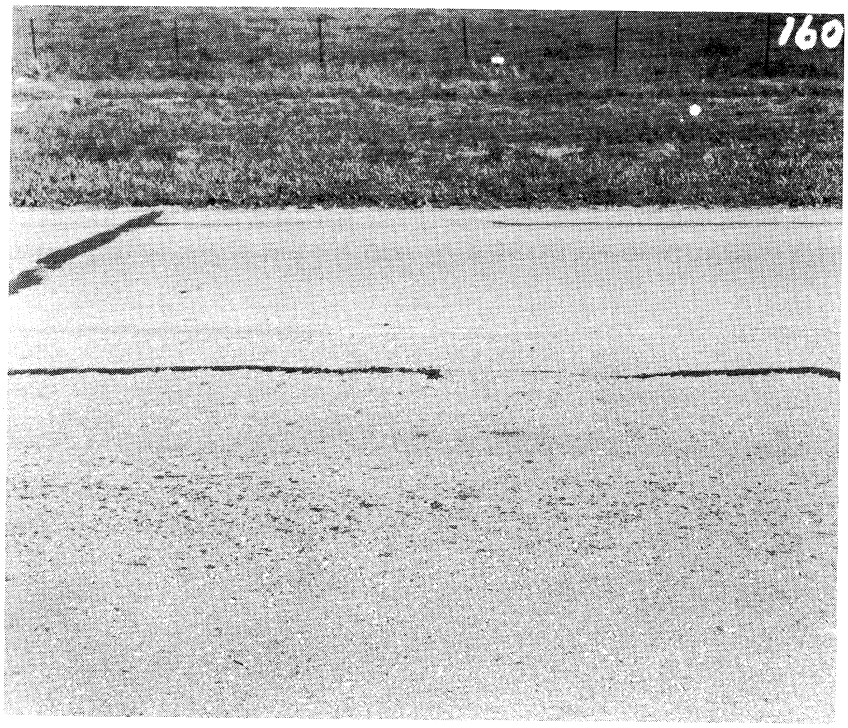
Picture 156. At Station 215+00, texture of paving in OWP, southbound lane.



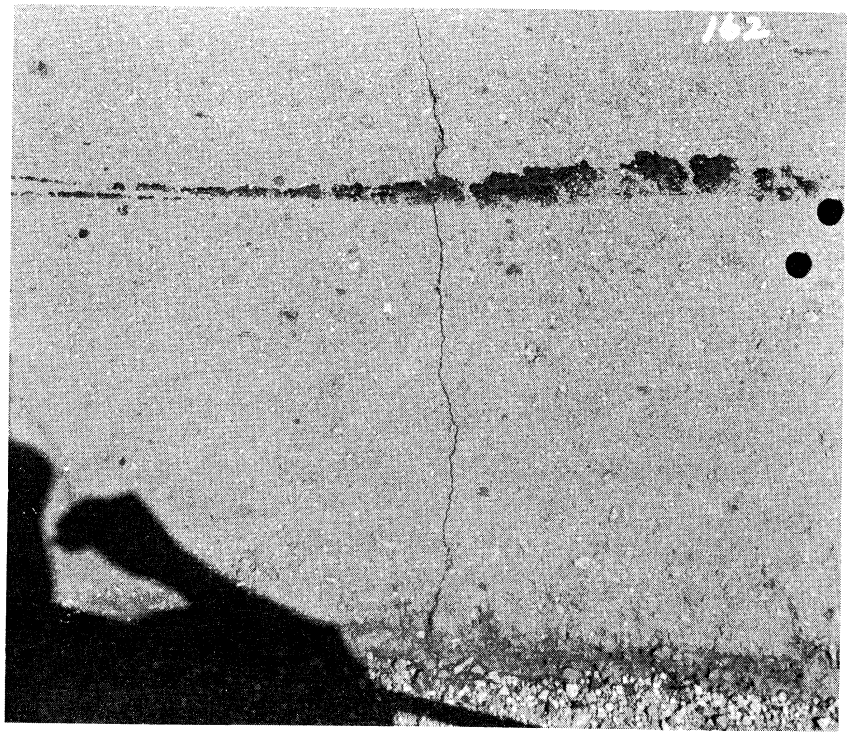
Picture 158. View of a typical transverse crack pattern. There is a uniform occurrence of short, random cracks, approximately 1 to 2 ft long, within 3 ft on each side of the centerline.



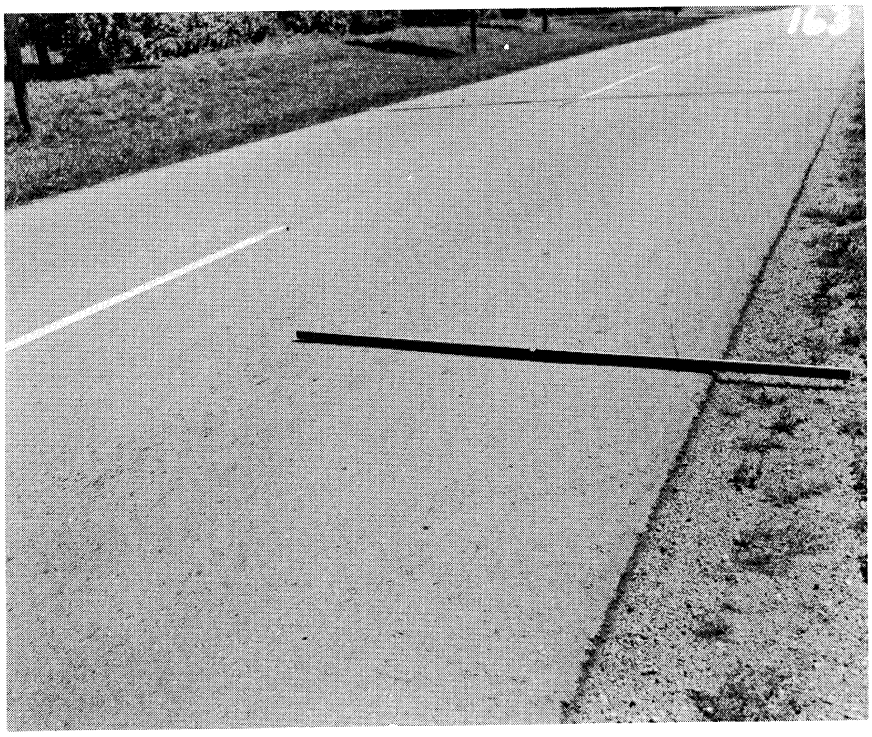
Picture 159. A view of the longitudinal crack at the junction between the old concrete paving and the widened section. These cracks are of relatively infrequent occurrence.



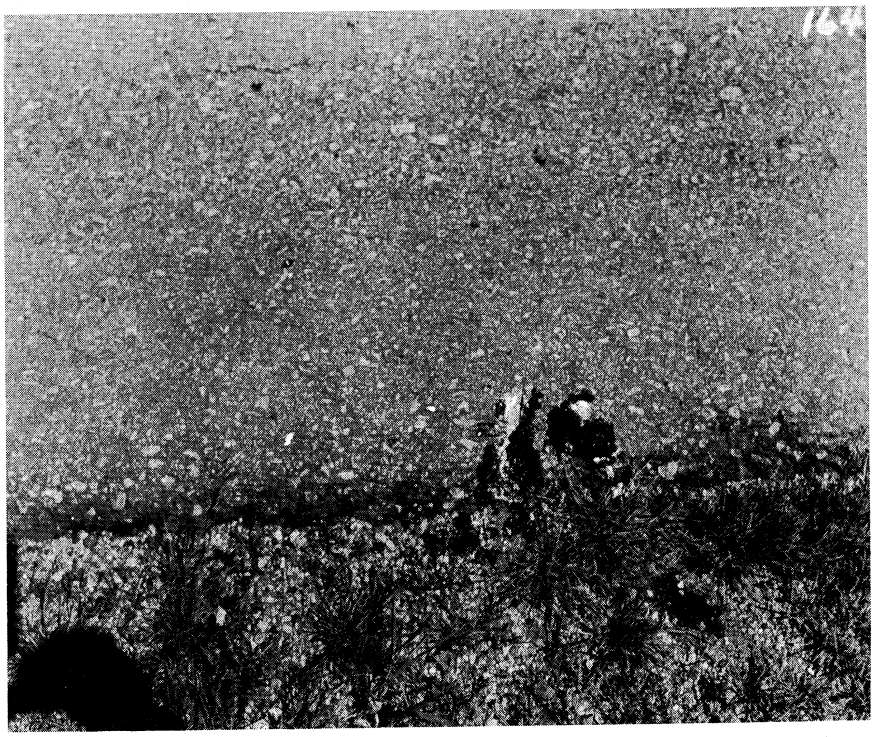
Picture 160. At Station 265+00, transverse view of paving, with marker for Station 265+00 in the background.



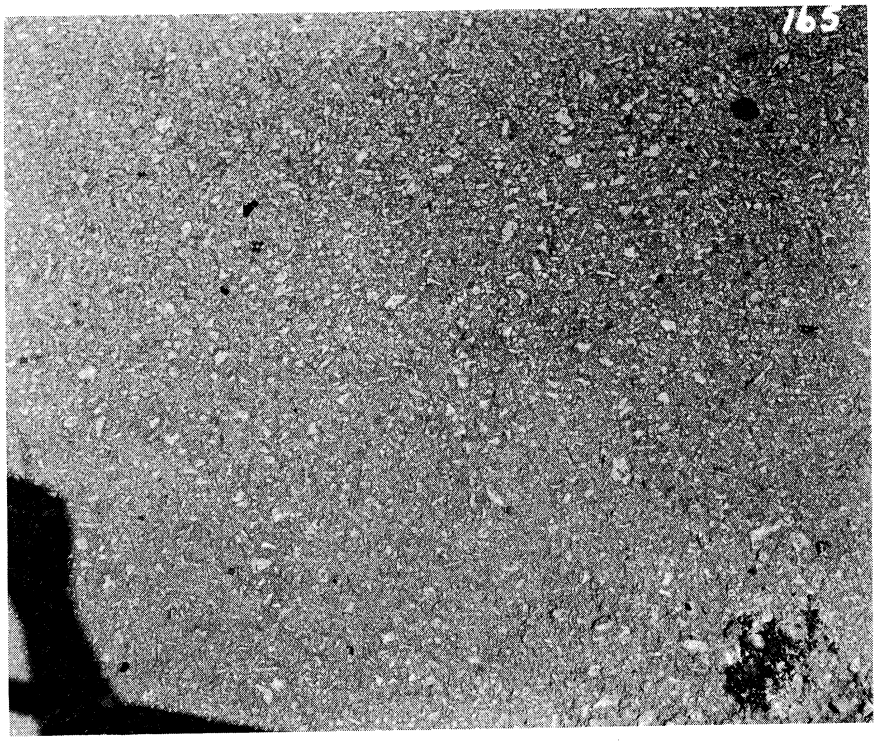
Picture 162. Station 315+00. View of crack in the underlying concrete base, running from the centerline to the west edge of the road in the southbound traffic lane.



Picture 163. A view of straightedge placed across the OWP of the southbound traffic lane at Station 315+00. No visible rutting noted.



Picture 164. View of material picked from the paving surface at the paving edge at Station 365+00. The interior of the paving mixture was rich, shiny black in color, live, and tacky with good asphalt coverage over the aggregate particles.



Picture 165. Station 365+00. Close-up view of the paving texture in the OWP of the southbound traffic lane.

APPENDIX NO. 9

MINNEAPOLIS, MINNESOTA

ASPHALTIC CONCRETE PAVING

FIELD INSPECTION REPORT

INTRODUCTION

Inspection of the Minneapolis paving records shows that the earliest use of Wyoming penetration grade asphalt occured in 1942. This was material used in maintenance projects, and no records of paving locations are available. During the years of World War II, little or no work was done. Since 1946, Husky Oil Company has supplied all of the paving asphalt with the exception of 1953, when Berry Asphalt Company was the low bidder and its Arkansas asphalt was used. The sampling and inspection was restricted to paving constructed with Husky asphalt. From 1943 to 1954, 60-70 penetration grade material has been used, but starting with the 1954 season, 85-100 penetration material has been specified.

As the asphalt was from the same source, no comparison between different refinery sources is possible. The greatest difference in the composition of the mixtures lies in the choice of coarse aggregate. Paving built between 1943 and 1948 contained traprock aggregate from Dresser Junction, Wisconsin. This material has a specific gravity of 2.95. Some crushed gravel was employed in 1949. The specific gravity of this material is 2.70, with an absorption of 1.12%. Since 1949 the only aggregate used has been granite which has a specific gravity of 2.70.

The paving mixture composition and processing appear to have been well standardized. The paving mixture was produced at a central city plant, where all laboratory testing and mixture control is handled under the supervision of Mr. E. J. Evans. Inspection of the records indicated consistent attention to aggregate gradation and testing of the bituminous material, with the exception that no record of the specific gravity of the asphalt was available. There had been no subsequent sampling of the paving after laying nor any study of the behavior of the paving mixture.

A comment was made on the Wyoming asphalt: it was found necessary to reduce the percentage required about 0.25% as compared with the Berry asphalt from Arkansas. Mr. Evans advised that unless this was done the mixture made from Wyoming material appeared to be over-asphalted. The control temperatures seem to have been uniformly maintained at about 310° for all aggregate, 240° for Wyoming asphalt, and 275° for the laying temperature. All city paving inspected has had an application of emulsified asphalt (0.3 gal/sq yd) covered with granite chips (22lb/sq yd).

The results of the visual inspection of the paving are presented below. Reference to the photographs and the picture index will be made as necessary.

Minnehaha Avenue from Lake Street to Minnehaha Parkway
Constructed 1946, Traprock Aggregate
Husky Oil Company, 60-70 Penetration Asphalt
(Picture Reference 169 to 173)

This paving replaced old wood-block construction. The original concrete base, which was retained, appeared to be of poor composition and strength. It had broken up badly while serving as base for the wood block, and required excessive thickness of asphaltic concrete to replace the block and the sand leveling course and to correct the alignment of the broken concrete. This operation required paving thickness of from 5 to 7 inches.

Until Hiawatha Avenue, City Route T. H. 55, was paved in 1949, Minnehaha Avenue carried heavy passenger car and truck traffic. Present loadings are principally light commercial and passenger vehicles. The general appearance of the asphaltic surface is good, with very little of the traprock aggregate used in the mixture visible through the overlying seal coat. The well-interlocked nature of the mixture and the attendant high density of the paving has combined to prevent any evidence of rutting, shoving, rippling, or corrugating. Throughout the project, even in the more heavily used semi-commercial areas, there is no evidence of depressions along the curb due to parking vehicles. Although there is a heavy bus schedule maintained on this street, there is only minor evidence of shoving at bus stops.

Royalston Avenue from Glenwood Avenue to Olson Memorial Highway
Constructed 1949, Crushed Gravel Coarse Aggregate
Husky Oil Company Asphalt, 60-70 Penetration Grade

This is one of the few examples of city paving in which crushed-gravel aggregate was used. The asphaltic concrete paving was placed over old concrete base previously surfaced with wood block. As illustrated by pictures 174 to 178 inclusive, rather excessive wear may be observed in the paving area within the limits of the existing 90° reverse curves which are employed on this project. There is also considerable abrasion evident in the wheel paths on the tangent sections, as shown by picture No. 178. This raveling or abrasion is confined to the removal of the fine aggregate surrounding the larger particles. Such large particles are firmly locked and bonded in place.

Nicollet Avenue from 58th Street S to 62nd Street S
Constructed 1948, Traprock Aggregate
Husky Oil Company, 60-70 Penetration Asphalt.

This is an excellent example of asphaltic concrete on concrete base. The use of 100% crushed-traprock aggregate has facilitated mechanical interlock of particles and produced a paving structure of high stability. Where sampled, the asphaltic concrete was 1-3/4 to 1-7/8 in. thick, laid directly on the concrete slab. This is an especially heavily traveled route extending southward from downtown Minneapolis and carries extensive truck and bus traffic. The original surface chip-and-seal cover shows no indication of wear in either the wheel paths or parking areas. There is no indication of surface irregularities. Compared with all other municipal paving inspected, this section is superior in appearance and performance.

28th Avenue South from E. 54th Street to Minnehaha Parkway
Constructed 1952, Crushed Granite Aggregate
Husky Oil Co. Asphalt, 60-70 Penetration.

This street is a link in the combined City, State, and Federal metropolitan highway system designed to serve as an arterial access route from the south into down-town Minneapolis. The paving operation was conducted as a part of the State of Minnesota Federal Aid program, under specifications as provided by the State of Minnesota. The paving was laid and processed by the Street Department of the City of Minneapolis.

Throughout this project the appearance of the paving is very satisfactory, with the exception of that between 53rd and 54th Streets. The northbound lane at this location is on an ascending grade of between 2.0 and 3.0%. There are slight corrugations forming in the wheel paths, which appear to be due to the acceleration required to overcome this ascending grade. The paving has not been in service for a sufficiently long time to develop pronounced irregularities. The surface has been sealed with the standard application of 0.3 gal. of asphalt emulsion and 22.0 lb of granite chips per sq yd. Outside of the area noted, there is no evidence of rippling, shoving, or rutting. Concrete platforms have been provided at all bus stops.

Riverside Avenue from 27th Avenue S to 7th Street
Constructed 1950, Crushed Granite Aggregate
Husky Oil Company Asphalt, 60-70 Penetration.

This asphaltic concrete paving replaced old wood block which had been laid over concrete base. The concrete base had become damaged and required the application of a leveling course of variable thickness prior to placing the asphaltic concrete. Total bituminous paving thickness ranged from 5 to 7 in.

The paving on this street carries extremely heavy truck and bus traffic between St. Paul and downtown Minneapolis. Most of the abutting property is occupied by small businesses and factories having relatively heavy haulage requirements. The existing centrally located car tracks have been abandoned, and the original paving at that location is quite rough. This condition tends to channel traffic over the asphaltic concrete paved section. During the four-year period of service there has been no breakage, raveling, corrugating, or shoving. There have been numerous transverse and longitudinal cracks transmitted from the underlying old concrete. The bituminous paving is bordered with 6-ft-wide concrete curb and gutter, and concrete platforms have been provided at all bus stops.

PAVING MATERIAL TEST DATA

City of Minneapolis, Minnesota
Asphaltic Concrete Paving, 1946 to 1952
60-70 Penetration Asphalt, Husky Oil Company

INTRODUCTION

The records indicate that the use of Wyoming asphalt began in 1946. The source of supply has been the Husky Oil Company of Cody, Wyoming, with the exception of the year of 1953 when Arkansas asphalt, supplied by the Berry Asphalt Company, was used.

The data discussed in this section is presented in Table 1, this appendix.

DISCUSSION OF TEST DATA

Irrespective of the type of aggregate, the composition of the mixtures as extracted from the paving samples was very similar. There is a marked

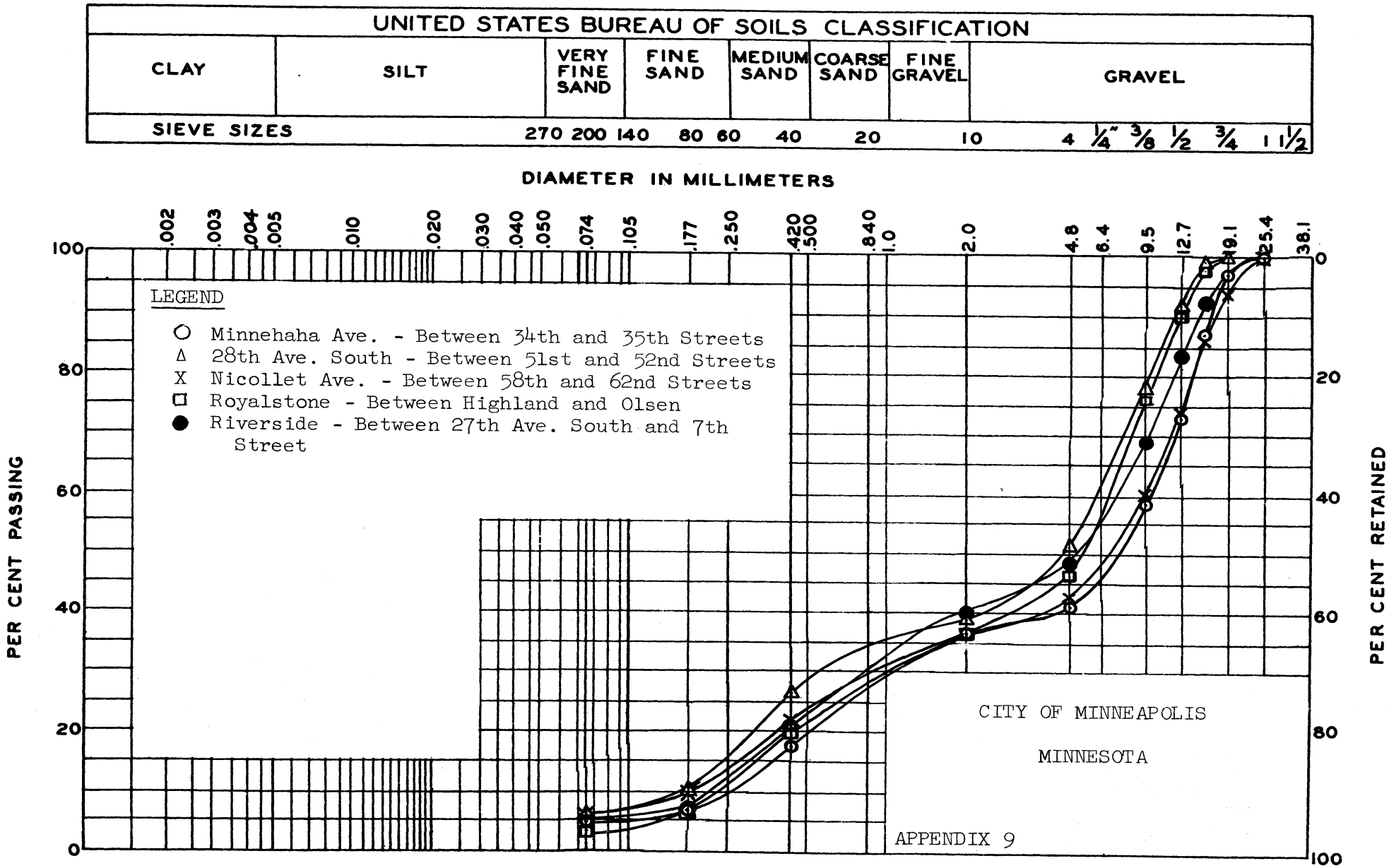
difference between the recorded City mixtures and those of the several samples. The City data indicates the use of both binder and surfacing layers in all paving. Both such mixtures were supposed to have been much coarser than those actually found. Analyses of the mixtures were not made at the plant, and the recorded compositions seem to be those which were proposed rather than those actually laid. There seems to be no other way to account for the difference between the originally reported mix composition and that obtained from the ERI paving samples.

The properties of the asphalt used in the several paved areas between 1946 and 1952 are closely identical. Irrespective of time in service, the test data on the recovered asphalt are quite similar. It may be significant that the greatest drop in penetration and the commensurate increase in softening point occurred in the asphalt of the gravel mixture used on Royalston Avenue. After 6 years in service in that location, the changes in the asphalt were more pronounced than on Minnehaha Avenue, laid in 1946, where traprock aggregate was used. The data on the asphalt are given in the following tables.

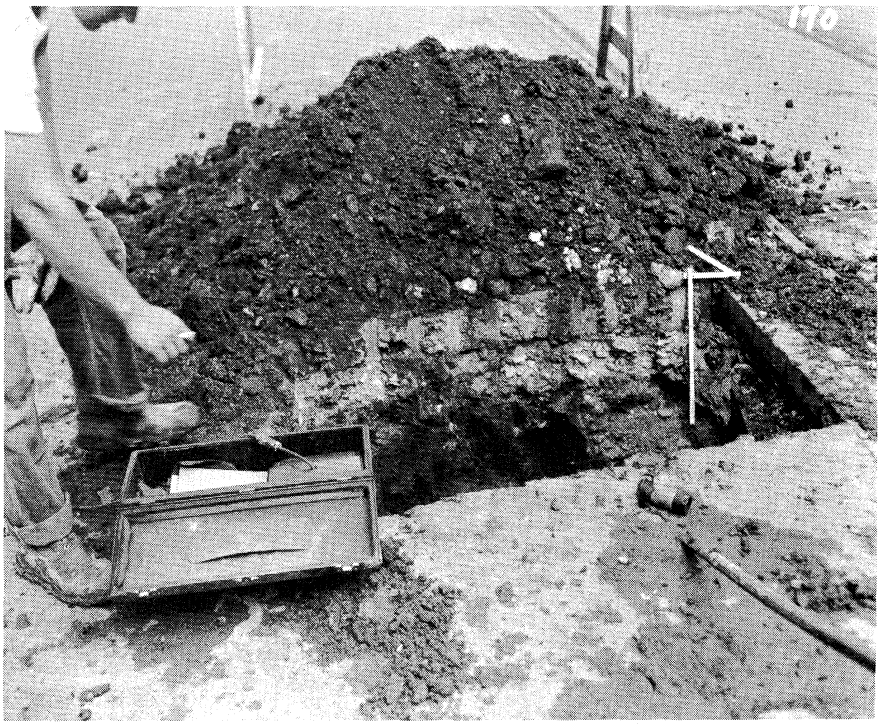
RELATIONSHIP BETWEEN PENETRATION AND SOFTENING POINT

Date and ERI Samples	Orig Pen	Orig S.Pt	Ratio S.Pt to Pen	ERI 1954 Pen	ERI 1954 S.Pt	Ratio 1954 ERI S.Pt to ERI Pen	Ratio 1954 ERI to Orig
1946 Constn							
M120-M121	65			47	129	2.745	
1948 Constn							
M124	64			45	132	2.933	
M125	64			41	134	3.268	
1949 Constn							
M126	64			40	137	3.425	
M127	64			40	136	3.425	
1950 Constn							
M128	66			50	134	2.680	
M129	66			50	131	2.620	
1952 Constn							
M122-M123	66			48	129	2.688	

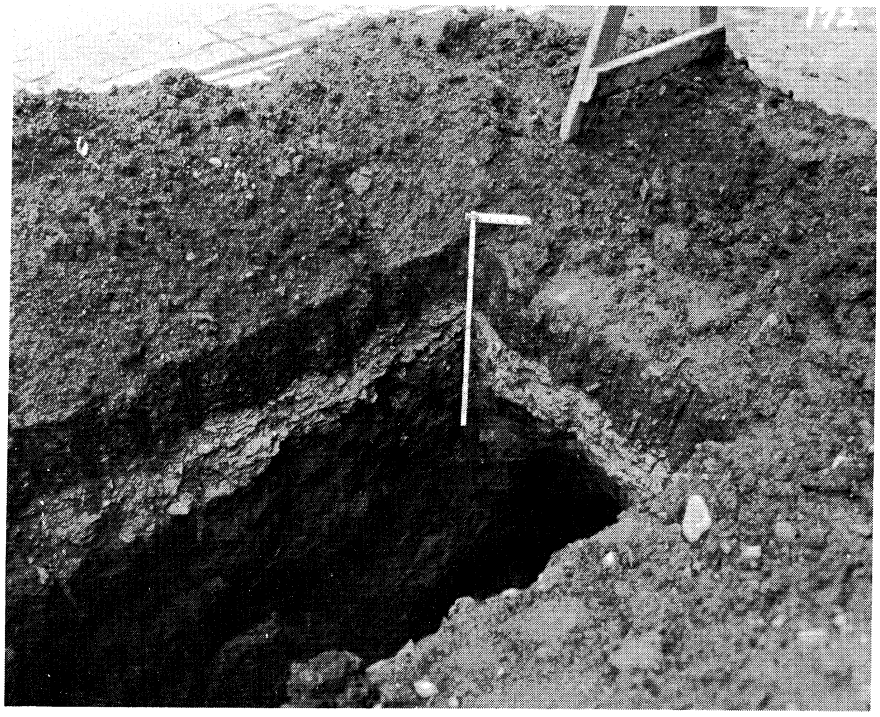
Control Items	Minnehaha Ave 1946 Constn			Nicollet Ave 1948 Constn			Royalston Ave 1949 Constn			Riverside Ave 1950 Constn			28th Ave S 1952 Constn		
	ERI Traf M120	City Data	ERI Traf M121	ERI Traf M124	City Data	ERI Park M125	ERI Park M126	City Data	ERI Traf M127	ERI Traf M128	City Data	ERI Traf M129	ERI Park M122	City Data	ERI Traf M123
Orig pen		65			64			64			66			66	
1954 ERI pen	47		47	45		41	40		40	50		50	47		49
Pen-% orig	72		72	70		64	63		63	76		76	71		74
Orig duct at 77°F		125+			100+			100+			100+			100+	
Orig duct at 39.2°F		9.0			9.6			9.2			8.7			8.5	
1954 ERI duct	150+		150+	150+		150+	150+		150+	150+		150+	150+		150+
Orig s.pt															
1954 ERI s.pt	129		129	132		134	137		136	134		131	129		129
Flash-orig		528			515			550			547			545	
Spec grav	1.02		1.02	1.02		1.02	1.02		1.02	1.02		1.02			
Loss on htg		0.167			0.06			0.05			0.093			0.08	
Pen residue		51			51			53			59			56	
Oliensis		neg			neg			neg			neg			neg	
ERI spot	neg		neg	pos		pos	sl. pos		sl. pos	sl. pos		sl. pos	neg		pos


UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
PER CENT RETAINED
0 20 40 60 80 100
LEGEND
Minnehaha Ave. - Between 34th and 35th Streets
28th Ave. South - Between 51st and 52nd Streets
Nicollet Ave. - Between 58th and 62nd Streets
Royalstone - Between Highland and Olsen
Riverside - Between 27th Ave. South and 7th Street
CITY OF MINNEAPOLIS
MINNESOTA
APPENDIX 9

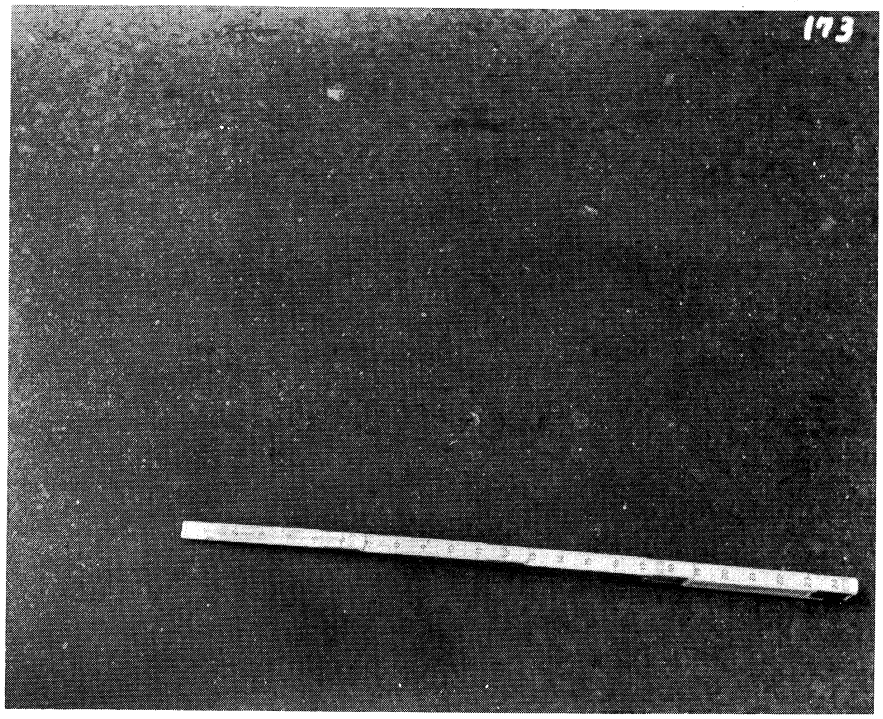
Picture 169. General view of Minnehaha Avenue taken from the south end of the project at Minnehaha Parkway, looking north toward Lake Street.



Picture 170. View of the asphaltic concrete paving placed in 1946, replacing old asphalt impregnated wood block. The thickness of the wood block and sand leveling course was approximately 5 inches.

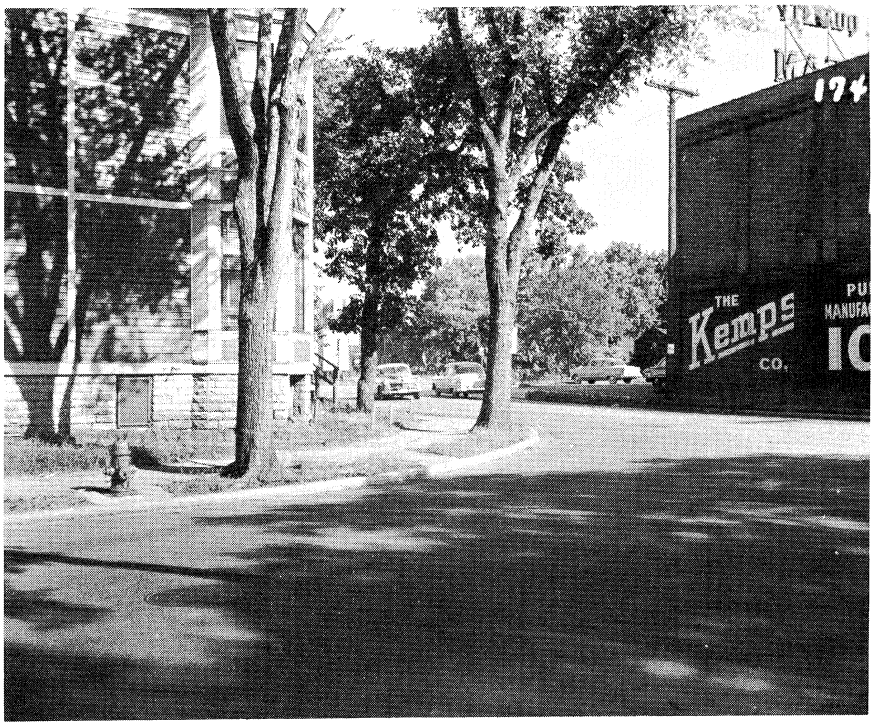


Picture 172. A view of the paving cut in front of residence at 3421 Minnehaha Avenue. This location was in the northbound traffic lane. The asphaltic concrete paving was approximately 7-1/2 inches thick and was placed on an 8-inch concrete base.

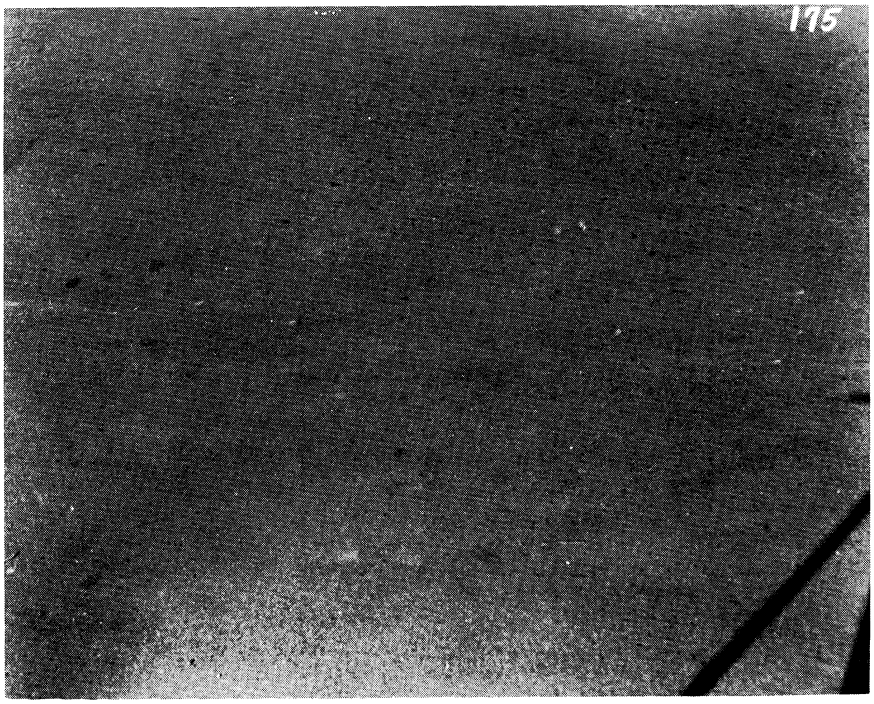


Picture 173. Cloudy rainy weather presented clear definition of the paving texture when this picture was taken. The aggregate in the paving mixture was of rather coarse texture as may be observed through close inspection of the photograph.

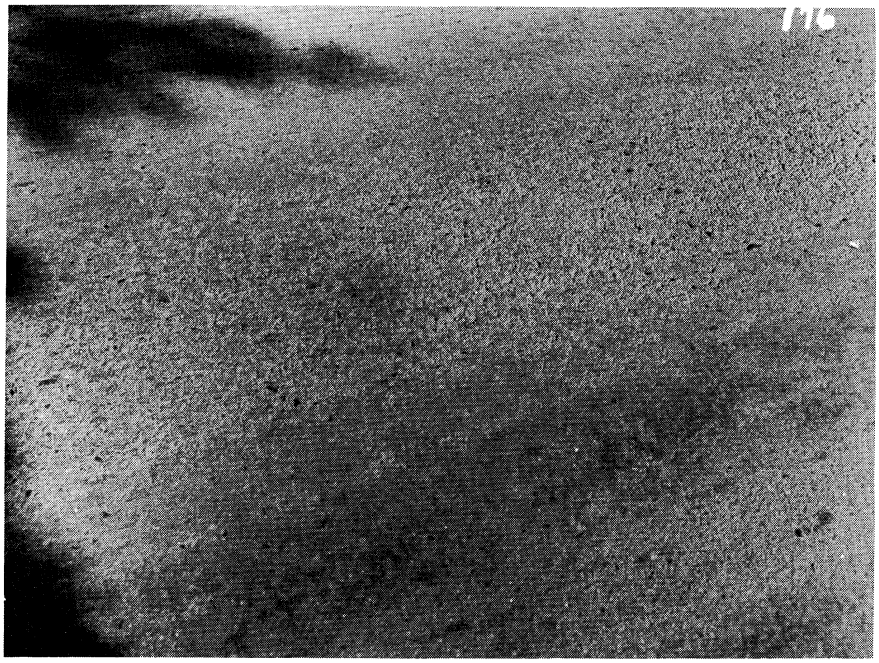
Royalston Ave., Glenwood Ave. to Olson Mem. Hwy--Constructed 1949



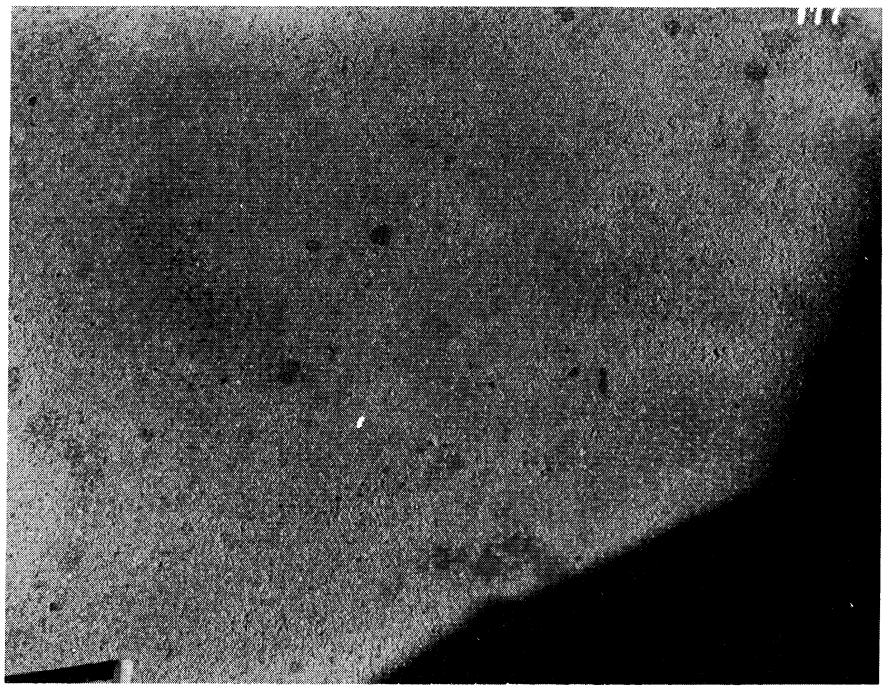
Picture 174. View of portion of this street. There are five 90° reverse curves with practically no intervening tangent in the length of this paving. One such typical curve is shown in this picture.



Picture 175. View of the exposed larger pieces of the gravel aggregate and existing paving texture in the wheel path on curve at the intersection of Royalston and Highland Ave. The seal coat is almost entirely removed by traffic action.

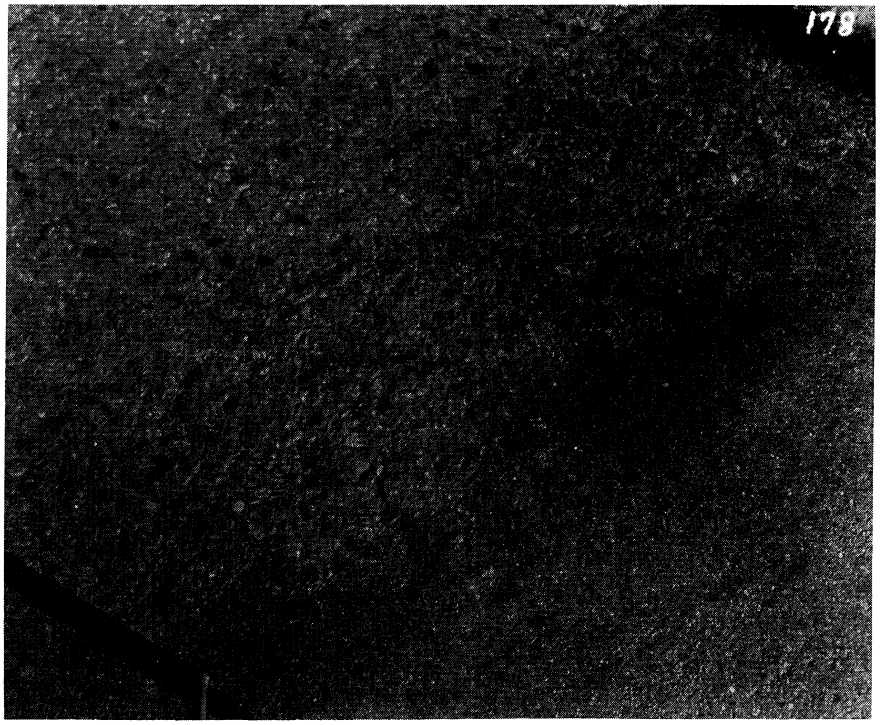


Picture 176. View of the exposed gravel texture just north of the 90° reverse curve at Highland Ave. This is approximately the location where vehicles accelerate after coming out of the 90° curve. Stripping of the fine material from between larger aggregate fractions is very pronounced.



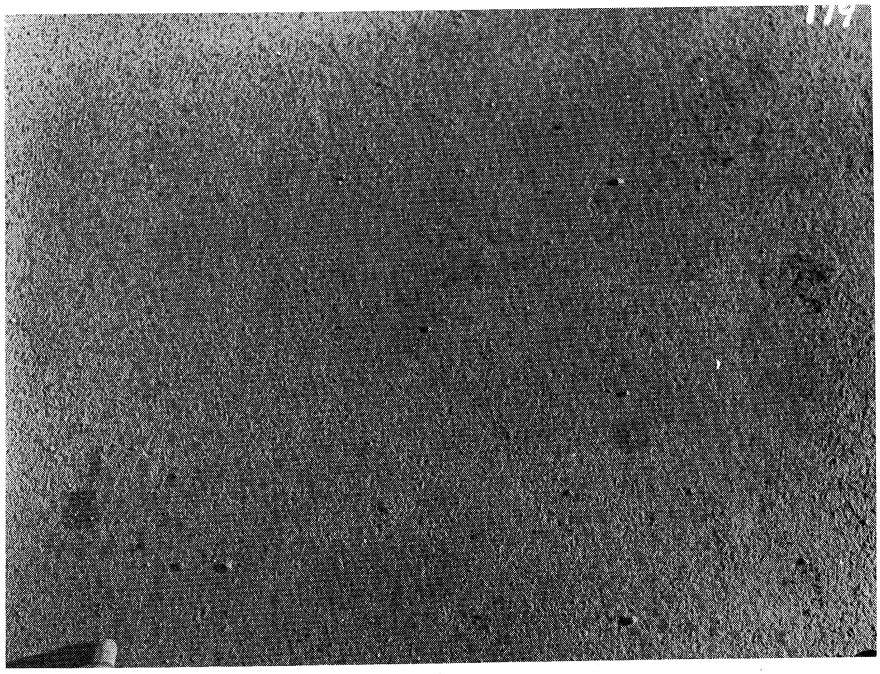
Picture 177. In contrast to the badly abraded paving surface in the wheel paths on the turns, this picture illustrates the condition of the paving surface in the parking areas along each side of the street. The original seal coat is undisturbed.

Royalston Ave., Glenwood Ave. to Olson Mem. Hwy--Constructed in 1949

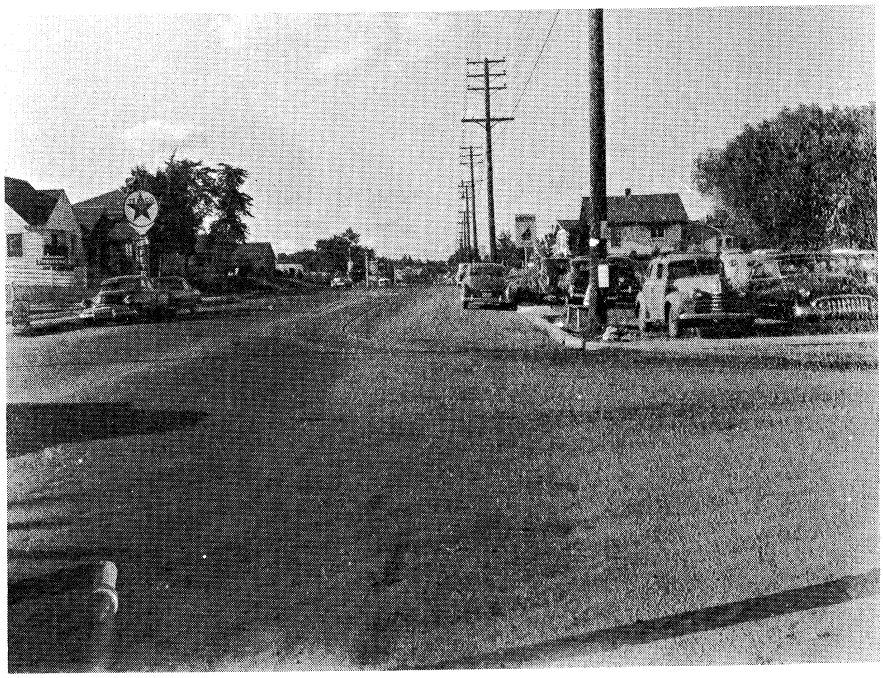


Picture 178. This is a view of the exposed gravel aggregate in the wheel path on the straightaway paving section or tangent. In contrast to the adjacent untraveled area in the right foreground, stripping and abrasive action may be noted.

Nicollet Ave., 58th St. S to 62nd St. S--Constructed in 1948.



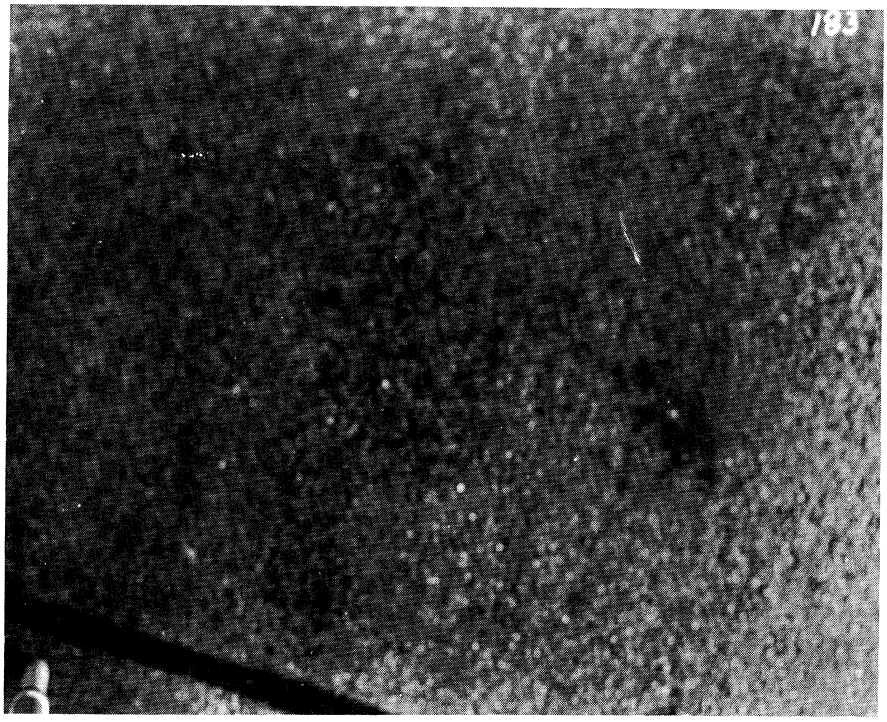
Picture 179. Typical granite-chip-seal surface over asphaltic concrete paving resurfacing of old concrete. This view is taken of the surface in the side parking areas. It is typical, however, of the heavily traveled wheel paths. The six years of heavy serv- since 1948 have produced little or no evidence of wear, and the present surface is in excellent condition.



Picture 180. General view of Nicollet Ave. taken from the south city limits at 62nd St. Throughout the length of this paving it serves small business areas and carries heavy truck and passenger car traffic entering Minneapolis from the south.

28th Ave. S, E. 54th St. to Minnehaha Pkwy--Constructed 1952

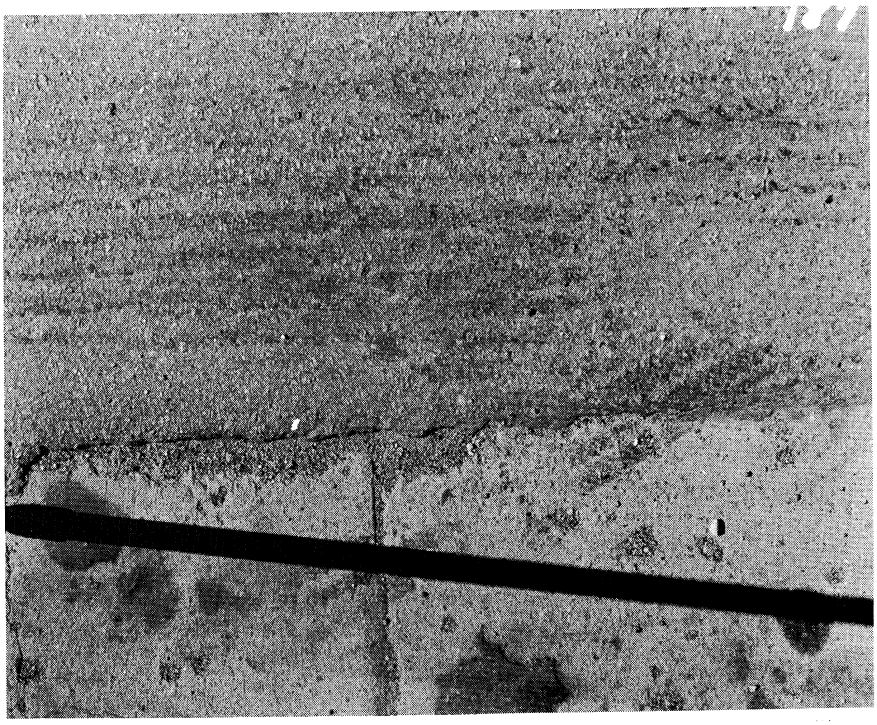
Picture 181. This paving was in accordance with State of Minnesota specifications and requirements.



Picture 183. This view, taken between 51st and 52nd Sts., is typical of the paving surface texture throughout the project. In common with all other Minneapolis projects, the asphaltic concrete surface upon completion in 1952, was sealed with 3/8-inch-maximum size chips and emulsified asphalt seal.

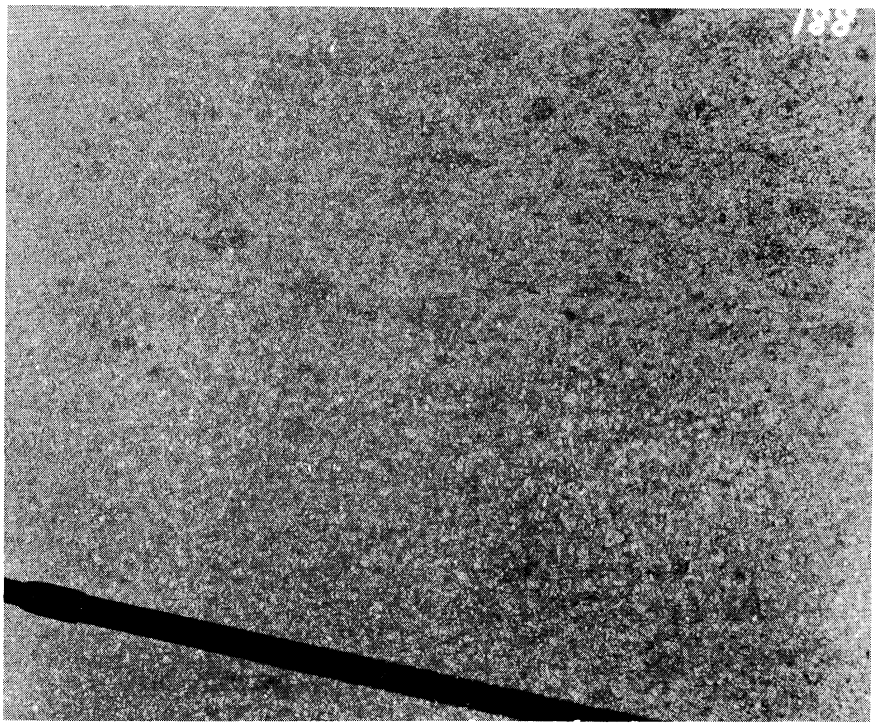
Riverside Ave., 27th Ave. South to 7th St.--Constructed 1950

Picture 186. This is a general view of Riverside Avenue taken at the intersection of Riverside and 27th Avenue, S. The centrally located street car tracks are not in use.



Picture 187. View of the paving surface and texture taken in the westbound traffic lane at the approximate location of sampling. The surface ridges or inequalities have resulted from the seal coat application. Tire marks have been made in the somewhat rich seal coat and do not reflect an excess of asphalt in the body of the paving.

Riverside Ave., 27th Ave. South to 7th St.--Constructed 1950



Picture 188. Typical paving surface and texture in the heavily traveled wheel path adjacent to the central street-car track area.

APPENDIX NO. 10

STATE OF MINNESOTA DEPARTMENT OF HIGHWAYS

ASPHALTIC CONCRETE PAVING

FIELD INSPECTION REPORT

State of Minnesota Project 6206 MD-11
Route T.H. 10, from St. Paul, Minnesota, City Limits, 4.2 Miles North
100-150 Penetration Asphalt—Ohio Oil Company, Built 1948
(Picture References 190 to 200)

Route T.H. 10 is the state highway extension of Lexington Avenue in the city of St. Paul, Minnesota. This route is a principal arterial highway between St. Paul, Minnesota, and Fargo, North Dakota. It carries heavy commercial and passenger car traffic. The particular section under consideration extends a distance of 4.2 miles northwest toward Anoka, Minnesota.

The asphaltic concrete paving was constructed in 1948 by the State Highway Department Maintenance Division as re-surfacing for old concrete paving. As Maintenance Department operations do not require the preparation of detailed plans, the construction records on this project are limited. In general, the paving was constructed of gravel aggregate, laid to a thickness of from 1-1/4 to 1-1/2 in., with 100-150 penetration grade asphalt supplied by the Northwest Refining Company, St. Paul.

Immediately following construction in 1948, the surface of the asphaltic concrete paving was covered with an application of 0.07 gal. RC-0 and 3.0 lb of sand per square yard. The paving surface at the time of inspection indicates that subsequent seal coats have been applied, although no record is available, as this work was performed under routine maintenance.

Throughout the project the condition of the asphaltic concrete paving itself is generally satisfactory. There is no obvious rutting, shoving or flushing, but there has been some abrasion loss in localized areas, particularly in the wheel paths as shown in pictures 191 and 194, which portray the most adverse conditions observed.

The most pronounced type of irregularity is the relatively closely spaced transverse cracking throughout the length of the project. These are due to failures in the underlying concrete base, which have been transmitted to the surface of the asphaltic concrete. There has been considerable vertical displacement at the edges of the cracks. Maintenance records indicate that the old concrete paving was in an advanced stage of deterioration when the asphaltic concrete was laid. The probable condition of the concrete is indicated by pictures 195 and 196, which were taken at the junction between the

asphaltic concrete and concrete paving at the northern end of the project.

The character of the gravel aggregate available for construction in Southern Minnesota is unfavorable. It contains a relatively high percentage of soft material, which is conducive to surface pitting and high absorption of the bituminous material. This condition has been partially offset by the use of seal coats, which are extensively employed in Minnesota.

The sampling for this project was done near Station 184+80 in the northbound traffic lane. This location is one which has been selected by the Minnesota State Highway Department for study under their Investigation No. 99, "The Weathering Properties of Asphalt."

State of Minnesota Project S.P. 1304-08
Route T.H. 61, North Branch to Rush City, Minnesota, Built in 1951.

This portion of T.H. 61 was constructed in 1951, using gravel aggregate and 200-300 penetration asphalt, supplied by the Ohio Oil Company. The asphaltic concrete was placed over gravel base used as a leveling course over the old concrete paving. The finished surface received a seal coat consisting of asphalt emulsion and aggregate chips immediately after completion. This initial seal coat is still in service.

The relatively short service life of this paving has not resulted in any material irregularity in the paving surface throughout the length of the project. Transverse cracking, apparently caused by previous faulting of the underlying concrete paving, is apparent throughout the job, these cracks being spaced approximately 35 to 40 feet. There has been no appreciable rutting,shoving, raveling, or flushing. The riding qualities of the paving are extremely good, there being no noticeable vertical displacement at the edges of the transverse cracks.

ERI samples M89 and M90 were obtained at Station 1777+95, from the northbound traffic lane, at the east edge and outer wheel path, respectively. This location has been used for sampling in connection with the Minnesota Highway Department Investigation No. 99, "The Weathering Properties of Asphalt." The data obtained by the State Highway Department since this paving was constructed have been made available for inclusion in this report.

State of Minnesota Project S.P. 4001-17
Route T.H. 13 from Waterville, Minnesota, North to Junction with T.H. 99.
Built in 1947.

The asphalt for this project was supplied by the Husky Oil Company, Cody, Wyoming, and was 150-200 penetration grade. The aggregate for both the

gravel base and the asphaltic concrete mixture was obtained from a local supply adjacent to the project, and was of relatively poor quality, containing many soft particles. On the north end of this project, Portland cement was mixed with the gravel aggregate, providing an experimental section to permit the evaluation of this type of stabilization. The southern half of the job consists of 7-in. gravel base, 2 in. of asphalt-stabilized gravel, covered with approximately 1-1/2 in. of asphaltic concrete.

Throughout the job, the most pronounced fault is the extensive pitting of the surface. This is due to the disintegration of large particles of soft aggregate, producing pits or holes in the surface which range from 3/4 to 1-1/4 in. in diameter and 1/2 in. in depth. These extend through the seal coat application, which was placed immediately after initial construction.

In addition to the pitting, there has been extensive and almost continuous transverse cracking, particularly in the southern end of the job, in which gravel base has been used. This condition appears to have been caused by subgrade settlement, base consolidation or both. However, data shown in Table 1 indicates that the loss in penetration of the asphalt has been extremely high, which may have been a factor contributing to the present condition of the paving.

In contrast to the exceptionally closely spaced transverse cracks noted in the gravel base section, which extends from mile 0.0 to mile 5.6, the cracking in the adjoining cement-stabilized section is greatest in the longitudinal direction.

A review of the job construction records indicates that the procedure employed in placing the cement-stabilized base materially contributed to this unsatisfactory condition. Construction joints, at work stoppage planes, were feathered or sloped instead of being vertical. This unusual method of finishing construction joints permitted the placing of stabilized material used on adjoining section over the sloped layer of material previously laid. Under such conditions the two layers were not properly bonded, were poorly consolidated, and have been the cause of extensive joint failures. Such typical joint conditions are illustrated by pictures 225, 226 and 227. During the inspection, examination of the cement-stabilized base course disclosed that there had been poor mixing, as evidenced by isolated lumps of cement-treated aggregate, extreme friability in the existing base course mixture, variable base thickness, and apparent low density. These items have been stressed in order that they may receive proper consideration when evaluating the performance of the asphaltic concrete paving.

Sampling of this paving was made at Station 336+00, in the gravel base section, at the location previously selected by the Minnesota State Highway Department in connection with their above-mentioned Investigation No. 99. ERI samples M115 and M116, taken from that location, appear to be representative

of the average paving composition. In addition, a sample was obtained at Station 378+55, northbound traffic lane, which was in the cement-stabilized area. This sample consisted of fragments from the badly map-cracked area shown in picture 227. It is interesting to observe that the penetration of the asphalt recovered from this broken area was 21, in contrast to 28 and 24 at Station 336+00; this will be discussed later in this appendix.

The paving condition on this project, with the exception of that between Carlton and Scanlon, Route T.H. 61, reported elsewhere, is undoubtedly the worst encountered during this survey. Maintenance operations, consisting of resealing, application of wearing course, and replacement of failed sections, have been extensive. From visual inspection, it appears that the major source of the trouble has been caused by subgrade and base conditions. However, there were extensive changes in the asphalt, which will be discussed later.

State of Minnesota Project 7201-18
Route T.H. 5, Sibley County.

The paving in this project extends from Arlington, Minnesota, to the Junction with 212 in Carver County. This is a particularly heavily traveled route, carrying light and heavy commercial vehicles destined for the Twin Cities from the southwest section of Minnesota. Both subgrade conditions and gravel aggregate used in construction were unfavorable. In Sibley County, from Arlington to the south Carver County line, a layer of asphaltic concrete 1-1/2 in. thick was placed over an existing 1-in.-thick bituminous mat, which was supported by a gravel base varying in thickness from 7 to 12 in. It appears that the bituminous mat was in relatively poor condition at the time the asphaltic concrete was placed. Portions of the old mat, visible where it projects beyond the edges of the new paving, are very brittle, dry and lifeless. For the volume and intensity of traffic observed at the time of the inspection, it is apparent that the existing road structure is not adequate. The present surface has received almost continuous maintenance, seal coat, and patching. In Carver County a seal-and-chip application has been applied, which obscures the surface of the old paving. Partially filled cracks, showing through this seal, indicate that the asphaltic concrete paving was in approximately the same condition as that observed between Arlington and the Carver County line. For the reason that only the Sibley County paving was accessible for inspection and sampling, that portion will be considered in this report.

The surface of the paving is uniformly and extensively pitted by holes ranging from 1/4- to 1-1/4-in. in diameter and from 1/4 to 3/4 in. in depth. There has been extensive transverse-crack sealing by maintenance crews, and large map-cracked areas have been either resealed or covered with wearing course material. This paving received an initial seal-and-chip treatment shortly after construction. The initial treatment has practically disappeared, particularly in the wheel paths, where it has been replaced by later

applications. Maintenance operations have provided for the high-speed traffic and, except where settlement has occurred in the map-cracked areas, the riding surface is fairly satisfactory.

Throughout the inspection the paving was examined by removing small sections with a pick. The weather was cool and rainy, which decreased the cohesion of the bituminous fraction. Invariably, the interior of the paving mixture was rich black in color but the material seemed to be particularly grainy and somewhat dry and lifeless. The entire condition indicates the need for early extensive reconditioning or reconstruction.

State of Minnesota Project S.P. 0910-04
Route T.H. 61, from Carlton to Scanlon, Minnesota

This is a particularly heavily traveled section of T.H. 61 between the Twin Cities and Duluth, Minnesota. Before the asphaltic concrete surfacing was laid in 1946, a gravel leveling course ranging from 4-1/2 to 11-1/2 in. was placed over the old concrete. The concrete paving was only 18 ft in width and the roadway was widened 4 ft on each side, gravel base of varying thickness being used for this purpose.

The paved roadway traverses typical northland bog and swamp areas between Carlton and Scanlon. From the job records, maintenance started with the completion of construction and has been continuous up to the present time. It is difficult to find the original paving except at the extreme outer edges, as the central areas have been extensively resealed or resurfaced.

Failures can be attributed solely to subgrade conditions and the initial inadequate base course construction. High water table and severe frost action have produced a marked effect upon the paving behavior.

The selection of the site for sampling was made at Station 47+00 because the most representative initial paving was accessible at this location.

State of Minnesota Project 6917-14,
Route T.H. 53, from Eveleth to Cotton, Minnesota

This paving was constructed in 1946, using local gravel aggregate and asphalt of 200-300 penetration grade supplied by the Ohio Oil Company. Samples were taken at two locations which had been sampled previously by the State Highway Department in connection with their study on the weathering of asphalt. Information obtained is presented in Table 1 of this appendix.

The greater portion of this project traverses swampy, low-lying ground. The present paving was laid over old concrete. In order to correct for grade and cross section, gravel leveling courses from 5 to 7 in. thick were placed over the old concrete. In limited areas the old concrete was removed and the poor subgrade was replaced with selected gravel fill. The gravel base course, which was pit run material, was topped with an asphaltic road-mixed layer approximately 1-1/2 in. in thickness. Asphaltic concrete paving, to a design depth of 1-1/2 in., was placed over the road mix to a width of 22 ft.

The gravel leveling course was not effective in preventing the transmission of the crack pattern from the underlying old concrete. In numerous instances the wheels of passing vehicles produced a definite impact when passing over old joints. There was also an almost continuous occurrence of longitudinal cracking at the junction of the old concrete and the gravel widening.

The surface of the asphaltic concrete had received the customary chip-seal application when completed. This seal was still in good condition and prevented visual examination of the asphaltic concrete surface. There was no shoving, rutting, flushing or raveling throughout the length of the project. Riding qualities of the paving were excellent, and surface appearance and texture were uniform. The samples as obtained at Stations 1795+00 and 2026+00 are typical with respect to texture, surface appearance, and thickness.

State of Minnesota Project S.P. 0303-25
Route T.H. 34, Detroit Lakes to Osage, Minnesota

The asphaltic concrete paving was constructed in 1946, using locally available gravel aggregate and asphalt of 200-300 penetration grade supplied by the Carter Oil Company, Billings, Montana. Prior to this construction, the roadway consisted of a layer of stabilized gravel placed at the rate of 1200 cubic yards per mile and surfaced with a 2-inch asphalt-stabilized gravel wearing course. The original work was completed in 1942.

The newer construction is composed of a 6-inch stabilized-gravel base on the old wearing course and is surfaced with a 1-1/2-in. thickness of asphaltic concrete. The highway is located in an area of rolling terrain in which drainage conditions are generally favorable. Traffic is not intensive, being largely confined to occasional heavy commercial vehicles serving the towns along the route and a considerable volume of tourist traffic to the many lakes and vacation spots in the Detroit Lakes area.

Throughout the project the appearance of the surface and the paving texture is remarkably uniform. There is no rutting, shoving, corrugating, raveling, or bleeding. The original surface was sealed and chipped upon

completion and was resealed in 1949, using an experimental treatment of RCS obtained from Socony Oil Company. The riding qualities of this paving are excellent. There has been very little transverse or map cracking.

Station 1467+30 in the westbound traffic lane, is the site of sampling for the Minnesota Highway Department, "Investigation of the Weathering of Asphalt." Samples M97 and M98 were obtained for our laboratory study from this site. The other two were obtained at Station 879+26 in the westbound lane.

State of Minnesota Project S.P. 1401-27
Route T.H. 10, from Hawley to Dilsworth, Minnesota

The asphaltic concrete paving was constructed in 1951, using locally available gravel aggregate and asphalt supplied by Carter Oil Company, Billings, Montana, which was 100-120 penetration grade. A typical section of the paving consists of an old 9-7-9 concrete paving, 18 ft in width, widened at the time of this construction with a 6 ft concrete slab of 8-in. uniform thickness, located on the north side of the existing concrete. A bituminous leveling course, approximately 1-7/8 in. thick in the center and 3/4 in. at the edge was laid over the existing concrete and surfaced with asphaltic concrete to a depth of 1-1/2 in.

The paving had been in service for only about three years and no irregularities could be noted. As indicated in pictures 251 and 252, there had been some shoving between the car tracks at Glyndon, Minnesota. This condition was examined and sampled at the request of the Highway Department. It was obvious that the distortion of the surface was due to lack of uniformity in the paving thickness and not caused by mixture instability.

Throughout the project there was no evidence of rutting, corrugations, shoving, bleeding, or raveling. Shortly after completion, a seal coat application had been placed over the full width of the paving, preventing visual inspection of the asphaltic concrete surface. ERI samples M103, M104, M105, and M106, sent to our laboratory for study, are representative of the paving on this project.

State of Minnesota Project S.P. 1403-13
Route T.H. 32, from the Junction with T.H. 10 to Ulen, Minnesota

The asphaltic concrete paving was constructed in 1951, using aggregate from local sources and 200-300 penetration grade asphalt supplied by Husky Oil Company, Cody, Wyoming. This was an untreated gravel road prior to construction. The existing material was used as sub-base and from 5 to 9 in. of additional gravel sub-base and 3 in. of selected gravel base course were

added. Asphaltic concrete surfacing 1-1/2 in. thick completed the road section. Traffic is relatively light, consisting of passenger and farm-to-market vehicles, which use this highway as access to the principal east-west route, T.H. 10.

The service history of the paving is so limited that an evaluation of its probable behavior is not possible. The appearance and texture of the paving is very uniform. There is no indication of rutting, raveling, bleeding, shoving or corrugations. ERI samples M101 and M102 are typical of the paving over the project.

State of Minnesota Project S.P. 6508-05
Route T.H. 75, from Morton to Olivia, Minnesota

This paving was constructed in 1948, employing local gravel aggregate and 200-300 penetration grade asphalt supplied by the Texas Company, Casper, Wyoming.

Throughout this project there was extensive pitting of the surface and noticeable abrasion in the wheel paths. The character of the local gravel aggregate is unfavorable. It contains large percentages of soft sandstone and shale particles, and the more durable pieces are usually covered with a fine silty powder, very difficult to remove by normal production methods. Transverse cracking is extensive, requiring annual sealing operations. The water table is high, and the subgrade soil is susceptible to frost action. There is no rutting, shoving, flushing, or corrugations, and abrasion is apparent only in limited areas in the wheel paths.

State of Minnesota Project S.P. 5906-14
Route T.H. 75, from Lake Benton to Pipestone, Minnesota

This paving was constructed in 1951, employing local gravel aggregate and 200-300 penetration asphalt supplied by Saunders Petroleum Company, Coffeyville, Kansas.

In common with other projects in southwest Minnesota, extensive surface pitting, due to the soft aggregate particles, was very noticeable. This condition is illustrated by pictures 262 and 263.

The type of subgrade soil, its susceptibility to frost action, the poor character of the aggregate in both the gravel base and surfacing, have been factors contributing to the extensive maintenance required by this section of the highway. Without exception, each approach to bridges or culverts has settled to such an extent that the use of road mix paving over the full paved

width is required. Cracking or distortion of the paving surface elsewhere is very limited and, where it exists, is due largely to frost action.

State of Minnesota Project S.P. 5506-11
Route T.H. 42, from the Junction with T.H. 14 North to Olmsted County Line, Minn.
(No pictures were taken on account of heavy rain during inspection.)

This paving was constructed in 1951, employing local gravel aggregate and 200-300 penetration grade asphalt supplied by the Standard Oil Company, Casper, Wyoming. The sampling of this work provides a comparison between Standard Oil Company asphalt laid in 1948 on T.H. 5, Arlington, Minnesota, and the material used in 1951.

This is the only project in which both base course and asphaltic concrete surfacing were constructed on crushed-limestone aggregate. The base course varies in thickness from 9 to 12 in. and is covered with 1-1/2 in. surfacing. The samples obtained from Station 117+46 are typical of the entire project.

SAMPLE INDEX

Sample No.	Date Constd	Asphalt Pen	Asphalt Source	Sample Obtained From
M87	1948	100-150	Ohio	Minnesota Project 6206 MD-11, Route T.H. 10, North St. Paul city limits to 4.2 miles north. Sample from 1.5 ft from east edge of road in northbound traffic lane. Sample location same as for Minnesota Investigation No. 99. Approximate Station of sample—184+80.
M88	1948	100-150	Ohio	Same as for M87 except sample obtained from outer wheel path of northbound traffic lane.
M89	1951	150-200	Ohio	Minnesota Project 1304-08, Route T.H. 61, North Branch to Rush City, Minnesota. Sample from east edge of paving in northbound traffic lane at Station 1777+95.
M90	1951	150-200	Ohio	Same as for M89 except that sample obtained from outer wheel path of northbound traffic lane.
M91	1946	200-300	Socony	Minnesota Project 0910-04, Route 61, Carlton to Scanlon, Minnesota. Sample obtained from west edge of paving in southbound traffic lane, Station 47+00, which equals Station 6652+61.4 and is 0.8 mile north of road turn in Carlton.

Sample No.	Date Constd	Asphalt Pen	Asphalt Source	Sample Obtained From
M92	1946	200-300	Socony	Same as for M91 except sample obtained from outer wheel path in southbound traffic lane.
M93	1946	200-300	Ohio	Minnesota Project 6917-14, Route T.H. 53, Eveleth to Cotton, Minnesota. Sample obtained from Station 2026+00, between wheel paths in the southbound traffic lane. Sample location the same as for Minnesota Investigation No. 99.
M94	1946	200-300	Ohio	Same as for M93 and adjacent to Sample M93.
M95	1946	200-300	Ohio	Minnesota Project 6917-14, Route T.H. 53, Eveleth to Cotton, Minnesota. Sample obtained from Station 1795+00 in the outer wheel path, southbound traffic lane, which location is opposite entrance to State gravel pit No. 2472.
M96	1946	200-300	Ohio	Same as for M95 except sample obtained from between the wheel paths.
M97	1946	200-300	Carter	Minnesota Project S.P. 0303-25, Route T.H. 34, starting 11.0 miles east of Detroit Lakes to Osage, Minnesota. Sample obtained from Station 1467+30, between wheel paths in the westbound traffic lane. This location is identified by white sign "Bituminous Sample No. 1" and is test site for Minnesota Investigation No. 99.
M98	1946	200-300	Carter	Same as for M97 except sample obtained from outer wheel path in westbound traffic lane.
M99	1946	200-300	Carter	Minnesota Project 0303-25, Route T.H. 34, starts 11.0 miles east of Detroit Lakes to Osage, Minnesota. Sample obtained from Station 879+26, outer wheel path, westbound traffic lane.
M100	1946	200-300	Carter	Same as for M99 except sample obtained from between wheel paths in westbound traffic lane.

Sample No.	Date Constd	Asphalt Pen	Asphalt Source	Sample Obtained From
M101	1951	200-300	Husky	Minnesota Project S.P. 1403-13, Junction of T.H. 10 and T.H. 32, to Ulen, Minnesota. Sample obtained from Station 220+75.3 at east edge of paving in the northbound traffic lane.
M102	1951	200-300	Husky	Same as for M101 except that sample obtained from outer wheel path of the northbound traffic lane.
M103	1951	100-120	Carter	Minnesota Project 1401-27, Route T.H. 10, Hawley to Dilsworth, Minnesota. Sample obtained from Station 424+22, intersection of County Road 43, from the midpoint between wheel paths of the westbound traffic lane.
M104	1951	100-120	Carter	Same as for M103 except sample obtained from outer wheel path of the westbound traffic lane.
M105	1951	100-120	Carter	Minnesota Project 1401-27, Route T.H. 10, Hawley to Dilsworth, Minnesota. Sample obtained at Station 845+79, which is intersection of C.A.R. 47, from outer wheel path of the eastbound traffic lane.
M106	1951	100-120	Carter	Same as for M105 except that sample was obtained from between wheel paths of the eastbound traffic lane.
M107	1948	200-300	Texas	Minnesota Project S.P. 6508-05, Route T.H. 71, Morton to Olivia, Minnesota. Sample obtained at the Station coincident with the intersection of Road S.A.R. 2, from the outer wheel path of the northbound traffic lane.
M108	1948	200-300	Texas	Same as for M107 except that sample obtained from between wheel paths in the northbound traffic lane.

Sample No.	Date Constd	Asphalt Pen	Asphalt Source	Sample Obtained From
M109	1951	200-300	Saunders	Minnesota Project S.P. 5906-14, Route T.H. 75, Lake Benton to Pipestone, Minnesota. Sample obtained at Station 689+02, from outer wheel path of the southbound traffic lane.
M110	1948	200-300	Saunders	Same as for M109 except that sample was obtained from between wheel paths in the southbound traffic lane.
M111	1951	200-300	Saunders	Minnesota Project S.P. 5906-14, Route T.H. 75, Lake Benton to Pipestone, Minnesota. Sample obtained at Station 264+85, from outer wheel path of southbound traffic lane.
M112	1948	200-300	Saunders	Same as for M111 except that sample obtained from between wheel paths in southbound lane.
M113	1948	200-300	S.O. Co.	Minnesota Project Sibley County 7201-18, Route T.H. 5, Arlington to Carver County line. Sample obtained at the intersection of C.A.R. 1 and T.H. 5, which appears to be about at Station 650+48. Taken from the outer wheel path, southbound traffic lane.
M114	1948	200-300	S.O. Co.	Same as for M113 except that sample was taken from between wheel paths in the southbound traffic lane.
M115	1947	150-200	Husky	Minnesota Project S.P. 4001-17, Route T.H. 13, Waterville, Minnesota, north to junction with T.H. 99. Sample obtained at Station 336+00, southbound traffic lane, outer wheel path. This location used as test site under Minnesota Investigation No. 99.
M116	1947	150-200	Husky	Same as for M115 except that sample obtained from between wheel paths, southbound traffic lane.

Sample No.	Date Constd	Asphalt Pen	Asphalt Source	Sample Obtained From
M117	1951	150-200	S.O. Co.	Minnesota Project S.P. 5506-11, Route T.H. 42, junction with T.H. 14, north to the Olmsted County line. Sample obtained at Station 117+46, from outer wheel path, in the northbound traffic lane.
M118	1951	150-200	S.O. Co.	Same as for M117 except that sample was obtained from the midpoint between wheel paths in the northbound traffic lane.
M119	1947	150-200	Husky	Minnesota Project S.P. 4001-17, Route T.H. 13, Waterville, Minnesota north to the junction with T.H. 99. This sample was taken from a badly map-cracked area at Station 378+55, at the edge and outer wheel path of the northbound traffic lane. The base in this section was soil cement.

PAVING MATERIAL TEST DATA

State of Minnesota
Asphaltic Concrete Paving, 1946 to 1951.
Penetration and Source of Asphalt Shown Under Each Project Description

INTRODUCTION

After a preliminary inspection of the existing records at the material laboratory of the Minnesota State Highway Department, 12 projects were selected for field inspection and sampling. With the exception of one, all were constructed of Wyoming asphalt between 1946 and 1951. In conformity with Minnesota practice, all had received a chipped seal coat immediately after construction, the older paving, in some instances, having been retreated. The one project in which Wyoming asphalt was not used was believed to have contained Frontier asphalt, but it was later found that the binder was produced by Saunders Petroleum Company, Coffeyville, Kansas.

The general type of material employed, the source of supply, and the date of construction are tabulated below.

Source of Asphalt	Date Const	Pen Grade Used
N.W. Ref. Co., St. Paul	1948	100-150
Ohio Oil Co., Lovell	1946	200-300*
Ohio Oil Co., Lovell	1951	150-200
Socony-Vac., Casper	1946	200-300
Carter Co., Billings	1946	200-300*
Carter Co., Billings	1951	100-120
Husky Co., Cody	1947	150-200*
Husky Co., Cody	1951	200-300
Texas Co., Casper	1948	200-300
S.O. Co., Casper	1948	200-300
S.O. Co., Casper	1951	200-300
Saunders, Coffeyville	1951	200-300

*The asphalt and paving using this material was included in a weathering investigation conducted by the Minnesota S.H.D., identified as Project No. 99.

Information with respect to aggregate gradation and proportions, together with tests on the original asphalt, was available on all projects. The Department had selected locations with the intention of taking annual samples to provide data for the weathering study. Lack of personnel has prevented regular sampling, but those data which are available from such follow-up tests are included in this report.

Minnesota has used Wyoming asphalts extensively. These asphalts have been obtained from a number of different manufacturers, are of different penetration grades, and have been employed in bituminous surfacing over both old concrete and gravel bases.

The data tabulated in Table 1 indicates that the asphalts employed on the various projects had widely different original penetrations. The most complete records of the Department are those of the penetrations of the asphalts. To facilitate comparison between the service behavior of the several asphalts, using the penetration as the basis, it was thought that a common denominator might be useful. This required that some one material of known initial penetration be selected for reference. Accordingly, the Carter Oil Company asphalt used on Project 0303-25, having the highest initial penetration, 261, has been arbitrarily adopted as the "index material."

On this basis, the initial and successive residual penetrations of other asphalts have been expressed as percentages of the penetration of the index material. The difference between these percentages indicates the

reduction in penetration as referred to the index material. These differences, shown in parentheses, become the significant figures when comparing different asphalts.

DISCUSSION OF TEST DATA

Projects Constructed in 1946

Project Designation: 0910-14, Carlton to Scanlon, Route T. H. 61, Socony-Vacuum Oil Co., ERI samples M91 and M92. Pen. 200-300.

6917-14, Eveleth to Cotton, Route T. H. 53, Ohio Oil Co., ERI samples M93, M94, M95, and M96. Pen. 200-300.

0303-25, Detroit Lakes to Osage, Route T. H. 34, Carter Oil Co., samples M97, M98, M100. Pen. 200-300.

Gravel aggregate was used in all projects. The maximum size particle did not exceed 3/4 in. The asphalt content of the paving samples and that reported for the original mixture by Minnesota are in very good agreement and are very similar for all samples. In the absence of specific information regarding the properties of the original paving, that obtained from the paving samples constitutes the only data available for comparison. From inspection, it is apparent that the paving on Project 6917-14 had the greatest density, contained the greatest amount of asphalt by volume and, consequently, the greatest volume of aggregate voids filled with asphalt. Project 0910-14 is intermediate, and Project 0303-25 has the most voids and the least asphalt.

Information relative to the asphalt as obtained from later samples taken by the State and from the ERI samples is given in a table following.

The properties of the three asphalts used on these 1946 projects, when compared on the basis of the foregoing service record, indicate the following:

PENETRATION RELATIONSHIP TO INDEX MATERIAL

Source Asphalt	Orig. Pen.	1946	1947	1948	1950	1953	1954
1. Carter	261	100.0	38.3 (61.7)	44.5 (55.5)	21.5 (78.5)	23.0 (77.0)	23.0 (77.0)
2. Socony	217	83.2	--	--	--	--	14.8 (68.4)
3. Ohio	215	82.4	31.4 (51.0)	--	--	21.5 (60.9)	24.7 (57.7)

PENETRATION RELATIONSHIP TO INDEX MATERIAL (Cont.)

Source Asphalt	Orig. Pen.	1946	1947	1948	1950	1953	1954
3a. Ohio	208	79.7	37.9 (41.8)	36.4 (43.3)	--	27.6 (52.1)	27.2 (52.5)

Note: Figures on line with source of asphalt represent residual penetration expressed as a percentage of the index material having a penetration of 261.

Figures in parentheses represent the percent drop in penetration in comparison with the initial penetration of the particular asphalt, which has been expressed as a percentage of the index material.

When the basis of comparison is restricted to these results it is obvious that from the standpoint of change in the original asphalt, the material supplied by Ohio Oil Company shows the lowest drop in penetration. However, with respect to general service behavior, there are other factors which undoubtedly have contributed significantly. These are subgrade conditions, base course composition, contractor performance, traffic intensity, and maintenance operations.

Project 0910-14, Carlton to Scanlon, is located over very swampy, low-lying terrain. The asphalt surfacing was used over old badly broken concrete. The breakage and displacement of the slabs was so severe that gravel base course material to depths of 12 inches was employed to restore grade alignment. In numerous locations the old paving was entirely removed and replaced with selected borrow material. Water table throughout the job is uniformly high, frost action is a problem, and both passenger and commercial traffic is heavy. Records indicate continuous maintenance since completion in 1946. In addition, job construction records indicate poor contractor cooperation during construction and his inability or unwillingness to provide adequate equipment, particularly for subgrade modification or improvement. All indications are that poor subgrade and base course compaction was the rule rather than the exception. Irregular winter and spring frost action has developed extensive damage, which has necessitated the placing of one or more wearing courses in the central traveled area, continuous crack repair, and resealing. The extremely adverse conditions make it impossible for the Department to maintain this section in satisfactory condition.

In contrast, Project 6917-14, Eveleth to Cotton, on which Ohio Oil Company asphalt was used, has superior subgrade conditions. Even though traversing low-lying country with relatively high water table, the use of locally available sand and gravel in the construction of the grade, and its

COMPARATIVE ASPHALT TESTS, 1946 CONSTRUCTION

Control Items	Carlton to Scanlon, Proj. 0910-14			Eveleth to Cotton Proj. 6917-14			Detroit Lakes to Osage, Proj. 0303-25								
	Location Data			Location Data			Location Data			Location Data			Location Data		
	OWP ERI M91	State Data 47+00	OWP ERI M92	Bet. WP ERI M93	State Data 2026+00	Bet. WP ERI M94	OWP ERI M95	State Data 1795+00	Bet. WP ERI M96	Bet. WP ERI M97	State Data 1467+30	OWP ERI M98	OWP ERI M99	State Data 879+26	Bet. WP ERI M100
Orig. penetration		217			215			208			261			---	
After mixing					8			129-62.0%*						---	
1947 Test-State					82-38.1%*			99-47.6%*			100-38.3%*			---	
1948 Test-State								95-45.7%*			116-44.5%*			---	
1950 Test-State											56-21.5%*			---	
1953 Test-State					56-26.0%*			72-34.6%*			60-23.0%*			---	
1954 Test-ERI	40-18.4%*		37-17.1%*	64-29.8%*		65-30.2%*	66-31.7%*		76-36.5%*	59-22.6%*	---	60-23.0%*	60-23.0%*	---	60-23.0%*
Orig. ductility		63			100+			100+			100+			---	
1947 Test-State					150+			150+			150+			---	
1948 Test-State								150+			150+			---	
1950 Test-State											150+			---	
1953 Test-State					150+			150+			150+			---	
1954 Test-ERI	150+		150+	150+		150+	150+		150+	150+		150+	150+	---	150+
Orig. soft. point		---			---			109			90			---	
1947 Test-State					113			113			115			---	
1948 Test-State								114			111			---	
1950 Test-State											123			---	
1953 Test-State					120			115			118			---	
1954 Test-ERI	130		128	122		122	116		116	120		120	121	---	121
Flash-orig.		500			494			492			537			537	
S.G. orig.		1.010		1.020	1.020	1.020	1.020	1.020	1.020		1.018			1.018	
Loss on heating		0.34%			0.34%			0.34%			0.20			0.20	
Pen. res. after 1. on h.		164			176			171			195			195	
Oliensis		neg			neg			neg			neg			neg	
ERI spot	sl. pos		pos	pos		neg	pos		pos	pos		pos	pos		pos
Source of a.c.	Socony-Vacuum			Ohio Oil Co.			Ohio Oil Co.			Carter Oil Co.			Carter Oil Co.		

* % Original penetration

continuous elevation above surrounding ground, has materially contributed to the superior performance of the paving. Construction records and the accepted favorable reputation of the contractor handling this construction indicate another reason for more favorable performance. In common with the Carlton-Scanlon operation, this paving was laid over old concrete, and gravel leveling courses were used to obtain the desired grade and alignment. The gravel base course over the old concrete was usually 5 in. in thickness, with numerous locations where a foot or more of granular sub-base was provided. For the purpose of comparison with other projects covered in this report, it is considered that the paving on Project 6917-14, Eveleth to Cotton, is typical of Minnesota conditions, type of construction and maintenance operations.

Project 0303-25, Detroit Lakes to Osage, upon which Carter asphalt was used, is representative of paving placed upon superior subgrade. The terrain is generally rolling, and drainage is more readily attained. The subgrade soil is more granular. This paving has been placed upon granular base course 6 in. in thickness, which in turn was laid over a stabilized-gravel wearing course constructed in 1941 and 1942. The conditions of subgrade, drainage, and maintenance are decidedly more favorable on this project than on the Eveleth-Cotton section. It would not appear that the marked difference in residual penetration of the asphalt, as compared to that used on Eveleth-Cotton, could be attributed to anything but the basic difference in the original material. While definite information regarding the source of the crudes used by Carter Oil Company during 1946 is not available, from the information supplied by them during the visit to the refinery it is indicated that they were using a blend of Elk Basin, Oregon Basin, and Frannie Heavy at the time this material was supplied. As indicated by the test data, this asphalt as supplied, in common with that used on the other projects, was negative spot by straight Oliensis criteria.

Projects Constructed in 1947

Project Designation: 4001-17, Route T. H. 13, Waterville, Minnesota to junction with T. H. 99, Husky Oil Company asphalt. Penetration 150-200. ERI samples M115, M116, and M119.

In addition to the opportunity afforded to compare asphalt service behavior, this project has the added significance of being constructed over both gravel and gravel-cement stabilized base courses. In contrast to 1946 operations, the gravel, used for both base course and surfacing, contains a large amount of soft, friable particles. Absorption of bituminous material is much greater and the percent of material passing the 200 mesh is higher, although the asphalt content has been increased only slightly. The highway traverses rolling country, and extensive cuts and fills have been required. Fill settlement, the presence of subgrade moisture in cut sections, the absorptive properties of the gravel, and the recorded deficiencies in con-

struction operations and equipment of the cement-stabilized section have resulted in extensive cracking which requires continuous maintenance. No data relative to the composition or properties of the original paving mixture are available in the State records. ERI samples M115 and M116 were obtained at the site selected by the Department to provide information for the investigation of the weathering properties of asphalt. ERI sample M119 was taken from a badly map-cracked area in the northbound traffic lane in the portion of the project having cement-stabilized gravel base. Picture 227 illustrates the condition of the surface at this location.

COMPARATIVE ASPHALT TESTS, 1947 CONSTRUCTION

Waterville to Junction with T. H. 99, Project 4001-17

Control Items	OWP ERI M115	State Data 336+00	Bet. WP ERI M116	Map-Cracked, 378+55 ERI M119
Orig penetration		164		
After mixing		102-62.2%*		
1948 Test-State		59-36.0%*		
1953 Test-State		34-20.7%*		
1954 Test-ERI	28-17.1%*		24-14.6%*	21-12.8%*
Orig ductility		100+		
After mixing		120+		
1948 Test-State		150+		
1953 Test-State		150+		
1954 Test-ERI	150+		75	36
Original Softening point		---		
1954 Test-ERI	142		142	143
Flash-orig		460		
S.G.-orig		1.023		
Loss on heating		0.21		
Pen residue		129		
Sol. C.C.L.4		99.7		
Oliensis		neg		
ERI spot	pos		sl. pos	pos
Source of a.c.	Husky Oil Co.			

* Percent of original penetration.

The properties of this asphalt as referred to the index material previously explained are as follows:

		Penetration Relationships to Index Material					
Source of Asphalt	Orig Pen	Orig 1947	After Mix 1947	1948	1953	1954	
						Avg Road	Map-Crkd
1. Carter	261						
4. Husky	164	62.8%	39.1% (23.7)	22.6% (40.2)	13.0% (49.8)	10.0% (52.8)	8.05% (54.7)

Note: Figures on line with source of asphalt represent residual penetration expressed as a percentage of the index material having a penetration of 261.

Figures in parentheses represent the percent drop in penetration referred to the initial penetration of the particular asphalt, which has been expressed as a percentage of the index material.

The most apparent defects in the asphalt paving on this project are the extensive pitting, due to the apparent disintegration of soft aggregate particles, and the closely spaced transverse cracks. There is a great deal of map cracking, particularly in the outer wheel paths. Only in rare instances, on the south end of the job where gravel base was used, has longitudinal cracking connected the transverse cracks. In contrast, in the northern portion of the project, where the cement-stabilized gravel base was used, longitudinal cracking is most prominent. The transverse cracking on the gravel base section occurs throughout, on heavy fill and on light fill and cut sections. There is no pronounced evidence of spalling of the surfacing at the crack edges, nor has there been any detrimental vertical displacement. From the information provided by tests on the asphalt recovered from samples M115 and M116, it would appear that the low penetration of the asphalt might be a contributing factor to the prevalence of cracking. In considering this possibility, it must be remembered that the aggregate used in the paving mixture was extremely soft and absorptive, which may have been effective in taking up the lighter constituents of the asphalt during the seven-year period of service. However, the gravel base course material is quite high in fine sand and silt, and examination of the exposed base at point of sampling indicates that the material is loose and friable.

On the cement-stabilized section, the resultant base construction was very weakly bonded because of poor distribution of the cement. Base movement, some settlement, and consolidation are definitely evident. However, the present consistency of the asphalt binder, as evidenced by its extensive

drop in penetration, cannot be overlooked as a contributing factor to the poor behavior of the project.

Projects Constructed in 1948

Project Designation: 6206MD-11, St. Paul city limits north 4.2 miles on Route T. H. 10. Northwest Refining Co., St. Paul, Minnesota—100-150 penetration asphalt. ERI samples M87 and M88. Resurface over old concrete paving.

6508-05, Olivia to Morton, Minnesota on Route T. H. 71. The Texas Company, Casper, Wyoming—200-300 penetration asphalt. ERI samples M107 and M108. On gravel base.

7201-08, Sibley County, Arlington to south Carver County line on Route T. H. 5. Standard Oil Co., Casper, Wyoming—200-300 penetration asphalt. ERI samples M113 and M114. Over old bituminous surfacing and gravel base, reinforced with 7- to 10-in. additional gravel base over old construction, except where the reconstruction of the entire road was required.

Project 6206MD-11 was constructed by maintenance forces. No formal plans or specifications were prepared to cover this operation and there is virtually no information regarding mixture proportions and construction procedure. This section of road is subjected to extensive traffic, both passenger car and commercial. Project 7201-08 is also a heavily traveled route and is of relatively light construction, with much more adverse subgrade conditions than those of Project 6206MD-11. The Olivia-to-Morton section is the most lightly traveled route of this series.

Gravel aggregate was used in all projects. The maximum size of particle did not exceed 3/4 in. The gravel aggregate in both projects 6508-05 and 7201-08 contained many soft particles, which had disintegrated to cause extensive pitting of the surface and had abraded under traffic action. On the more heavily traveled route T. H. 5, Project 7201-08, extensive resealing of the surface in both wheel paths, together with numerous maintenance replacements of the paving, had been required. The asphalt content in the original mixtures was 4.6% for Project 6206MD-11, 4.9% average in Project 6508-05 and 4.6% in Project 7201-08. Asphalt recovered from the ERI samples was 3.8%, 4.5%, and 4.75%, respectively. Information relative to the original and recovered asphalt is given in a table following.

The properties of the three asphalts used on the 1948 projects, when compared after being referred to the index material are as follows:

COMPARATIVE ASPHALT TESTS, 1948 CONSTRUCTION

	St. Paul—4.2 Miles North on T.H. 10, Project 6206MD-11			Olivia-Morton Route T.H. 71, Project 6508-05			Arlington to South Carver County Line, Route T.H. 5, Project 7201-08		
	Location Data			Location Data			Location Data		
Control Items	Edge, ERI M87	State Data	OWP, ERI M88	OWP, ERI M107	State Data	Bet. WP, ERI M108	OWP, ERI M113	State Data	Bet. WP, ERI M114
Orig Pen-1948		168			255			219	
After Mixing		92 54.8%*							
1954 Test-ERI	37 22.0%*		26 15.5%*	57 22.4%*		57 22.4%*	35 16.0%*		41 18.7%*
Orig Ductility		100+			100+			98	
1954 Test-ERI	150+		150+	150+		150+	150+		150+
Soft. Point, Orig		115			---			---	
1954 Test-ERI	135		139	123		125	138		137
Flash		460+			460+			460+	
Spec. grav.		1.028			1.019			1.017	
Loss on heating		0.08			0.01			0.0	
Pen residue		139			199			180	
Sol. C.C.L.4		99.9			99.9			99.9	
Spot-Oliensis		neg			neg			neg	
ERI Spot	pos		pos	pos		pos	pos		pos
Source a.c.	Northwest Ref. Co.			Texas Co.			S.O. Co.		

*Percent of original penetration.

Source of Asphalt	Orig Pen	Percentage Relationship to Index Material: Orig Material	After Mixing 1948	ERI Samples 1954 Edge	ERI Samples 1954 OWP
5. Northwest Ref. Co.	168	64.4	35.2	14.2	10.0
			(29.2)	(50.2)	(54.4)
6. Texas Co.	255	97.7		22.4	22.4
				(75.3)	(75.3)
7. Standard Oil Co.	219	83.9		13.4	15.7
				(70.5)	(68.2)

Note: Figures on line with the source of asphalt represent the residual penetration expressed as a percentage of the index material having a penetration of 261.

Figures in parentheses represent the percent drop in penetration referred to the initial penetration of the particular asphalt, which has been expressed as a percentage of the index material.

Considering only the 1948 asphalt as referred to the index asphalt, the greatest percentage drop occurred in the case of the Texas Company material, followed by that of Standard Oil Company and that supplied by the Northwest Refining Company. Taking each asphalt individually, the Texas material, with the highest initial penetration, showed the highest residue, followed by that supplied by the Northwest Refining Company and the Standard Oil Company, in that order.

Projects Constructed in 1951

Project Designation: 1304-08, Route T. H. 61, North Branch to Rush City. Ohio Oil Co.—150-200 penetration asphalt. ERI samples M89 and M90. On gravel lifts over old concrete.

1403-13, Route T. H. 32, junction with T. H. 10 to Ulen. Husky Oil Co.—200-300 penetration asphalt. ERI samples M101 and M102. On gravel base course.

1401-27, Route T. H. 10, Hawley to Dilsworth. Carter Oil Co.—100-120 penetration asphalt. ERI samples M103, M104, M105, and M106. Resurface old concrete.

5906-14, Route T. H. 75, Lake Benton to Pipestone. Saunders Petroleum Co., Coffeyville, Kansas—200-300 penetration asphalt. ERI samples M109, M110, M111, and M112. Over gravel base course.

5506-11, junction with T. H. 14 to Olmsted County north line. Standard Oil Co.—200-300 penetration asphalt. ERI samples M117 and M118. Over gravel base course.

The paving in all projects was a dense graded type, having 3/4-in.-maximum sized particles. All contained gravel aggregate except Project 5506-11, which consisted of crushed limestone aggregate for both base and wearing courses. There was little difference in the grading except for Project 1403-13, which contained appreciably less aggregate retained on the No. 10 sieve. The only paving with soft, highly absorptive aggregate was on Project 5906-14, Lake Benton to Pipestone. There was extensive pitting in the paving surface on this project, largely due to shale and soapstone particles. The percent of asphalt in the mixtures ranged from 4.5 to 5.4% by weight of the mixture with no indication that soft or absorptive aggregate had been offset by higher asphalt content. The density of the sampled road surface reflected the consolidation of traffic. Projects 1304-08 and 1401-27 are the more heavily traveled routes and showed paving densities of 139 and 143 lb/cu ft, respectively. Lesser traveled routes covered by Projects 1403-13 and 5906-14 had densities of 136 to 138 lb/cu ft. The best density was obtained on Project 5506-11, which was composed of crushed limestone aggregate. None of the paved areas constructed in 1951 shows any appreciable irregularities which could be attributed to the paving mixture. There was noticeable transverse cracking and settlement on Project 5906-14, Lake Benton to Pipestone, all of which appeared to be due to inadequate subgrade and base compaction. Information relative to the characteristics of the asphalt is given in the table on page 261.

The properties of the five asphalts used on these 1951 projects, when compared upon the basis of the foregoing service record, all referred to the adopted index material, indicate the following:

PENETRATION RELATIONSHIP OF INDEX MATERIAL

Source of Asphalt	Orig Pen.	Orig Asphalt	ERI Samples 1954 Untraveled Area		Traveled Area	
8. Ohio Oil Co.	159	60.9	18.4	(42.5)	20.3	(40.6)
9. Husky Oil Co.	261	100.0	28.0	(72.0)	29.5	(70.5)
	107	41.0	19.2	(21.8)	14.6	(26.4)
10. Carter Oil Co.	112	42.9	14.6	(28.3)	16.9	(26.0)
	220	84.3	21.8	(62.5)	23.8	(60.5)
11. Saunders Pet. Co.	212	81.2	21.5	(59.7)	23.4	(57.8)

PENETRATION RELATIONSHIP OF INDEX MATERIAL (cont.)

Source of Asphalt	Orig Pen.	Orig Asphalt	ERI Samples 1954 Untraveled Area		Traveled Area	
12. Standard Oil Co.	235	90.0	25.3	(64.7)	30.9	(59.1)

Note: Figures on line with the source of asphalt represent the residual penetration expressed as a percentage of the index material having an initial penetration of 261.

Figures in parentheses represent the percentage drop in penetration referred to the initial penetration of the particular asphalt, which has been expressed as a percentage of the index material.

Considering only the 1951 material as based upon the index asphalt, the greatest percentage drop occurred in the case of the Husky Oil Company, which had the highest initial penetration, followed by Standard Oil Company material with an initial penetration of 235, Saunders Petroleum Company, initial penetration material of 212 and 220, Ohio Oil Company asphalt with initial penetration of 159, and finally, Carter Oil Company, with initial penetration of 107 and 112.

The behavior of the several asphalts used in Minnesota paving may now be condensed and summarized. Although the progressive reduction in penetration and changes in other properties are of interest, only the original data and that obtained from the 1954 ERI sampling will be included in this tabulation. This is done for the reason that test data covering the intermediate periods are not consistently available. To further facilitate comparison, all asphalt from a given source is grouped.

DUCTILITY TEST DATA

The ductility tests (Table 1) do not seem to provide significant information, except possibly in the cases of two asphalts. In most cases the asphalt recovered from the ERI samples had at least equal ductility to that originally reported. There are two specific instances where drop in ductility has been noted and may be significant. The Husky Oil Company asphalt used on Project 4001-17, 1947 construction, was reported as having 100+ ductility. Asphalt from ERI sample M115 tested 150+, but that from sample M116 showed 75 and M119 ran 36. The penetration drop of the asphalt on this project was high. The aggregate was extremely soft and absorptive. The existing paving exhibits a disproportionate amount of transverse cracking. The paving condition may have been affected by absorption of the lighter oily constituents of the asphalt

COMPARATIVE ASPHALT TESTS

Source of Asphalt	Year Constd	Project No.	ERI Samples	Orig Pen	% of Index Material**	ERI 1954 Penetration
Ohio	1946	6917-14	M93-M94	215		64.5=30.0% of original
			M95-M96	208		72.0=34.1% of original
			M93-M94		82.4	*57.7% pen drop
			M95-M96		79.7	*52.5% pen drop
Ohio	1951	1304-08	M89-M90	159		50.5=31.7% of original
			M89-M90		60.9	*41.6% pen drop
Husky	1947	4001-17	M115-M116	164		26.0=15.9% of original
			M115-M116		62.8	*52.8% pen drop
			M119	164		21.0=12.8% of original
			M119		62.8	*54.7% pen drop
Husky	1951	1403-13	M101-M102	261		75.0=28.8% of original
					100.0	*71.3% pen drop
Socony-Vacuum	1946	0910-14	M91-M92	217		38.5=17.8% of original
			M91-M92		83.2	*68.5% pen drop
Carter	1946	0303-25	M97-M98-M99-M100	261		60.0=23.0% of original
			M97-M98-M99-M100		100.0	*77.0% pen drop
Carter	1951	1401-27	M103-M104	107		44.0=41.1% of original
			M105-M106	112		41.0=36.6% of original
			M103-M104		41.0	*24.1% pen drop
			M105-M106		42.9	*27.2% pen drop
Northwest	1948	6206 MD-11	M87-M88	168		31.5=18.7% of original
			M87-M88		64.4	*52.3% pen drop
Texas	1948	6508-05	M107-M108	255		57.0=22.0% of original
			M107-M108		97.7	*75.3% pen drop

COMPARATIVE ASPHALT TESTS (continued)

Source of Asphalt	Year Constd	Project No.	ERI Samples	Orig Pen	% of Index Material**	ERI 1954 Penetration
Standard	1948	7201-08	M113-M114	255		38.0=17.3% of original
			M113-M114		83.9	*69.4% pen drop
Standard	1951	5506-11	M117-M118	235		73.0=30.9% of original
			M117-M118		90.0	*61.9% pen drop
Saunders	1951	5906-14	M109-M110	220		59.5=27.0% of original
			M111-M112	212		58.5=27.6% of original
			M109-M110		84.3	*61.5% pen drop
			M111-M112		81.2	*58.8% pen drop

Note: The notations marked "% of original" indicate the residual penetration of the asphalt as obtained from the ERI samples in 1954 as referred to the initial penetration of the specific asphalt.

*Penetration drop of the asphalt when referred to the index material.

**The samples were referred to the 261-penetration index material, as a standard for comparison.

into the porous aggregate. Movement of air and moisture through the paving mixture may have produced accelerated weathering effects.

The other project showing high ductility changes is the one constructed with Saunders Petroleum Company material. This work was done in 1951 between Lake Benton and Pipestone, Minnesota. It should be noted that this particular asphalt had an initial specific gravity of 0.994, the only one investigated which was less than 1.000. In the location represented by ERI samples M109 and M110, the initial ductility was 92. The asphalt from the sample taken from the wheel path had a residual ductility of 62, while that taken from between the wheel paths lightly traveled, tested 120. The location represented by ERI samples M110 and M111 had asphalt initially reported with a ductility of 93. In the asphalt recovered from the sample taken from the traveled wheel path the ductility was 54, and from the untraveled area it was 135. When these results were obtained, they were regarded with suspicion. The tests were repeated, with practically the same results.

SOFTENING POINT DATA

Softening point determinations have been made on all the asphalt which has been recovered from the ERI samples. This test has been performed by Minnesota's Department of Highways in only a few instances on the original asphalt and the recovered material which had been studied in connection with their weathering investigation. The values obtained are tabulated below:

COMPARATIVE ASPHALT TESTS

Source A.C., Date, and ERI Sample	Orig Pen	1954 ERI Pen	Pen Drop	Orig S.Pt	1954 ERI S.Pt	% Change in S.Pt	Ratio % Change S.Pt to Pen	Ratio ERI S.Pt to ERI Pen
Ohio-1946								
M93-M94	215	64.5	150.5	109	122	11.9	.1700	1.891
M95-M96	208	71.0	137.0	109	116	6.4	.0971	1.634
Ohio-1951								
M89-M90	159	50.5	108.5	---	125	---	-----	2.475
Husky-1947								
M115-M116	164	26.0	138.0	---	142	---	-----	5.462
Husky-1947								
M119	164	21.0	143.0	---	143	---	-----	6.810

COMPARATIVE ASPHALT TESTS (Cont.)

Source A.C., Date, and ERI Sample	Orig Pen	1954 ERI Pen	Pen Drop	Orig S.Pt	1954 ERI S.Pt	% Change in S.Pt	Ratio % Change S.Pt to Pen	Ratio ERI S.Pt to ERI Pen
Husky-1951 M101-M102	261	75.0	186.0	---	117	---	-----	1.560
Socony-1946 M91-M92	217	38.5	178.5	---	129	---	-----	3.351
Carter-1946 M97-8-9-100	261	60.0	201	90	120	33.3	.4325	2.000
Carter-1951 M103-M104	107	44.0	63.0	---	126	---	-----	2.864
Carter-1951 M105-M106	112	41.0	71.0	---	128	---	-----	3.120
Northwest-1948 M87-M88	168	31.5	136.5	115	137	19.1	.2349	4.349
Texas-1948 M107-M108	255	57.0	198	---	124	---	-----	2.175
Standard-1948 M113-M114	219	38.0	181.0	---	138	---	-----	3.632
Standard-1951 M117-M118	235	73.0	162.0	---	118	---	-----	1.616
Saunders-1951 M109-M110	220	59.5	160.5	---	129	---	-----	2.168
Saunders-1951 M111-M112	212	58.5	153.5	---	128	---	-----	2.188

An interesting hypothesis may be made from the information presented in the above table. From the condition of the several paving sections included in the survey, it would appear that the ratio of softening point to penetration of a given asphalt, when both are taken after equal periods of service exposure,

may be significant. For example, of four asphalts in service since 1946 (8 years) the softening point penetration-ratio was maximum-3.351, minimum-1.634, average-2.219. The single asphalt in service since 1947 (7 years) had a softening point-penetration ratio of 6.136. The three in service since 1948 (6 years) showed 4.349 maximum, 2.175 minimum, 3.385 average values. The seven asphalts in service since 1951 (3 years) had values of 2.475 maximum, 1.560 minimum and 2.302 average. Evaluating the several materials based upon the source of the asphalt, and listing them in order of increasing ratios, the following relationship may be observed:

1946 Construction-8 years exposure

Ohio, Ohio, Carter, Socony.

1947 Construction-7 years exposure

Husky, very high ratio of 6.136, only asphalt included in 1947.

1948 Construction-6 years exposure

Texas, Standard, Northwest Ref. Company

1951 Construction-3 years exposure

Husky, Standard, Carter, Carter, Saunders, Saunders, Ohio

In general, the asphalt having the highest initial penetration exhibited the greatest penetration drop and the greatest increase in softening point. The initial penetration listed in order of increasing values of the softening point-penetration ratio for the asphalt used on Minnesota projects is as follows:

1946 Construction-8 years exposure

Ohio	Ohio	Carter	Socony
208	215	261	217

1947 Construction-7 years exposure

Husky
164

Only asphalt reported.

1948 Construction-6 years exposure

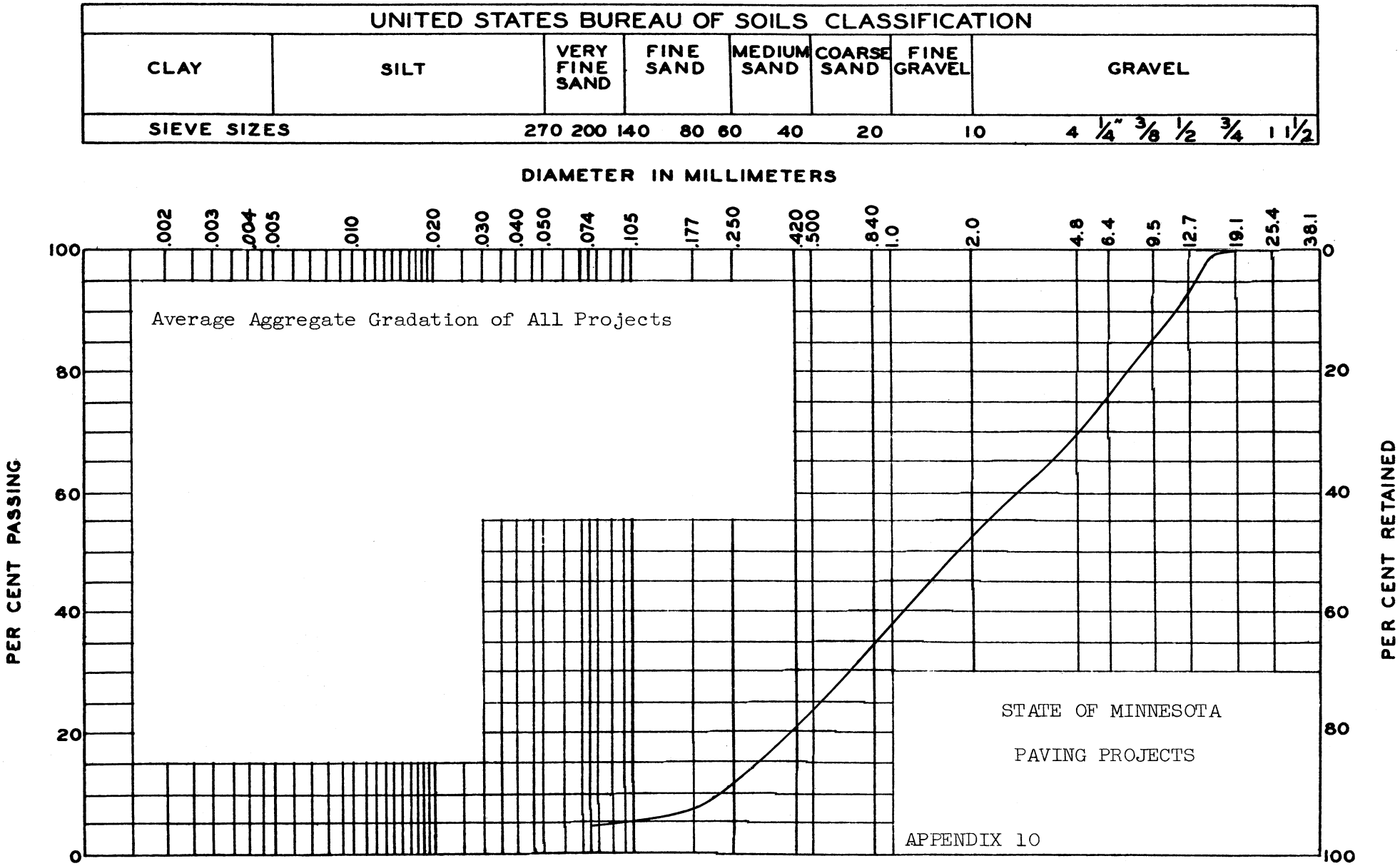
Texas	Standard	Northwest
255	219	168

1951 Construction-3 years exposure

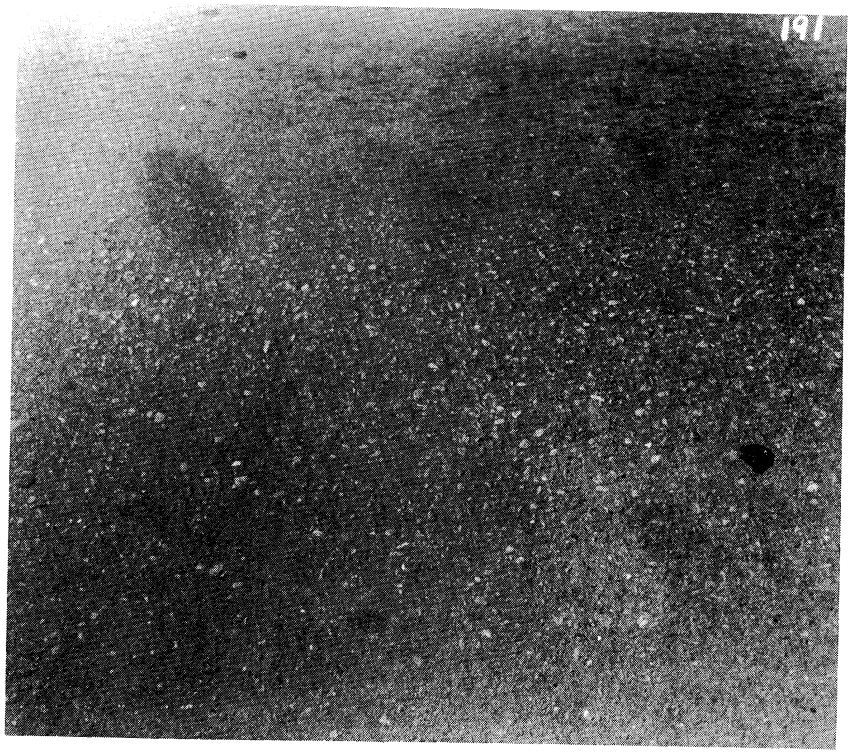
Husky	Standard	Carter	Carter
261	235	112	107

Saunders	Saunders	Ohio
220	212	159

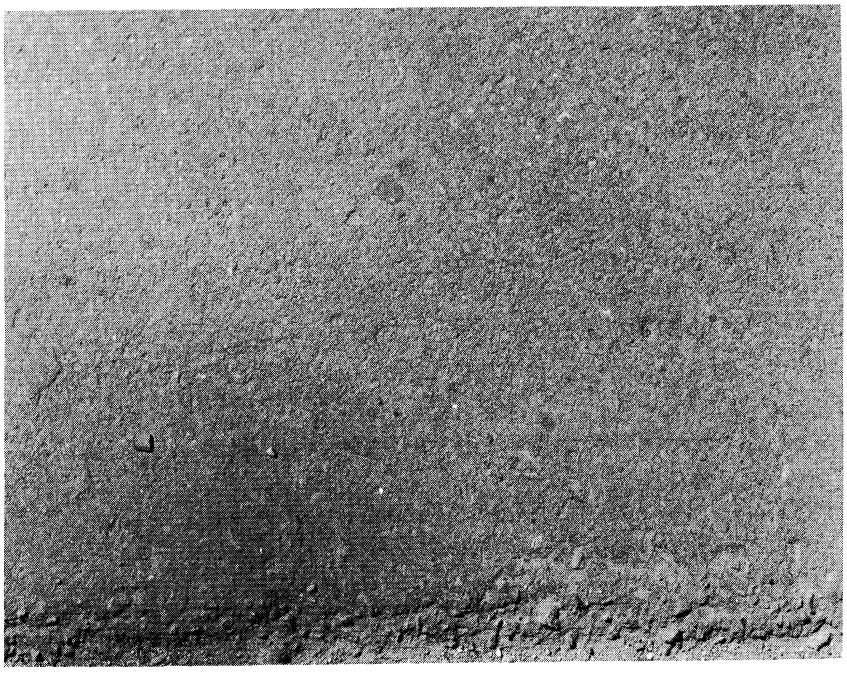
The Husky Oil Company asphalt, 164 initial penetration, had a softening point-penetration ratio of 6.136 after 7 years exposure. The extreme hardening indicated by the tests is confirmed by the inspection of the paving surface.


UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
PER CENT RETAINED
0 20 40 60 80 100
Average Aggregate Gradation of All Projects
STATE OF MINNESOTA
PAVING PROJECTS
APPENDIX 10

Picture 190. Mile 0.0, start of the project at the north St. Paul, Minnesota city limits. General view of the highway looking north.

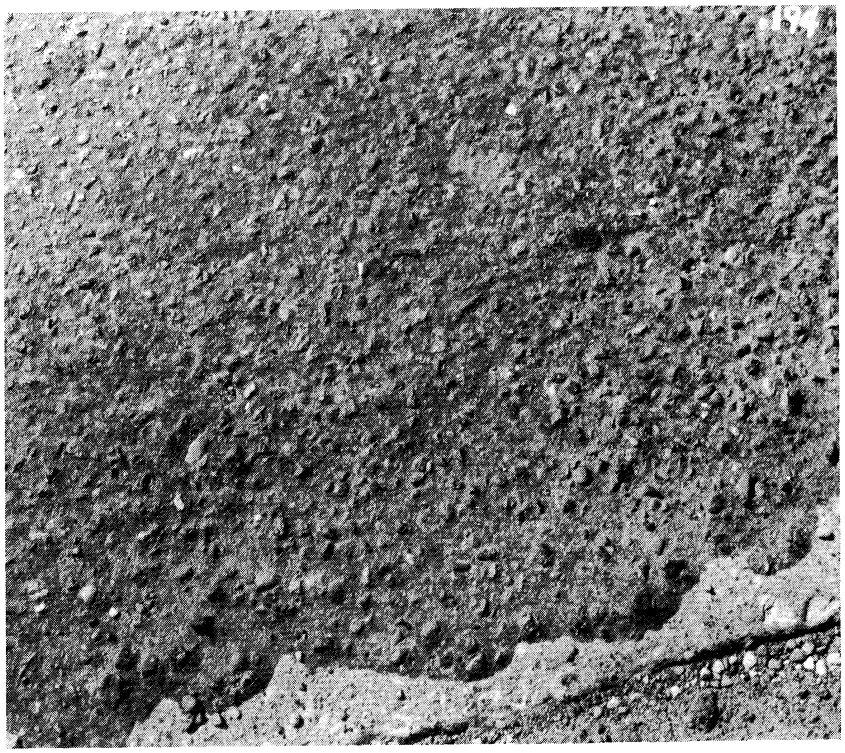


Picture 191. Mile 0.5, close-up view of the paving texture in the wheel path. Indication of some abrasive action due to traffic action.

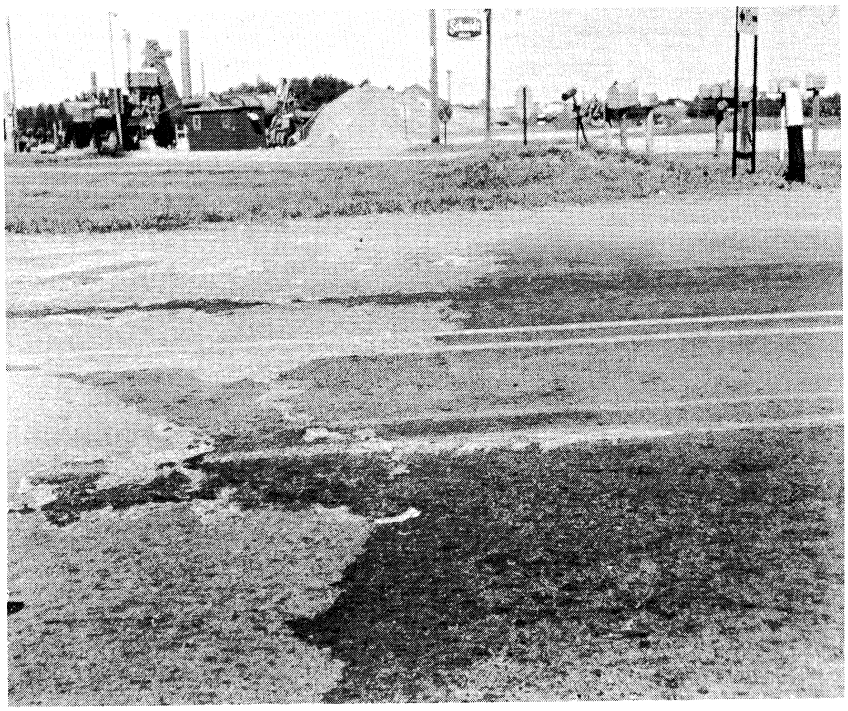


Picture 192. Mile 0.5, close-up view of the paving texture at the edge of the paving. In contrast with the preceding picture taken in the wheel path, the paving surface remains well closed, and no abrasive action of traffic can be noted.

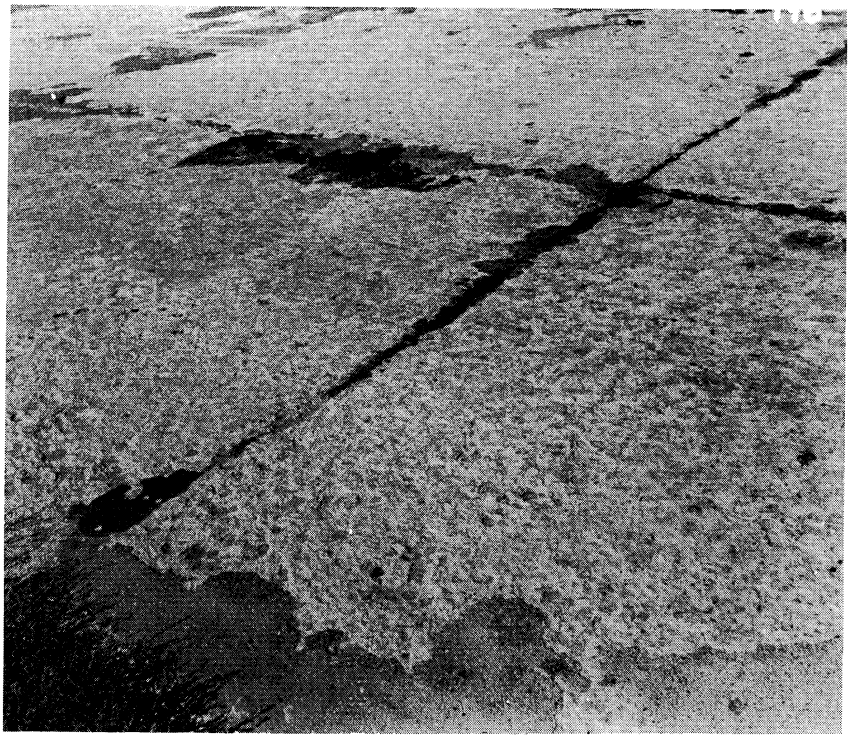
Picture 193. Mile 0.5, close-up view of a typical transverse crack. In most cases maintenance operations have sealed up such cracking. At this location the edges of the asphalt concrete are above the surface of the abutting shoulder. No breakage, spalling, or cracking at these edges is apparent.



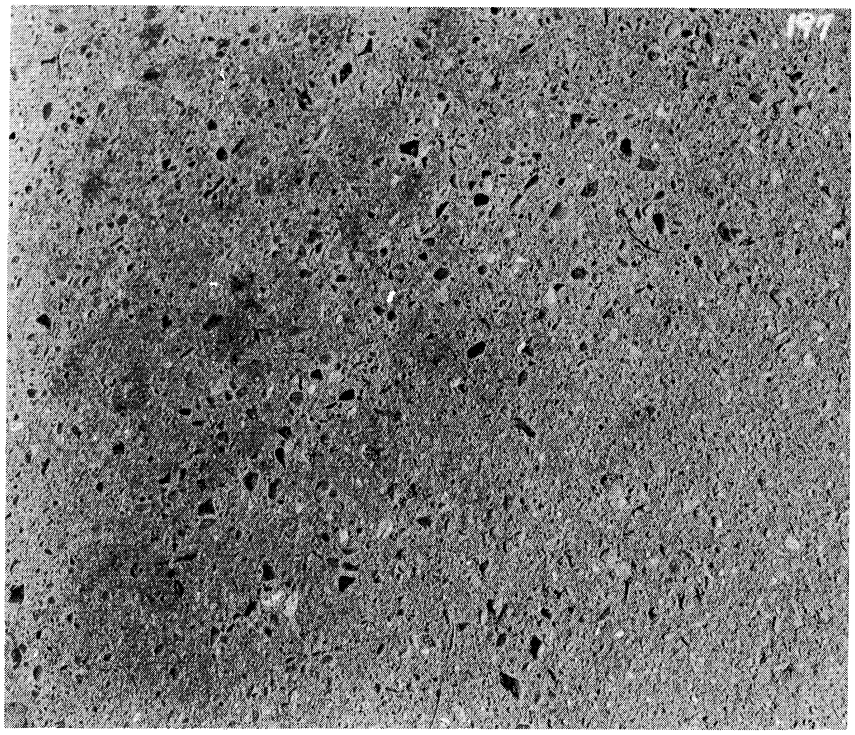
Picture 194. Mile 2.0, east edge of paving at intersection of county road C, where there is abrasive action of traffic at turn. The condition extends not more than 3 ft inward from the paving edge, beyond which the surface of the paving is normal.



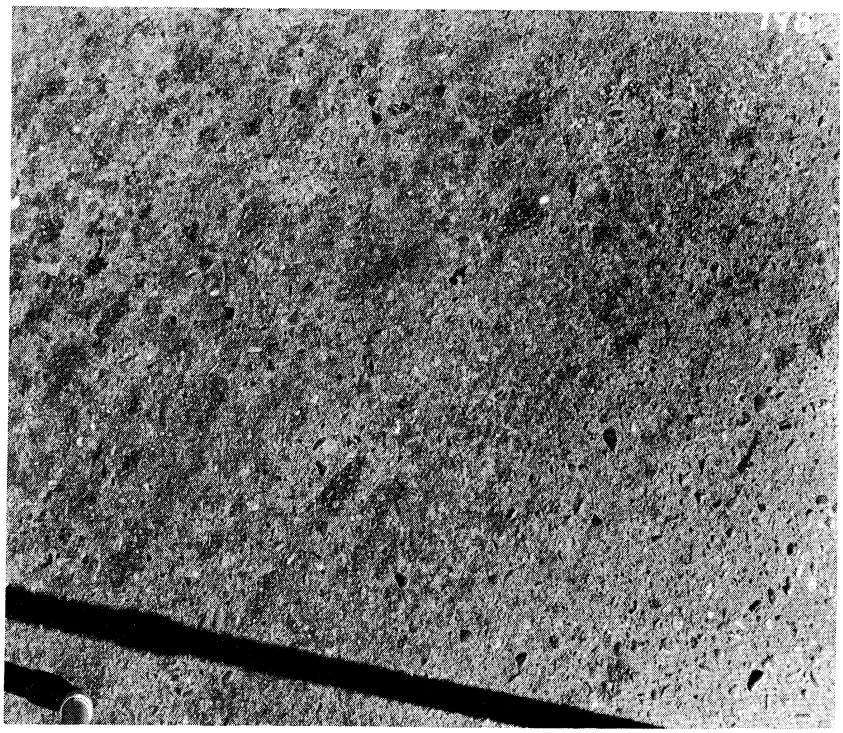
Picture 195. View of junction of present asphaltic concrete surfacing and present Portland cement concrete paving. The view shows the paving surface on the curve at the northern end of the project.



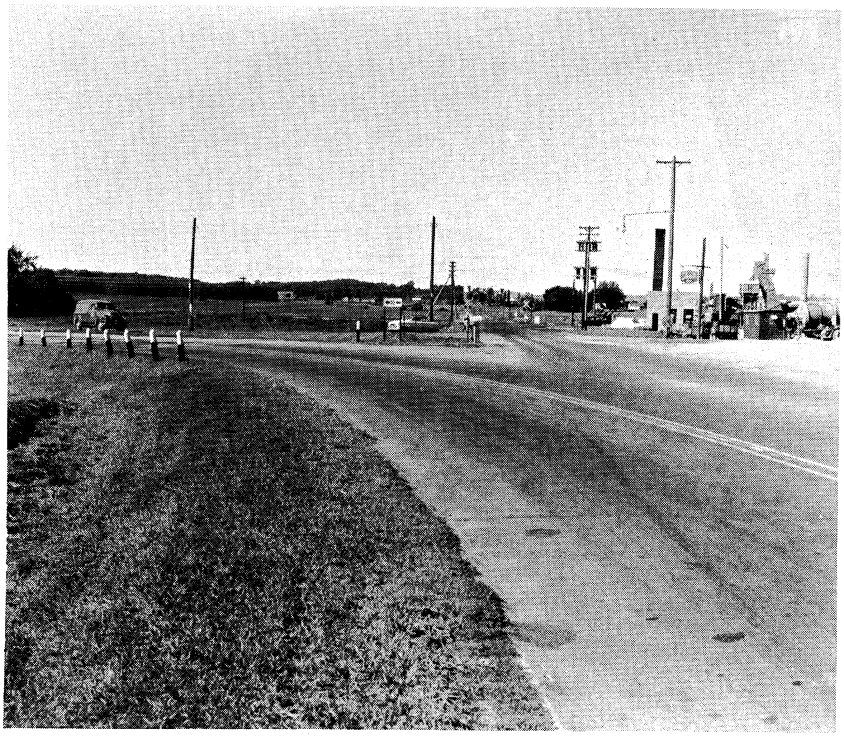
Picture 196. Close-up view of the concrete paving surface slightly north and west of the junction with the asphalt concrete surfacing. The concrete surface has been badly spalled with considerable transverse, block, and corner cracking.



Picture 197. Close-up view of the asphaltic concrete paving texture, just south of the north end of the project. This shows the untraveled west edge area.

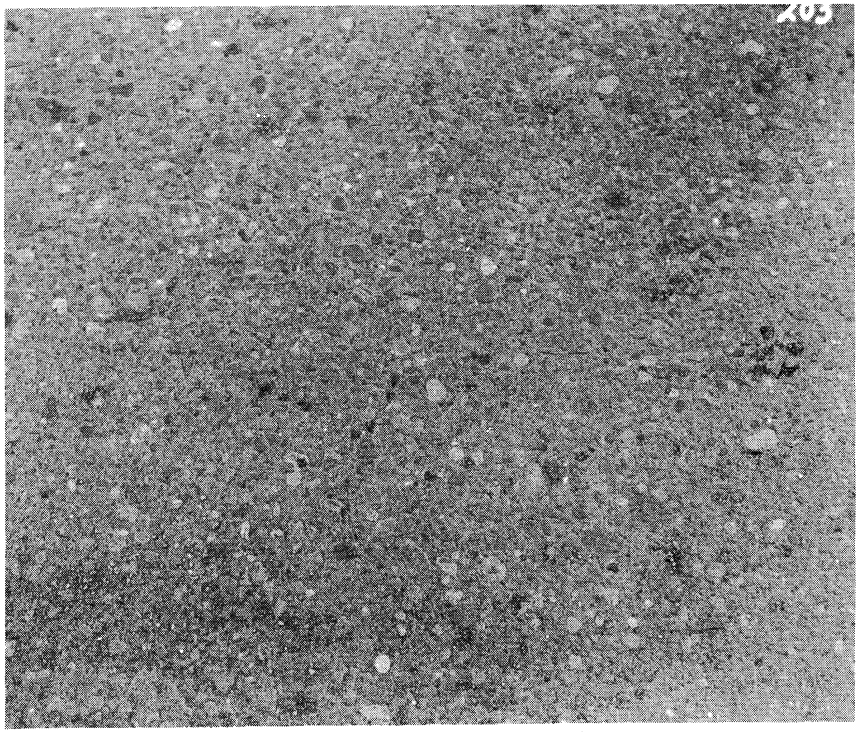


Picture 198. Close-up view of the asphalt concrete surface in the OWP of the southbound traffic lane just south of the end of the curve at the northern end of the project.

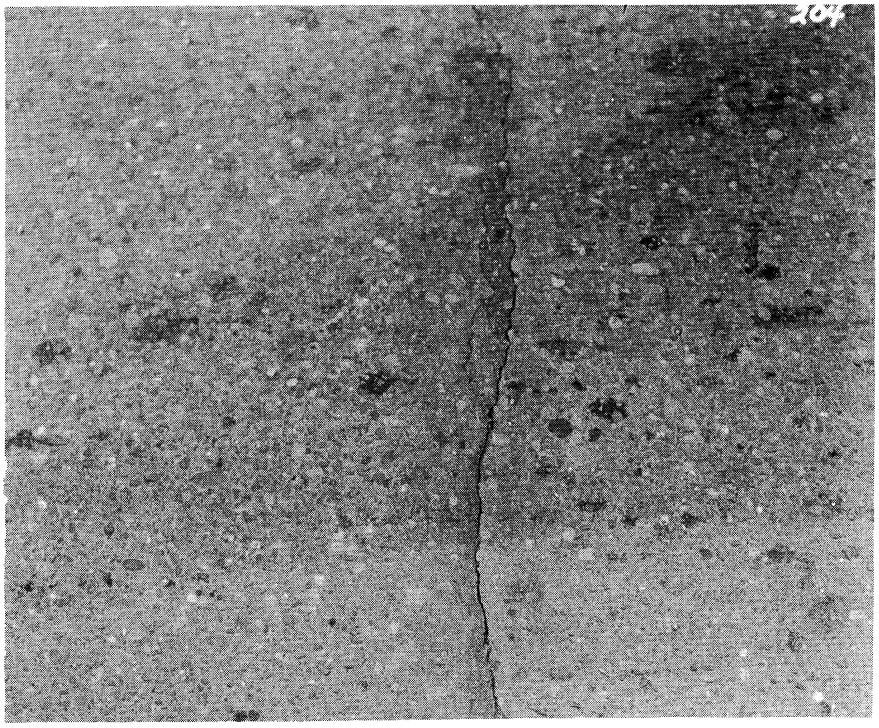


Picture 199. View of roadway at northern end of the project, looking northward around curve toward junction with old concrete paving.

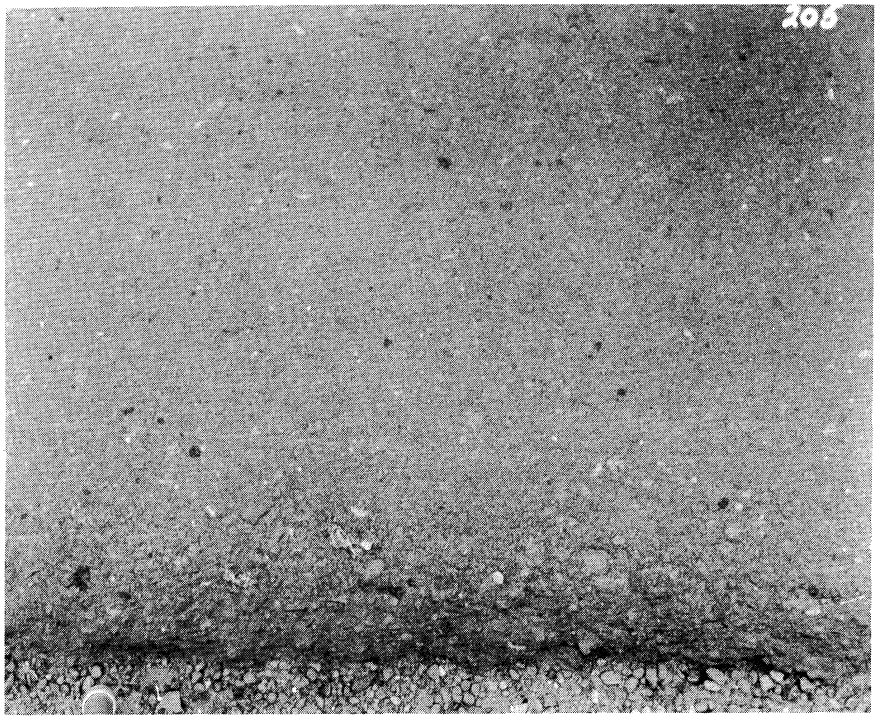
Picture 201. Mile 0.0 at Station 1672+35.3, start of the project, at the intersection of T.H. 61 and T.H. 95 in North Branch, Minnesota.



Picture 203. Mile 0.0, close-up of paving texture in the OWP, northbound traffic lane, at the start of the project.



Picture 204. Mile 0.0, view of transverse crack carried through from underlying old concrete paving, just north of the intersection of T.H. 61 and T.H. 95 in North Branch, Minnesota.

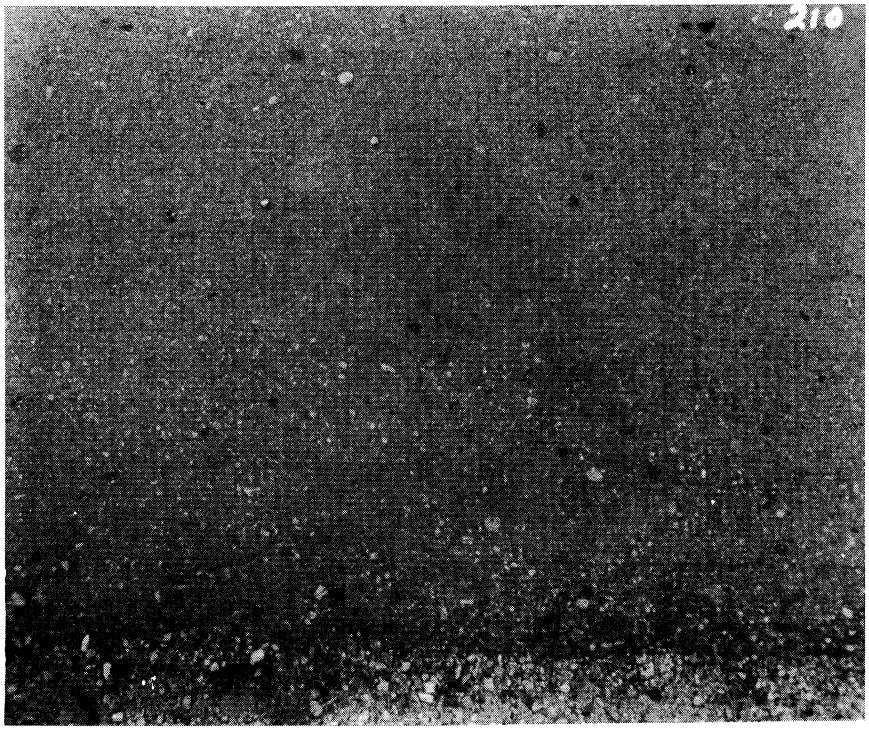


Picture 205. Mile 0.5, view of the surface texture of paving at the untraveled east edge in the northbound traffic lane.

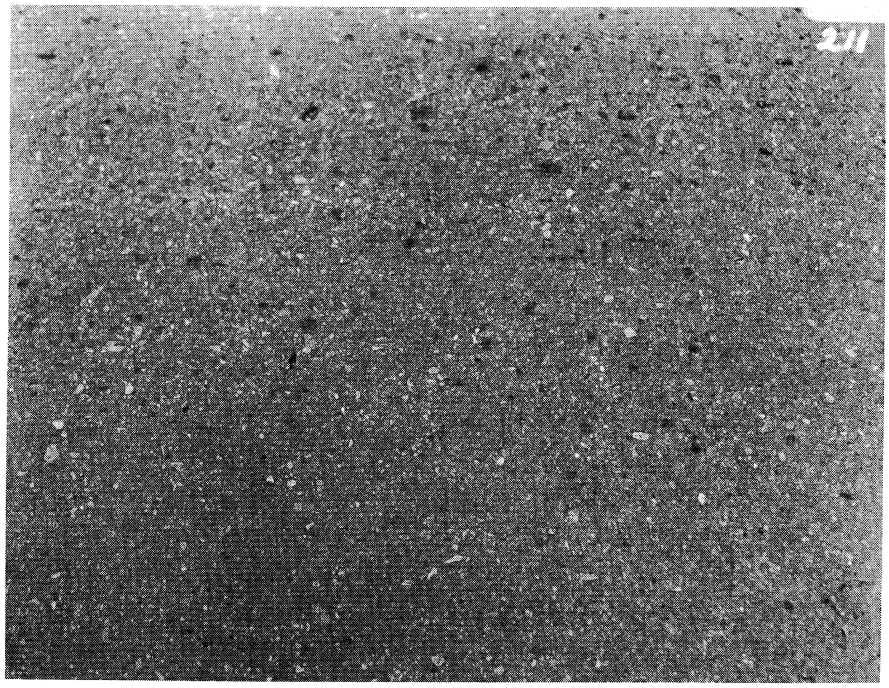
Project 1309-08, Route T.H. 61

Picture 207. Mile 1.0, general view of the rural road section looking north from Mile 1.0.

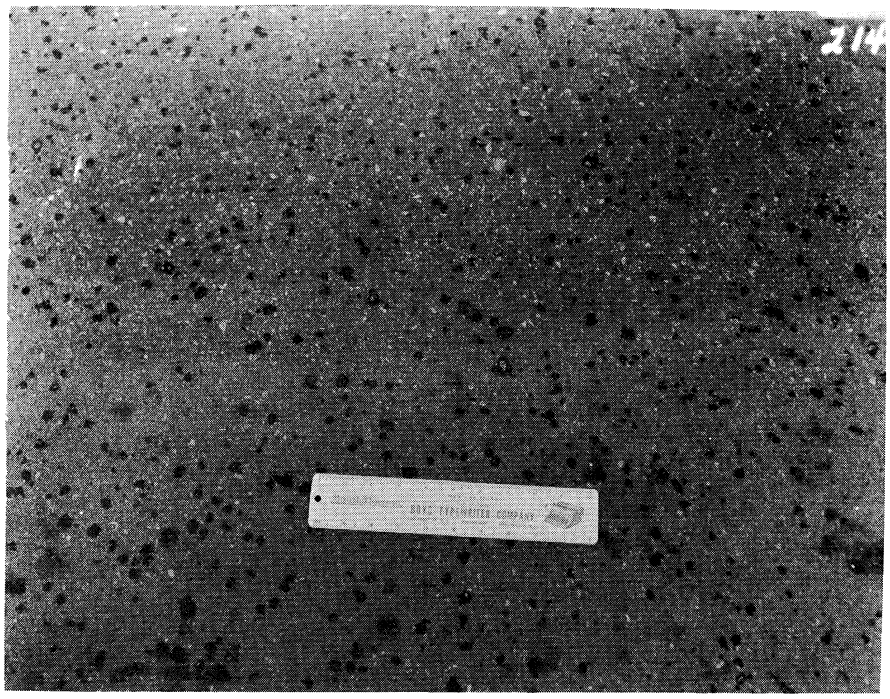
Picture 209. Mile 0.0, general view of Route 13 at the start of the project.



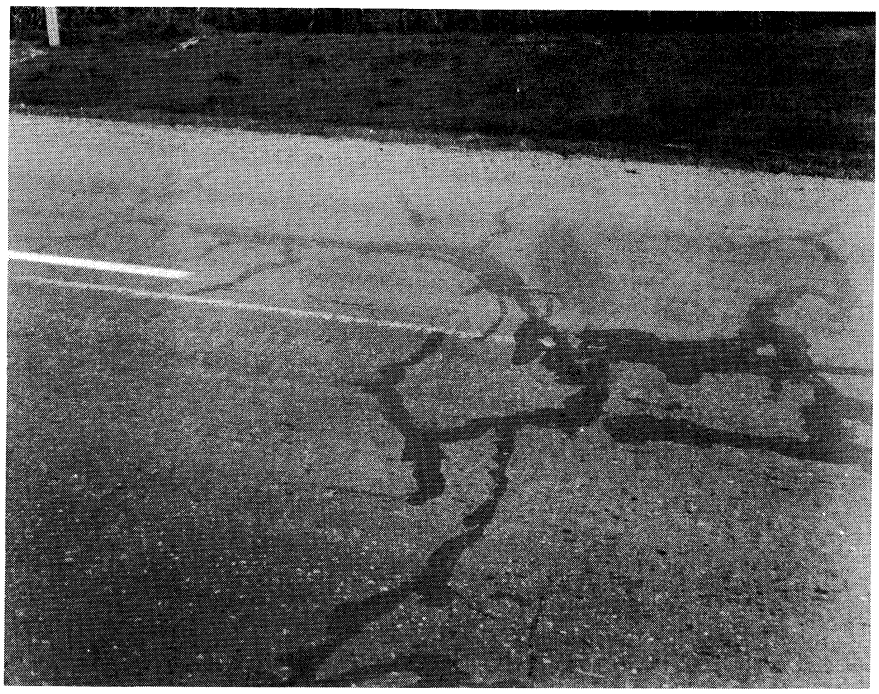
Picture 210. Mile 0.0, view of paving texture at edge of road in the northbound lane. There is considerable pitting of the surface due to the breakup of soft aggregate particles.



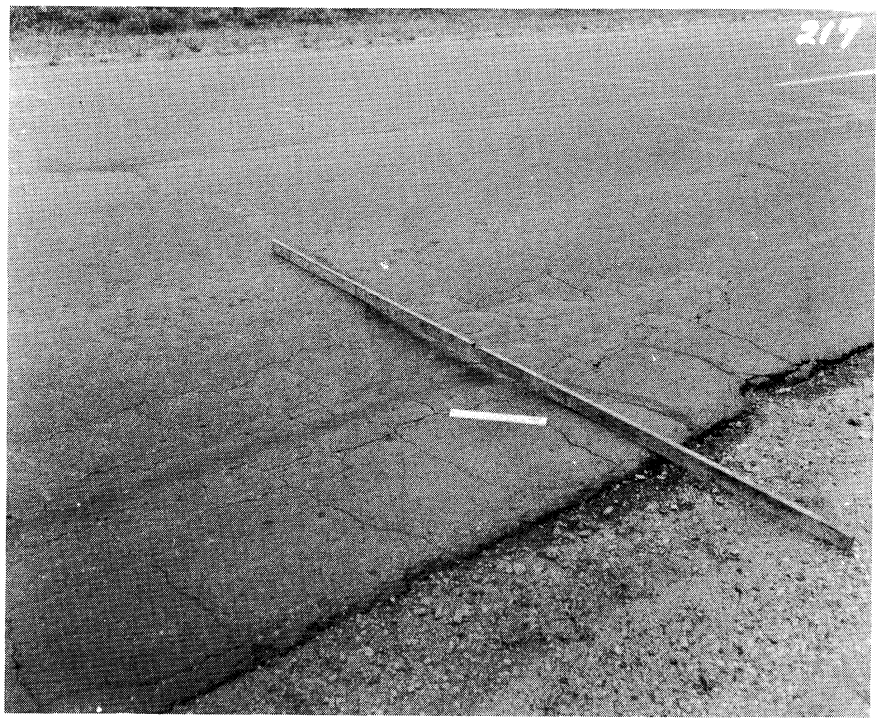
Picture 211. Mile 0.0, view of paving surface and texture in the OWP of the northbound traffic lane at the start of the project. Paving surface is severely pitted, due to the breakup of soft aggregate particles.



Picture 214. View of typical paving surface pitting at Mile 0.5. Moisture from recent showers had collected in the pitted spots, causing the dark color. This condition was most noticeable throughout the job.



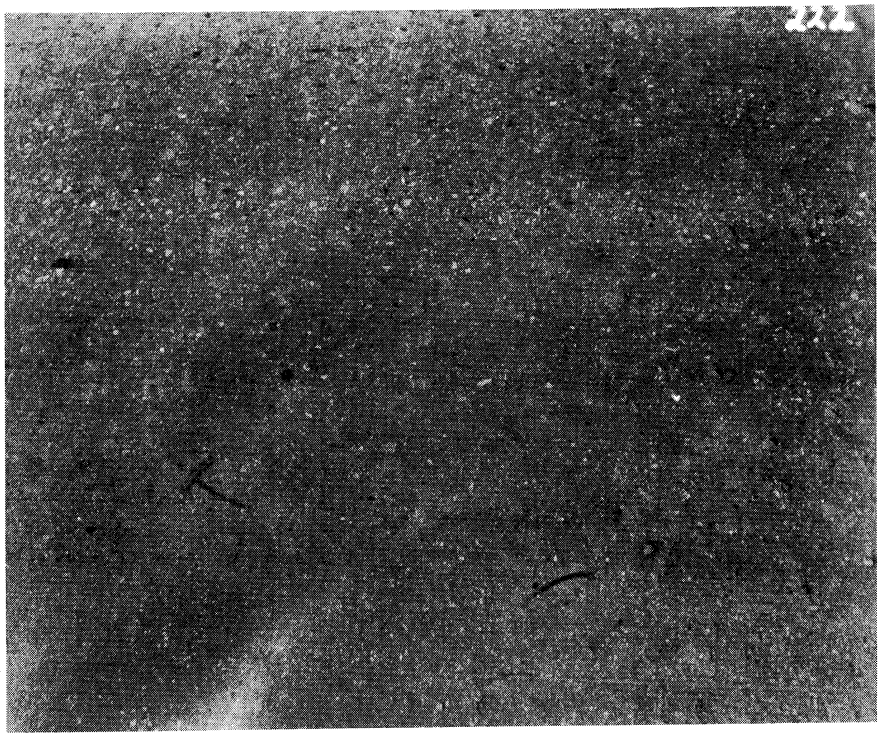
Picture 216. Mile 1.0, showing cracking, both sealed and unsealed, which was extensive throughout this project. The aggregate in the mixture was visible only in the wheel paths, where the seal coat had been removed through traffic action.



Picture 217. Mile 1.5, view of map cracking and depressions in surface occurring in the OWP, northbound traffic lane. Transverse cracking in this section is almost continuous, being spaced at 2.0 to 6.0 intervals.

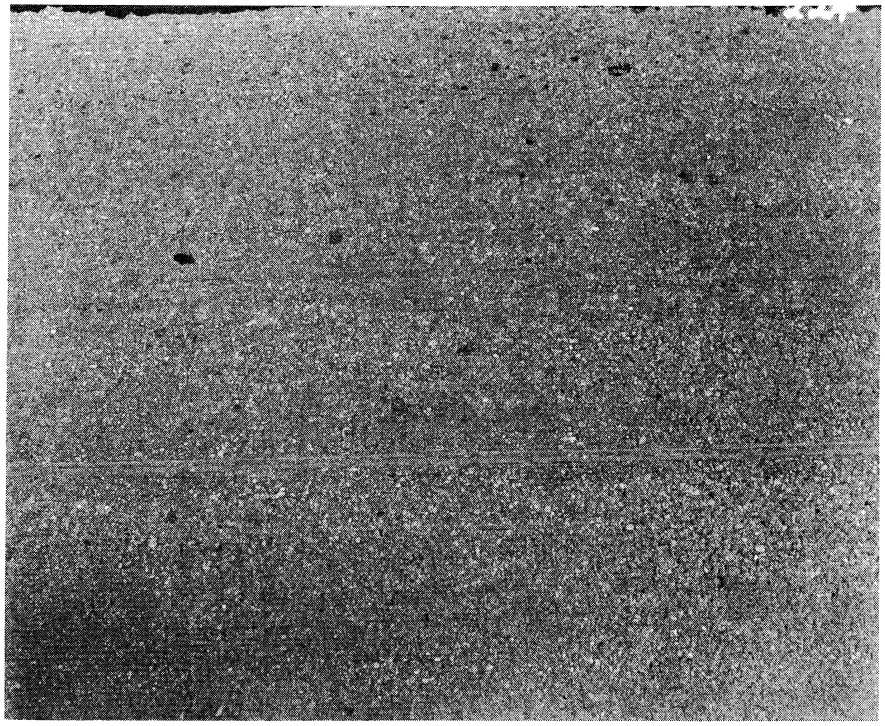
Picture 220. General view at Mile 4.0, showing the extensive crack repair prevalent over the greater portion of this project.

Picture 221. Mile 5.2, Station 336+00, view of the location where a sample was taken showing the typical transverse cracking. This location had been used in the Minnesota S.H.D. Weathering Study.



Picture 222. Mile 5.2, Station 336+00, view of the paving surface and texture at the sampling location in the southbound traffic lane.

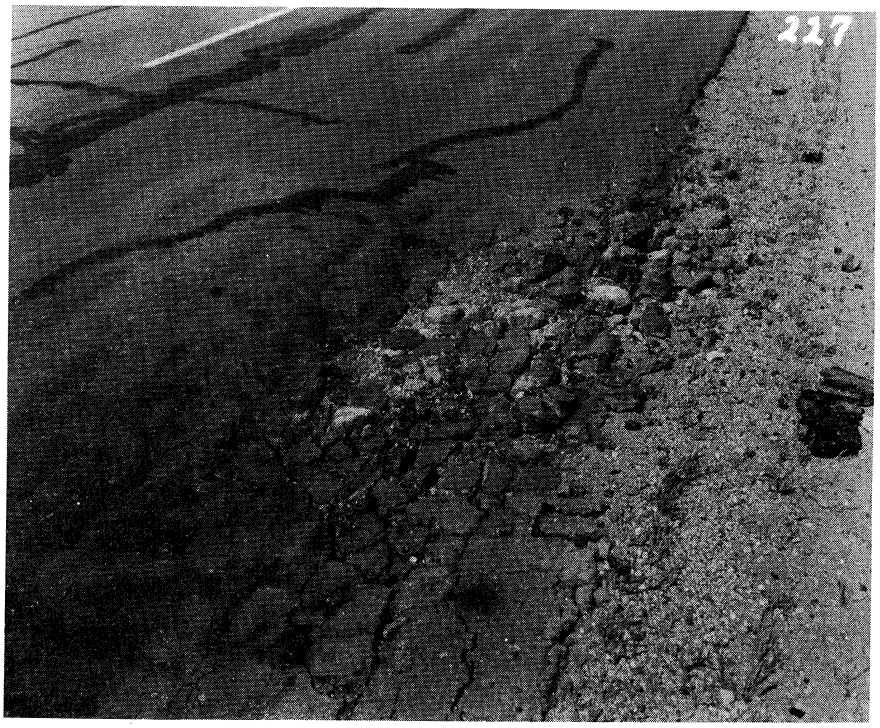
Picture 223. Mile 5.2, Station 336+00, general view of the paving at the location where a sample was taken. Note the extensive transverse cracking which was typical for this project.



Picture 224. Mile 5.6. At this point the previous gravel base course construction had been changed to cement stabilized gravel. This view shows a close-up of typical paving texture.

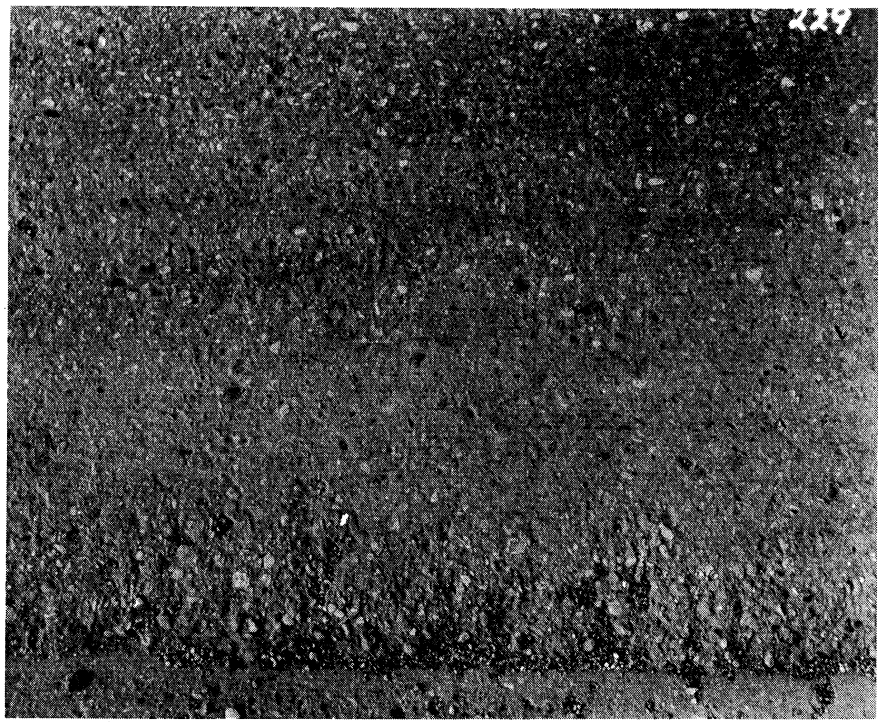
Picture 225. Mile 5.6. Cement stabilization of the gravel base was employed from this point to the junction with T.H. 99, the end of the project.

Picture 226. Mile 5.6. View of sealed longitudinal and transverse cracking present along the centerline and about 4 ft from each edge of the cement-stabilized section.

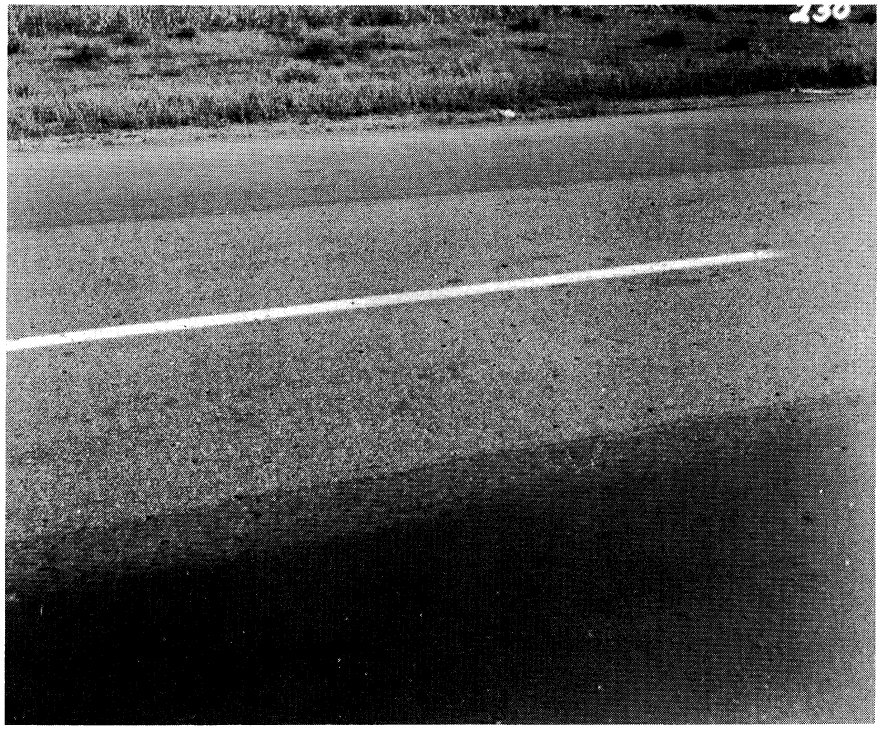


Picture 227. Mile 6.1. View of the worst map-cracked area in the entire project. Sample M 119 was taken from this cracked area.

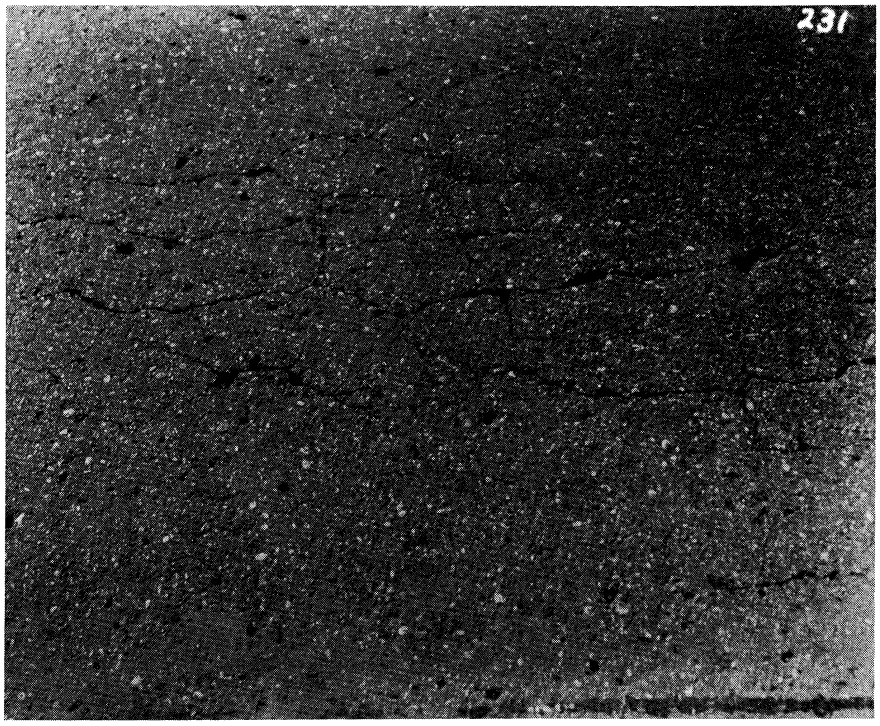
Picture 228. Mile 0.0. General view at the start of the project, at the junction of the existing concrete paving and the asphaltic concrete just north of Arlington, Minnesota.



Picture 229. Mile 0.0. Typical paving surface and texture. Note the extensive surface pitting due to soft aggregate, which was typical throughout the project. There was extensive maintenance resealing of the surface.

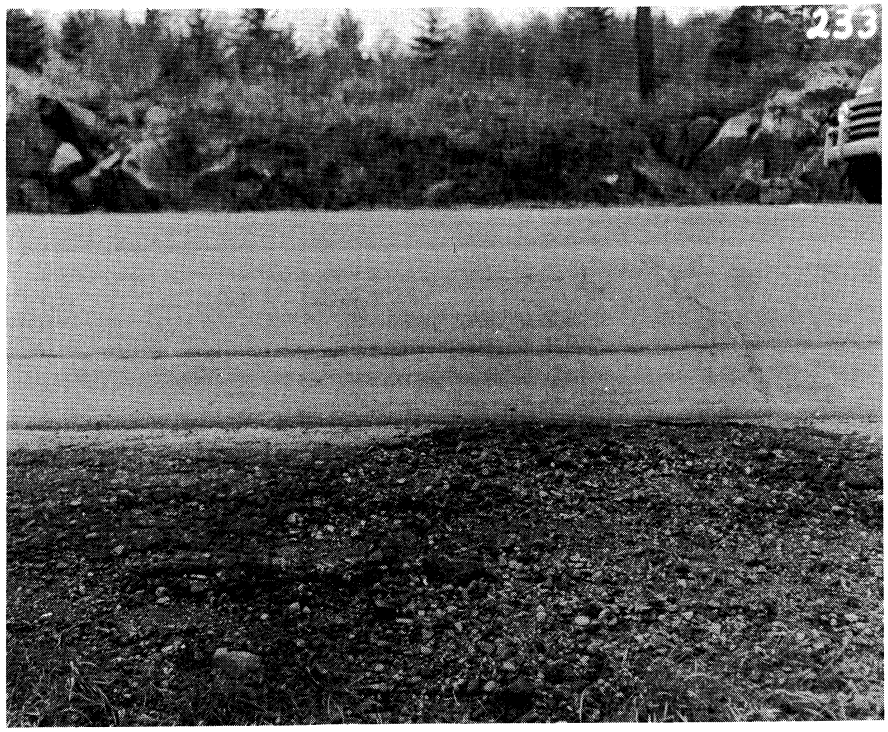


Picture 230. Mile 1.0. View of typical paving surface showing the extensively pitted texture. Maintenance seal applications had been applied at relatively close intervals in both traffic lanes.

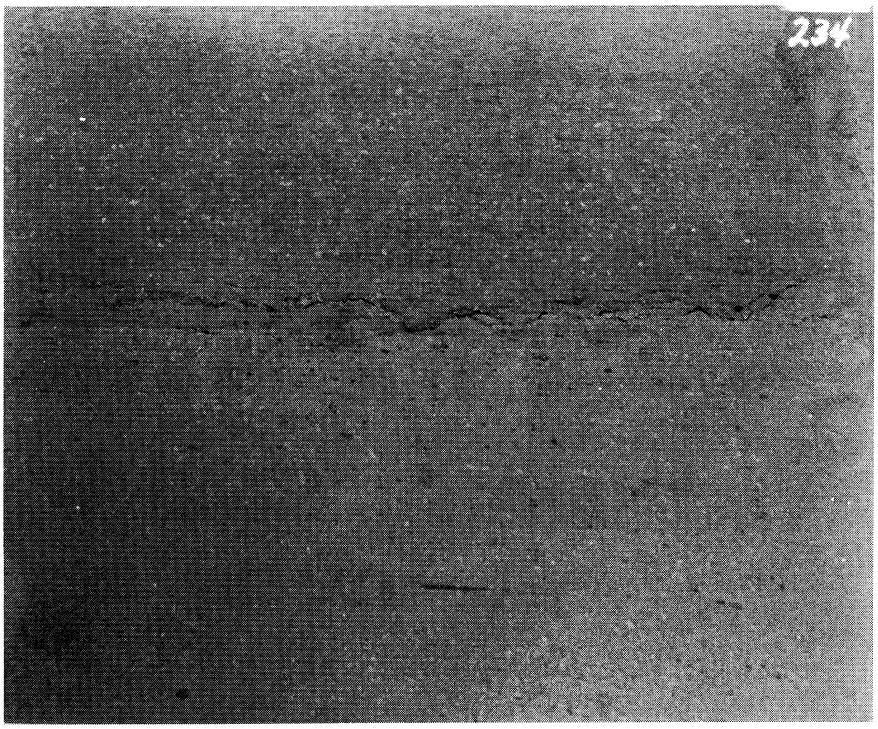


Picture 231. Mile 5.0. View of map cracking present in the northbound traffic lane. This condition was observed in both traffic lanes at random locations.

Picture 232. Station 47+00, located 0.8 mile north of the road-turn in Carlton, Minnesota on Route 61 between Carlton and Scanlon, Minnesota. Samples M91 and M92 were obtained from the location shown in this picture.



Picture 233. Mile 0.0, Station 47+00. View transversely across the roadway, showing the asphaltic concrete on the stabilized gravel layer and wearing course which covers the major central section of the paving.



Picture 234. Mile 0.0, Station 47+00. View of the east edge of the paving, showing the surface texture, the crack at the junction of the old concrete and the gravel base widening in the OWP of the northbound traffic lane.

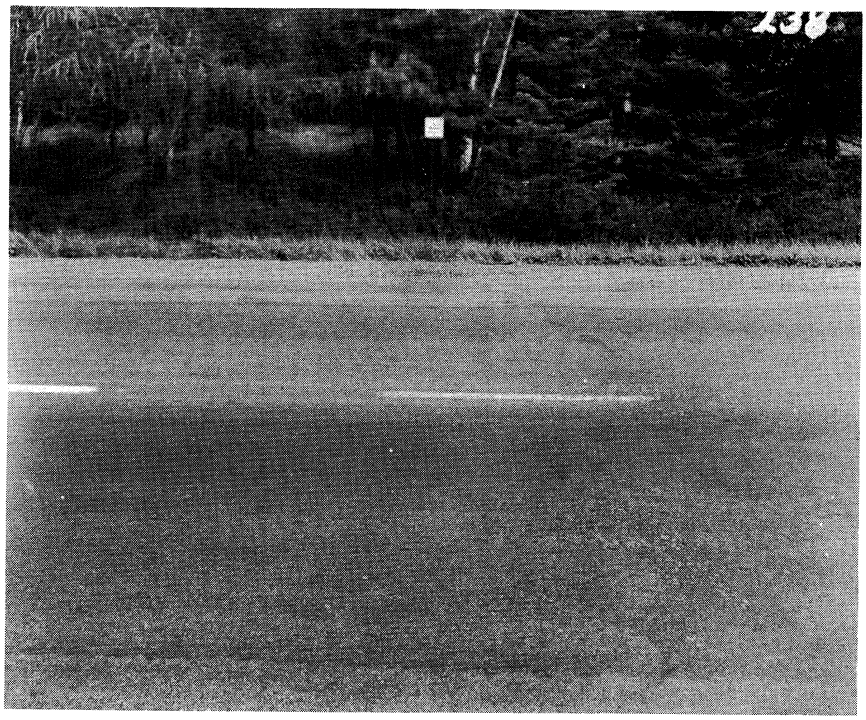
Picture 235. View of edge cracking at the edge of the southbound traffic lane. This condition was typical and prevailed throughout the length of the project.

Project S.P. 0910-04, Route T.H. 61

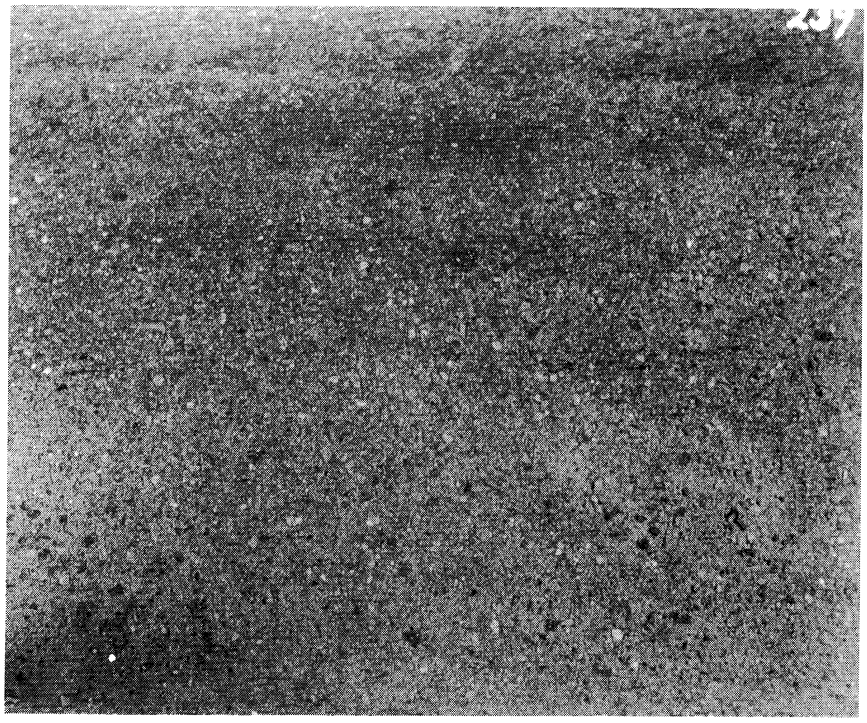
Picture 236. View of the original paving at the edge of the highway. The area in the wheel paths had received wearing course application in 1952. Sampling was done in the edge area.

Project 6917-14 St. Louis County, Route T.H. 53

Picture 237. General view of T.H. 53 taken at the junction with C.R. 49. This location is approximately 1000 ft south of Station 1576+00, the start of this project. This view shows the swampy low-lying terrain traversed by this highway.



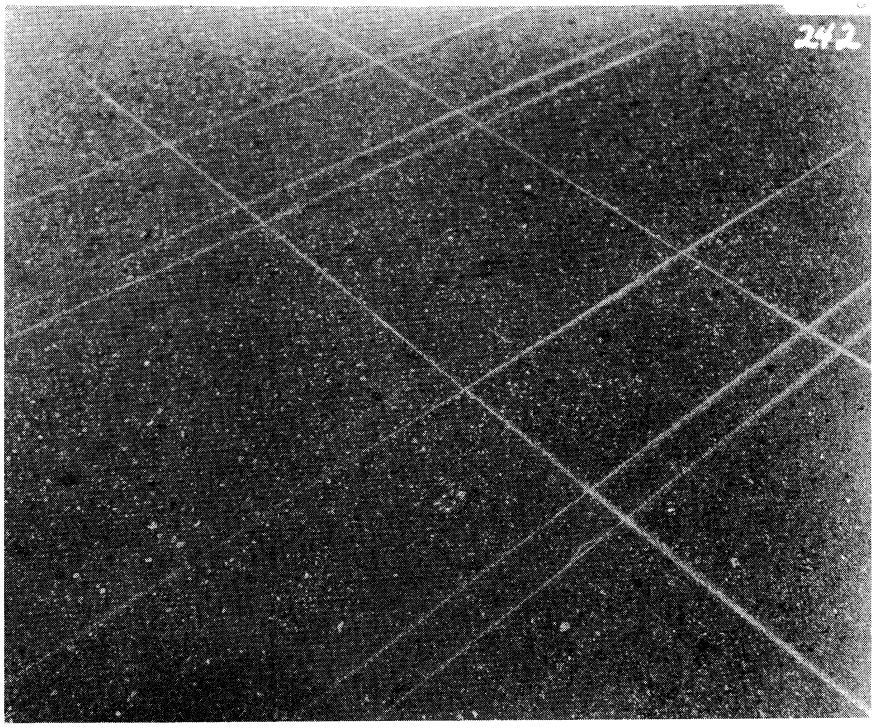
Picture 238. Mile 0.0, Station 1576+00, the start of the project. See F.A.P. sign 871-11 in the background, indicating the start of this Federal Aid project.



Picture 239. Mile 0.0, Station 1576+00. View of the sealed surface of the asphaltic concrete at the start of the project.

Picture 240. Mile 0.0, Station 1576+00. This view shows transverse crack and vertical displacement of underlying concrete slab. Edge crack in asphaltic concrete indicates the location of the edge of the old concrete paving and the gravel base widening.

Picture 241. View of water-filled ditches along the edge of the road.

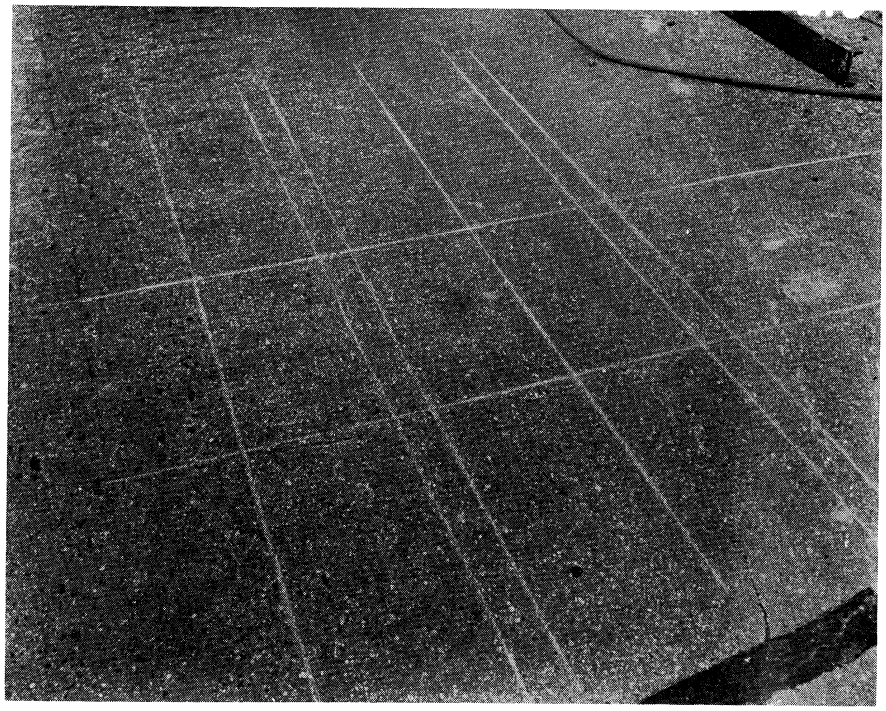


Picture 242. At Station 1467+30, westbound traffic lane, the site of paving sampling for Minnesota S.H.D. Paving Investigation No. 99 and ERI samples M97 and M98.

Picture 243. View of truck, Con-saw, and highway engineer, Mr. A. A. Steffin, who was assigned to assist in the sampling operations.

Picture 244. Station 1467+30, westbound traffic lane. View of paving samples and underlying gravel base.

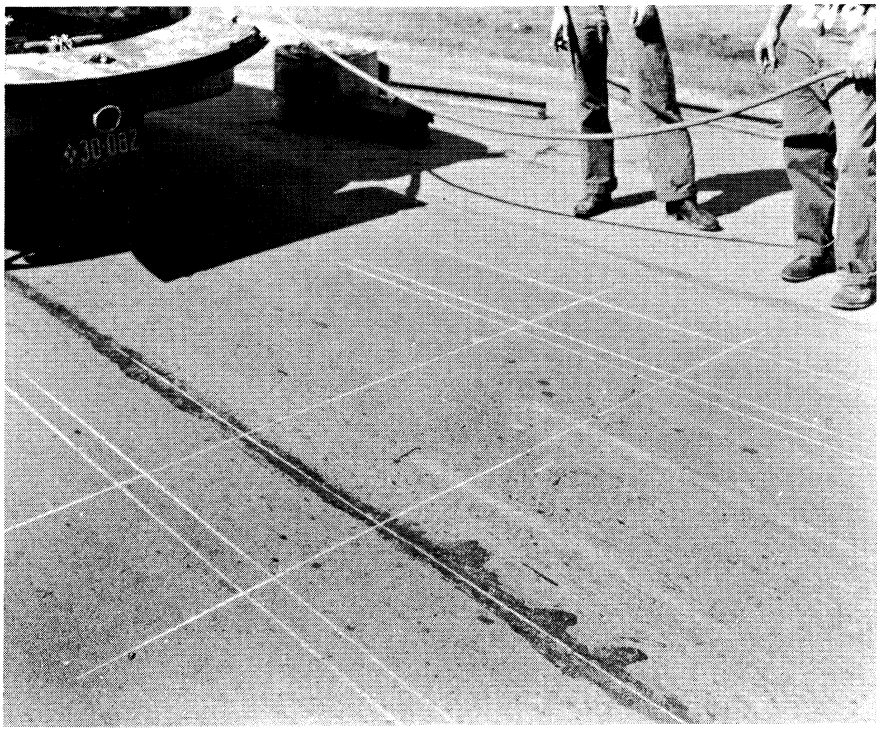
Picture 245. Station 1467+30. General view of the roadway looking west from point of sampling.



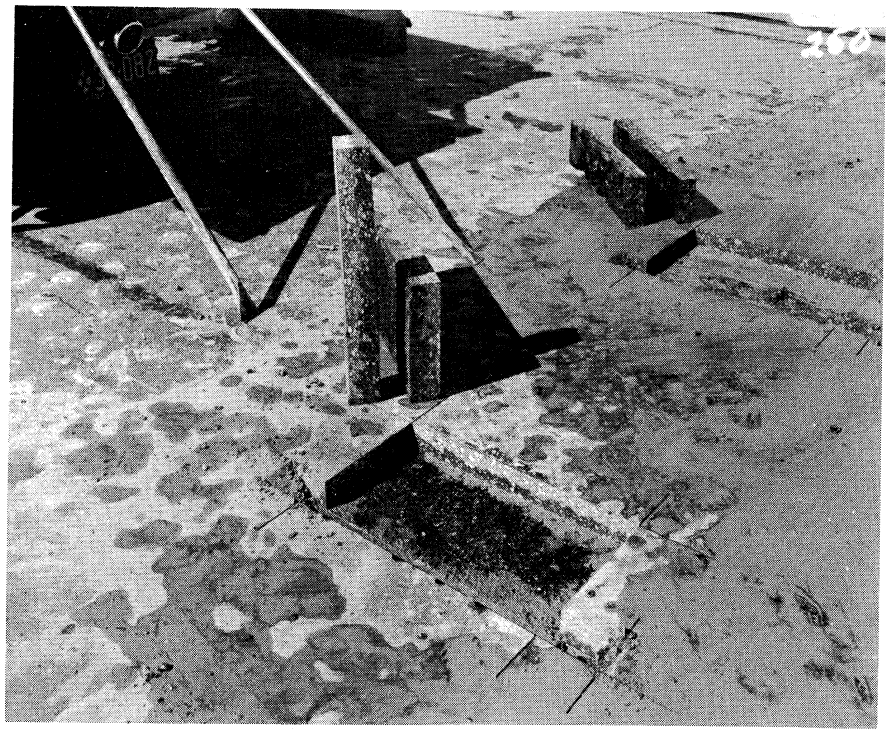
Picture 246. Station 879+25.6. This view shows the cutting layout for samples M99 and M100 and view of paving surface and texture, which is typical for this project.

Picture 247. Station 879+25.6. Samples M99 and M100 as cut from paving in the OWP and between wheel paths in the westbound traffic lane. Paving thickness is 2-3/8 in. as measured. Gravel base course.

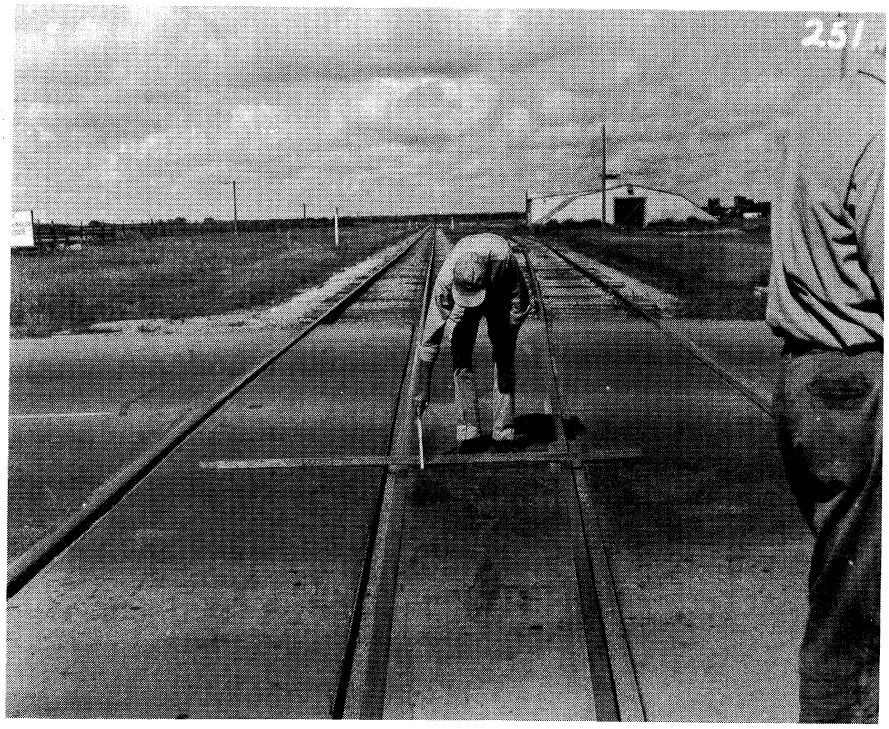
Picture 248. General view of Route T.H. 10 looking westward from Station 424+21.9.



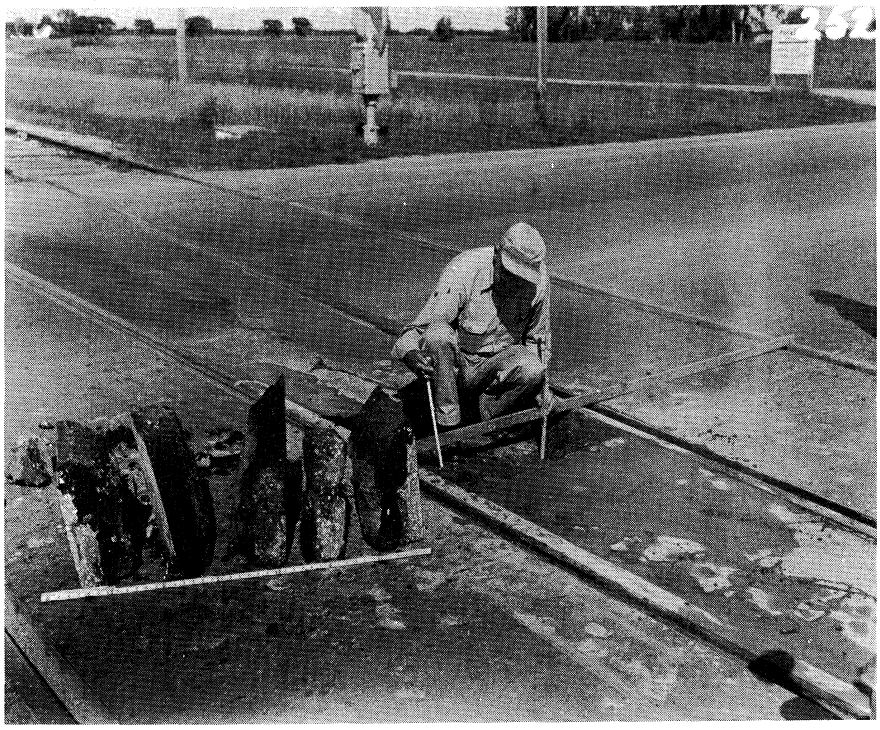
Picture 249. Station 424+21.9. View of paving cut layout and paving texture. Samples M103 and M104 were taken from this location.



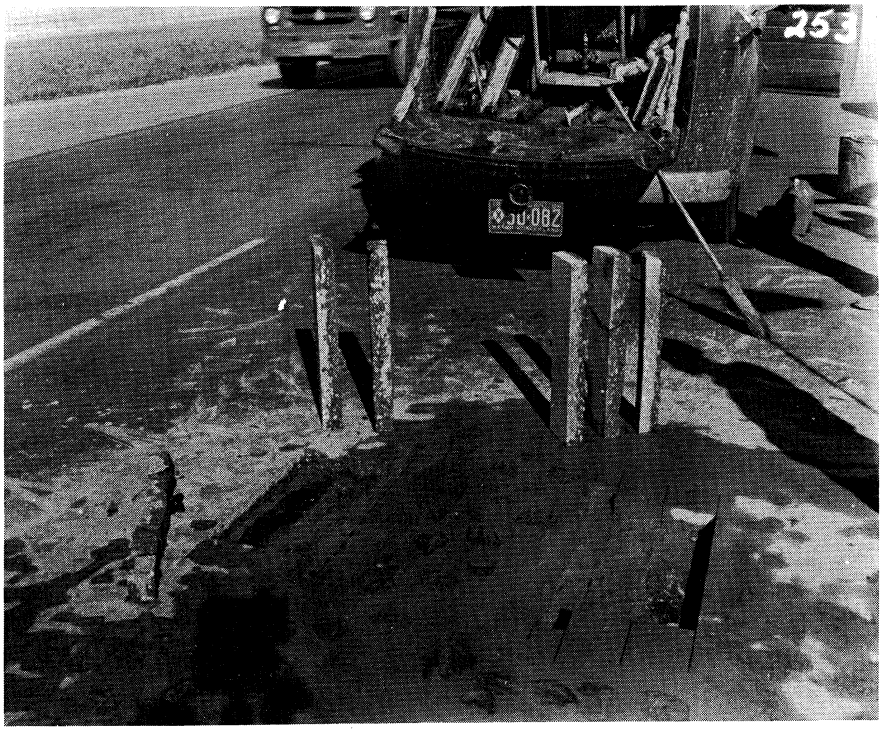
Picture 250. View of samples M103 and M104 taken at Station 424+21.9, the sample cut and a view of the underlying old concrete paving.



Picture 251. Considerable roughness, shoving, and rutting had been caused by traffic action at the railroad crossing at Glyndon, Minnesota, on Route T.H. 10. As measured from the straightedge laid across the rail, the depression measured 1-1/8 in.

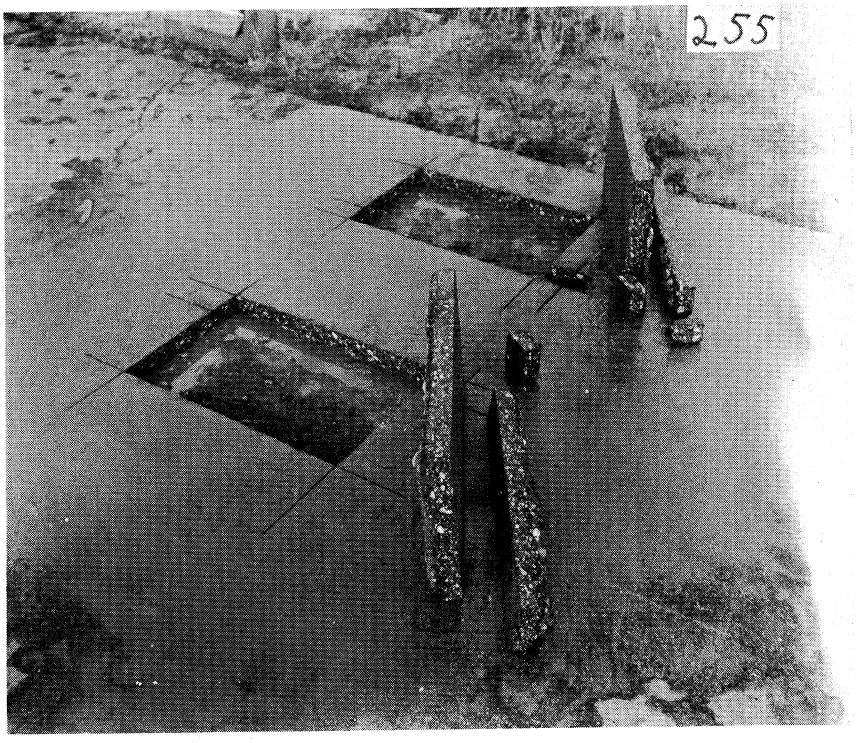


Picture 252. View of the samples as obtained from between the car tracks at Glyndon, Minnesota, on T.H. 10. The impact due to vehicle wheels passing over the top of the rails caused plastic flow of the bituminous material.

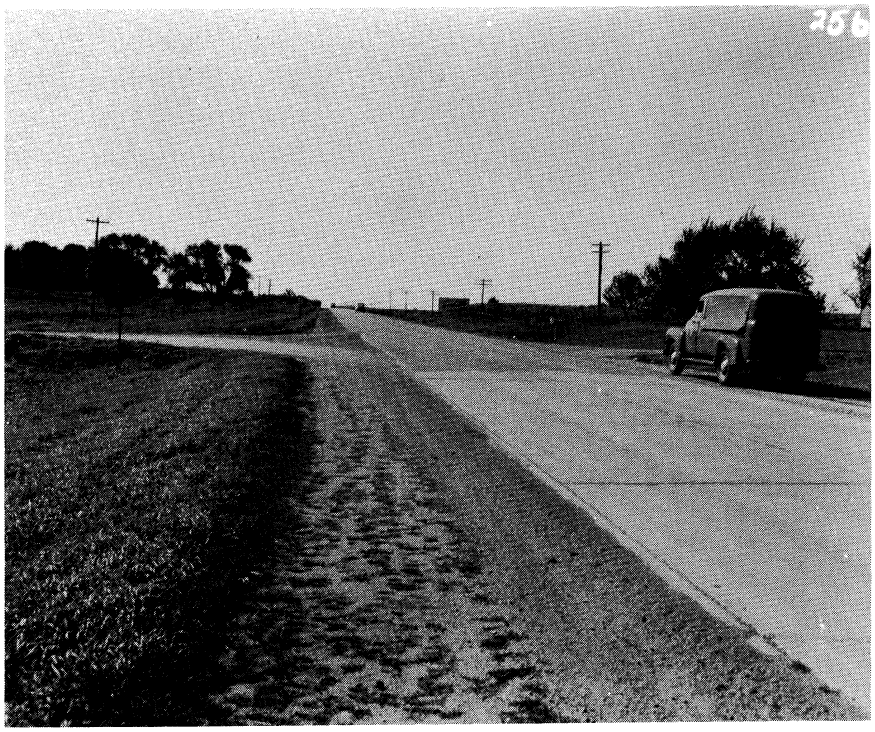


Picture 253. Station 845+79. View of samples M105 and M106, taken from the OWP and between wheel paths at this location.

Picture 254. General view of Route T.H. 32 looking northward from Station 220+75, point of sampling for M101 and M102.

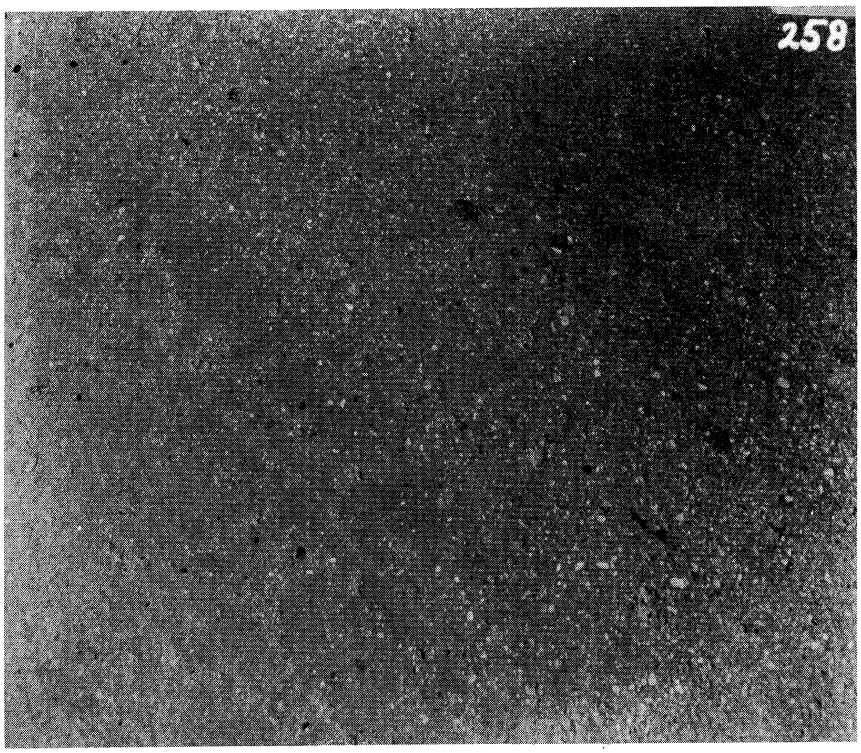


Picture 255. Station 220+75. View of samples M101 and M102, the sample cut and the underlying gravel base. These samples are typical for the project.

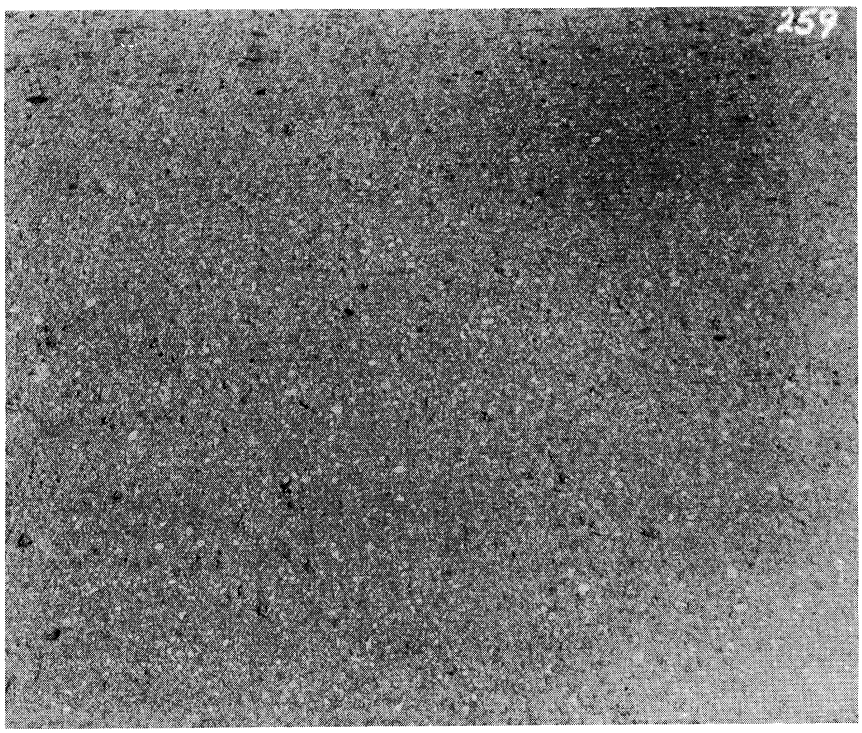


Picture 256. Mile 0.0, the start of the project. General view of the roadway from Olivia looking south.

Picture 257. Mile 0.0. View of surface pitting and stripping in the wheel path.

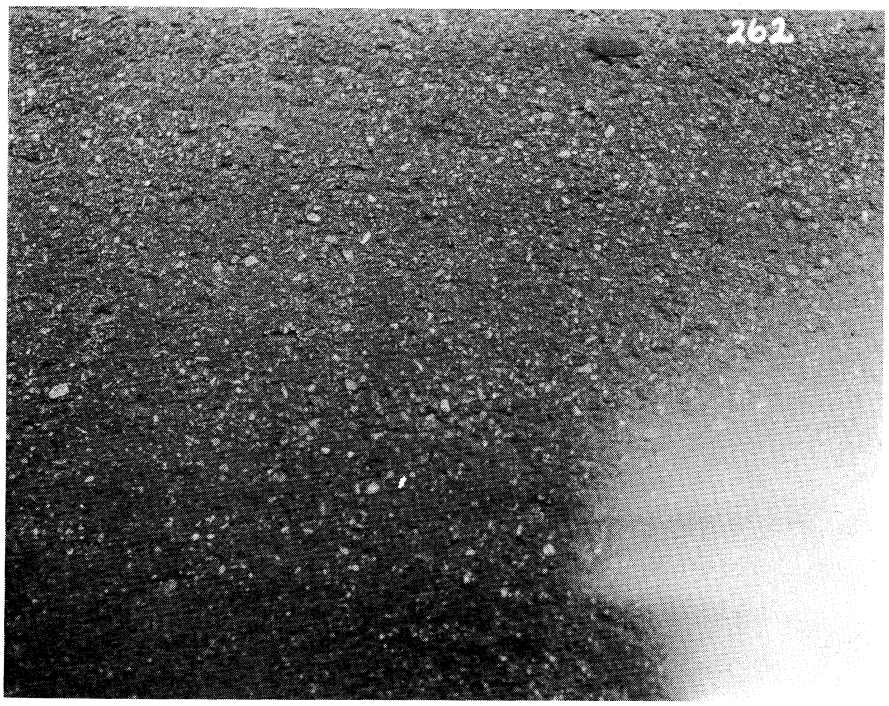


Picture 258. Mile 0.0. View of the paving surface and texture along the sealed untraveled west edge.

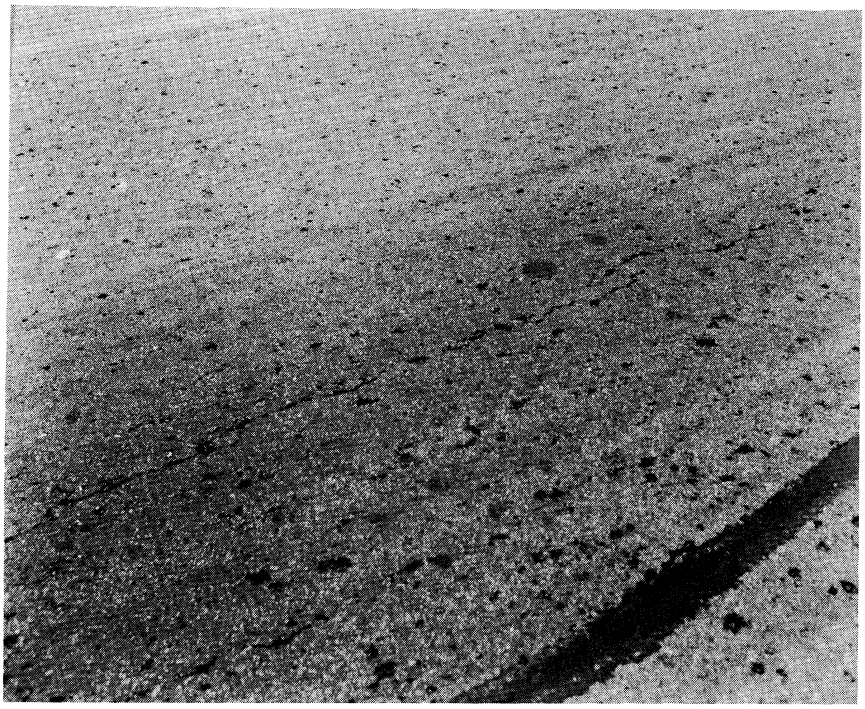


Picture 259. Mile 0.0. View of the east side, northbound traffic lane in the OWP. Note the pitting and slight stripping, which is noticeable in the traffic lanes only.

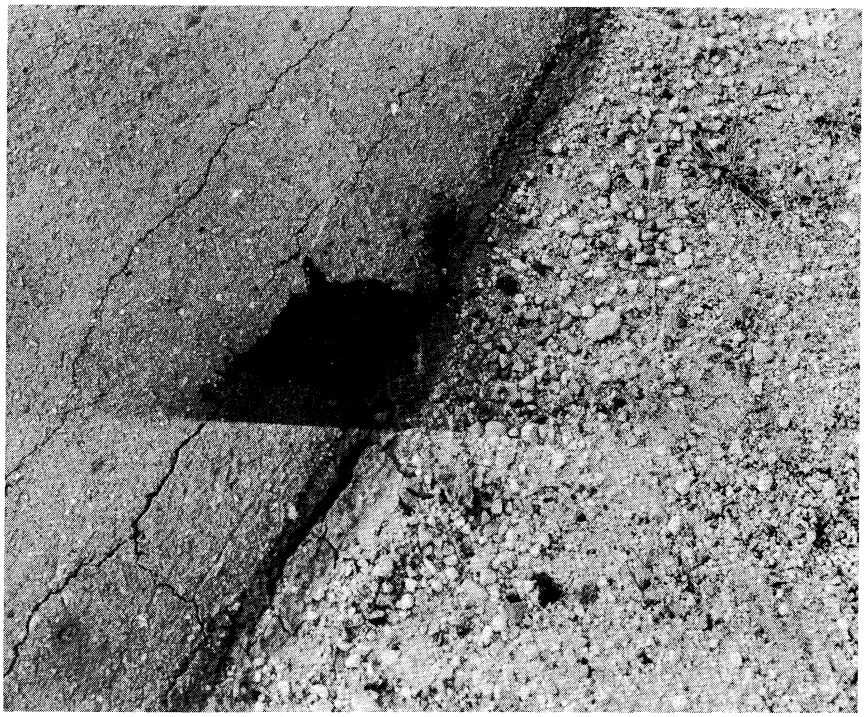
Picture 261. Mile 0.0, Station 34+70. North end of bridge in Pipestone, Minnesota, the start of the project. General view of roadway looking north.



Picture 262. Mile 0.0, Station 34+70. Close-up view of the paving surface and texture showing extensive pitting due to the disintegration of soft aggregate particles. This was universal throughout the job.



Picture 263. Mile 2.0. View of typical longitudinal cracking, which was practically continuous in the OWP. Pitting was also extensive, due to poor quality of the aggregate, which contained many particles of shale and soft soapstone, common to this area.



Picture 264. Mile 13.9, at the northern end of the project. This paving was on the inside of a curve and typical cracking as shown was present at practically all such locations. The broken pieces in the paving could be lifted out as shown in this picture.

APPENDIX NO. 11

MICHIGAN STATE HIGHWAY DEPARTMENT

EXPERIMENTAL PROJECT M 68-30 C8R

ROUTE U. S. 10

BETWEEN FLINT AND PONTIAC, MICHIGAN

ASPHALTIC CONCRETE PAVING

Michigan State Highway Department.
Project M 63-30 C8R. Experimental Bituminous Concrete Paving.
Location and Scope: On U. S. 10, between Flint and Pontiac, starting one mile south of the Genesee-Oakland County line in Oakland County. Total length of test sections-14400 feet with one mile organizational training section at each end. (See accompanying plan.)
Description and Conditions: Site is located on rolling, morainic terrain. The bituminous material was employed as surfacing for an existing 40.0 foot, four lane concrete pavement. Initial and resurfaced riding qualities of the paving may be relatively evaluated through inspection of roughometer data which will be submitted later in this report. Traffic survey made in 1949 indicates 1,100 tractor-trailer truck units per day, which constitutes a high intensity of heavy axle loads. A 1953 survey indicated a total average daily traffic of 12,000 vehicles.

Information pertaining to Michigan State Highway Department bituminous paving construction and its service performance will be condensed and assembled in this report. This section will be devoted to the above-captioned project constructed in August, 1954. Not enough time has elapsed since its construction to permit evaluation of the service behavior.

All the information presented has been extracted from a paper presented by Mr. Ward K. Parr, Laboratory Supervisor, and prepared in collaboration with Paul J. Serafin, Bituminous Engineer, and the late Tom Humphries, who was Assistant Construction Engineer, Michigan State Highway Department. This paper was presented at a meeting of the Association of Asphalt Paving Technologists in February, 1955. In the preparation of this report, excerpts from the original paper will be freely used. When this is done they will be identified as quotations.

"A departmental report was completed in 1952 covering the studies on 35 different asphalts, ranging in penetration from 60 to 175. The findings reported at that time indicated that some of the new sources had different physical characteristics from those with which satisfactory service experience had been obtained. Three main physical characteristics were found to be different; namely, difference in viscosities and temperature susceptibilities of the various asphalts and their stability toward heat. This investigation was continued in 1953 to explore the properties of asphalt material from Wyoming and Canadian crude oil sources. The same differences in these characteristics were also noted in the extension of this asphalt cement research program.

"Three problems were presented by the difference in the temperature susceptibility and viscosity of asphalt cements. These are enumerated as follows:

"(1) Lower mixing temperature required by the low viscosity cements

may present difficulty in drying the aggregate satisfactorily, a condition which had already been encountered in other areas with low viscosity asphalt cements.

"(2) The temperature susceptibility of asphalts also influences their behavior in the pavement surface and, unless otherwise demonstrated under field conditions, an asphalt with a high temperature susceptibility might tend to become excessively hard and brittle at low temperatures of exposure, thereby causing raveling of the asphaltic concrete surface under the severe winter climatic conditions present in Michigan.

"(3) Low-viscosity asphalt with a low-temperature susceptibility also may be more susceptible to bleeding and flushing under traffic in hot weather and require a change in mix design to avoid detrimental pavement behavior.

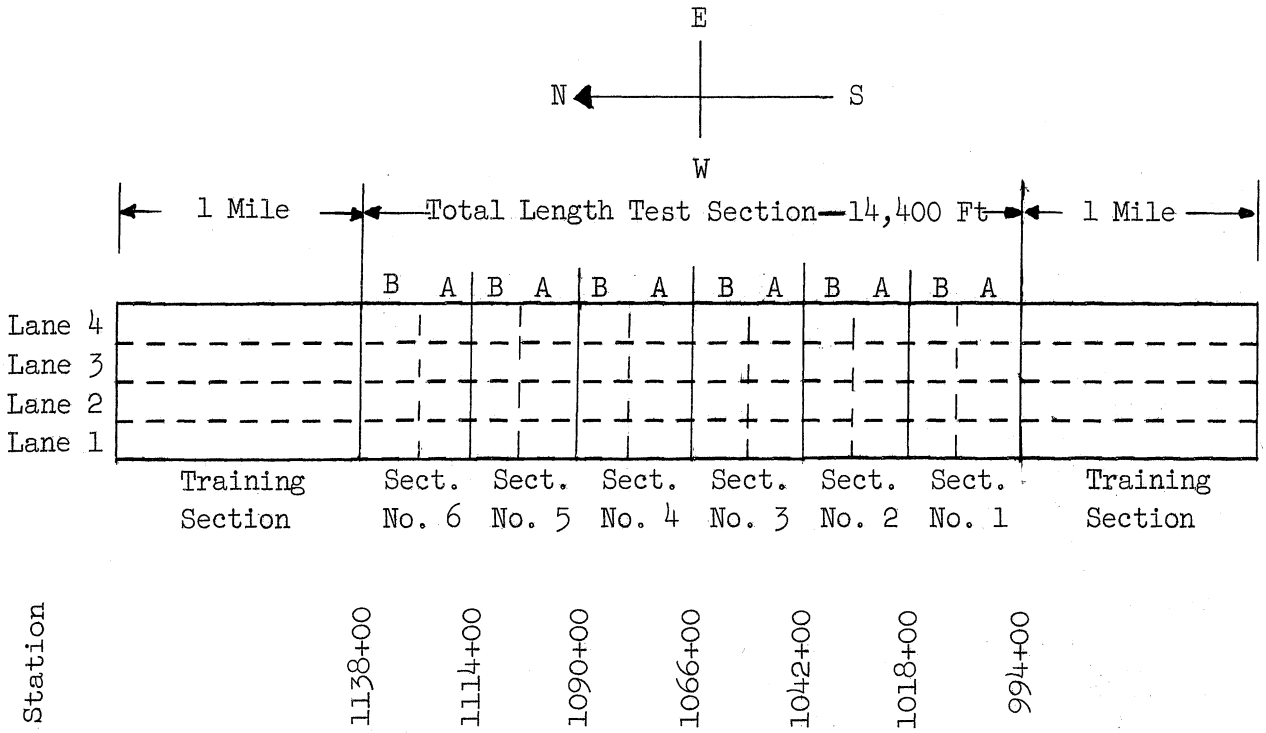
"These suppositions are not based entirely on a theoretical approach from the physical characteristics of the various asphalts, but have been observed under certain conditions in pavements containing asphalts having these characteristics."

"The test road objectives which were given to the field personnel are repeated here as a matter of information in the body of this report.

"(1) To determine the effect of the physical characteristics of the various sources of asphalt cements on construction operations, mix temperatures, coating, laying and compaction, etc.

"(2) Long range studies in changes of the various asphalt cements, densification of the mixture and change in stability and other related performance under traffic."

The plan of the project, together with general information relative to the distribution of the various asphalts in test sections, the general asphalt data, and the relative riding quality of the paving before and after surfacing, as obtained from roughometer studies, are submitted on the following pages.



PLAN LAYOUT, MICHIGAN EXPERIMENTAL PROJECT M 63-30 C8R

TEST SECTION DATA

Section No. 1
Wyoming Crude
Trumbull, Detroit, Michigan
C. O. A.-60-70 Penetration

Asphalt-%		Penetration		Coring		
Spec.	Rcvd	Orig	Rcvd	11-15-54	Lane No.	Sub-Sect.
5.5	5.5	61	41		1	A
5.5	5.5	61	41		2	A
5.5	5.3	61	48	41	3	A
5.5	5.2	61	51	42	4	A
5.3	5.4	60	43	43	1	B
5.7	5.2	62	46	47	2	B
5.7	5.5	62	47	42	3	B
5.3	5.2	62	42	42	4	B

Recovered ductility-150+.
See following sheets for mix-temperature data.

Section No. 2
Venezuelan Crude
American Bitumuls Co., Cincinnati, Ohio
C. O. A.-60-70 Penetration

Asphalt-%		Penetration		Coring		
Spec.	Rcvd	Orig	Rcvd	11-15-54	Lane No.	Sub-Sect.
5.5	5.2	61		41	1	A
5.5	5.2	61	47	35	2	A
5.5	5.5	61	40		3	A
5.5	5.6	61	39		4	A

Asphalt-%		Penetration		Coring		
Spec.	Rcvd	Orig	Rcvd	11-15-54	Lane No.	Sub-Sect.
5.3	5.1	60	42	39	1	B
5.7	5.3	61	41	37	2	B
5.7	5.5	60	45	36	3	B
5.3	5.2	60	44	39	4	B

Recovered ductility-150+.

See following sheets for mix-temperature data.

Section No. 3

Wyoming Crude

Leonard

C. O. A.-60-70 Penetration

Asphalt-%		Penetration		Coring		
Spec.	Rcvd	Orig	Rcvd	11-15-54	Lane No.	Sub-Sect.
5.5	5.6	68	46	44	1	A
5.5	5.2	68	45	44	2	A
5.5	5.5	65	46		3	A
5.5	5.2	65	45		4	A
5.3	5.2	68	44	43	1	B
5.7	5.6	68	43	44	2	B
5.7	5.4	70	44	42	3	B
5.3	5.2	70	46	43	4	B

Recovered ductility-150+.

See following sheets for mix-temperature data.

Section No. 4

Texas-Winkler Crude

Standard Oil Co.-Indiana

C. O. A.-60-70 Penetration

Asphalt-%		Penetration		Coring		
Spec.	Rcvd	Orig	Rcvd	11-15-54	Lane No.	Sub-Sect.
5.5	5.2	60	40		1	A
5.5	5.1	60	50	44	2	A
5.5	5.3	60	46	41	3	A
5.5	5.3	60	43		4	A
5.3	5.2	60	48	40	1	B
5.7	5.6	60	48	47	2	B
5.7	5.6	60	49	45	3	B
5.3	5.4	61	46	41	4	B

Recovered ductility-150+.

See following sheets for mix-temperature data.

Section No. 5
Arkansas-Smackover Crude
Lion Oil Co.
C. O. A.-60-70 Penetration

Asphalt-%		Penetration		Coring		
Spec.	Rcvd	Orig	Rcvd	11-15-54	Lane No.	Sub-Sect.
5.5	5.2	60	46		1	A
5.5	5.2	60	46	47	2	A
5.5	5.3	60	46	45	3	A
5.5	5.3	60	46		4	A
5.3	5.2	61	46	40	1	B
5.7	5.5	62	43	44	2	B
5.7	5.5	60	44	44	3	B
5.3	5.2	61	45	41	4	B

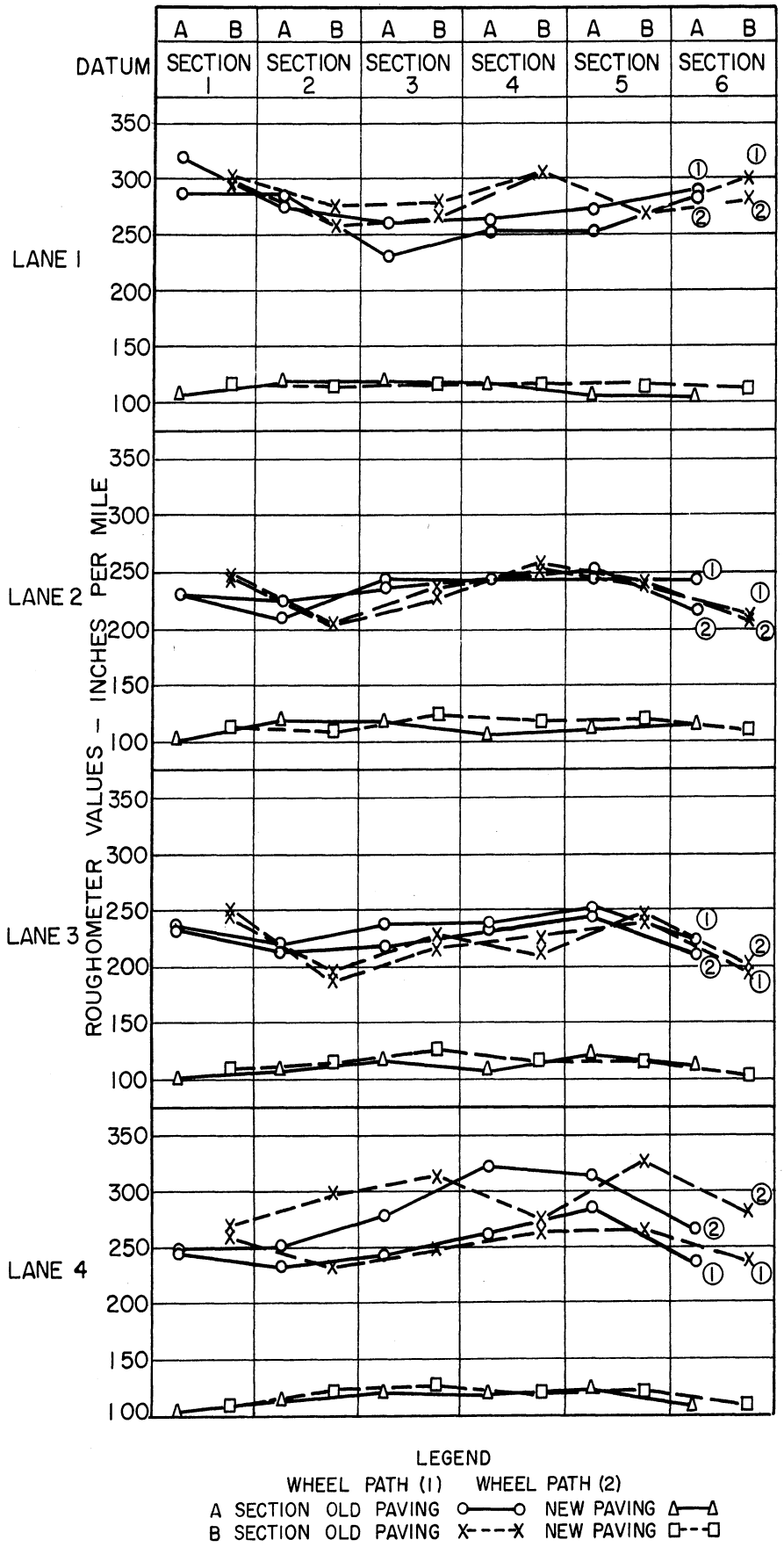
Recovered ductility-150+.
See following sheets for mix-temperature data.

Section No. 6
East Texas-Talco Crude
American Liberty Oil Co.
C. O. A.-60-70 Penetration

Asphalt-%		Penetration		Coring		
Spec.	Rcvd	Orig	Rcvd	11-15-54	Lane No.	Sub-Sect.
5.5	5.5	64	44	45	1	A
5.5	5.4	64	44	43	2	A
5.5	5.4	64	44		3	A
5.5	5.7	64	50		4	A
5.3	5.7	65	46	43	1	B
5.7	5.6	63	46	43	2	B
5.7	5.7	61	46	38	3	B
5.3	5.5	61	45	44	4	B

Recovered ductility-variable for this material. See ductility data on page 319.

A factor which has considerable bearing upon the service performance of the asphalt concrete surfacing is the condition of the existing concrete paving used as the base course. The Michigan progress report contains data relative to the condition of this base as determined by a roughometer survey. The tabulated data has been shown graphically on the following page. In evaluating this information an arbitrary classification applicable to new concrete paving surfaces has been employed. For displacement values from 0-130, paving rideability is GOOD; 131 to 174, AVERAGE; 174 and higher, POOR.



Roughometer Test Data

From the graphical presentation the following conditions are apparent:

ROUGHOMETER DATA

Lane No.	Section	Average Relative Roughness	Lane No.	Section	Average Relative Roughness
1	1 A and B	290-320	2	1 A and B	215-245
	2 A and B	245-285		2 A and B	205-240
	3 A and B	230-285		3 A and B	210-244
	4 A and B	252-305		4 A and B	240-258
	5 A and B	252-270		5 A and B	225-255
	6 A and B	270-300		6 A and B	205-242
3	1 A and B	218-250	4	1 A and B	235-270
	2 A and B	185-250		2 A and B	230-300
	3 A and B	195-238		3 A and B	235-317
	4 A and B	210-248		4 A and B	250-322
	5 A and B	217-252		5 A and B	246-325
	6 A and B	195-235		6 A and B	235-314

Based upon the averaged roughness values for each lane, both maximum and minimum, the following relationships are shown:

Lane No.	Ave. Max. Values	Ave. Min. Values	Mean Values	Sectional Roughness Relation Expressed as Greatest to Least
1	294	257	276	Sections 1,6,4,2,5,3
2	247	217	232	Sections 4,5,1,3,6,2
3	246	203	225	Sections 5,1,4,2,3,6
4	308	239	274	Sections 4,5,3,6,2,1

The Michigan progress report contains comprehensive data relative to the gradation of the aggregate, the composition of the various mixtures, density of mixture, and Marshall stability test results. A careful examination of this information shows that almost identical values exist between the mixtures in the various test sections. As ERI project No. 2249 is principally concerned with the asphalt, no extensive discussion will be incorporated in this report relative to the above-mentioned paving properties. The information will become available in the 1955 annual publication of the

Association of Asphalt Paving Technologists for use in any future study of the test-paving sections.

Attention will be concentrated upon the asphalt test data. Laboratory test results have been tabulated in the Michigan progress report and are reproduced on the following pages, together with comparative data on the recovered asphalt from the original mixture and that obtained from cores taken from the wearing course in November, 1954.

TESTS ON ASPHALT CEMENTS

Section	1	2	3	4	5	6
Source of Crude	Wyo.	Venez.	Wyo.	Wink.	Smack	Talco
Laboratory No.	1716	1640	1641	1485	1443	1299
Course	top	top	top	top	top	top
General Characteristics:						
Specific gravity—25/25°C	1.027	1.036	1.027	1.012	1.022	1.032
Pen. 15°C, 100 g, 5 sec, dmm	22	21	22	23	21	23
25°C " " "	63	60	67	60	61	65
35°C " " "	173	154	186	151	144	141
0°C, 200 g, 60 sec, dmm	16	16	13	15	14	19
4°C " " "	21	21	20	24	21	26
Flash, C.O.C.	320	282	326	316	356	300
L. on H. 163°C, 5 hr, 50 g, %	0.018	0.002	0.110	0.042	0.004	0.018
Pen. res., 25°C, 100 g, 5 sec, dmm	56	54	62	56	56	59
Soft. pt. R and B—°C	48.9	51.8	48.1	50.7	49.0	51.2
Ductility—4.0°C, 5 cm/min, cm	0	1	0	5	5	5
10.0°C " " " "	18	25	14	10	12	8
15.6°C " " " "	150+	150+	150+	150+	150+	77
20.0°C " " " "	150+	150+	150+	150+	150+	150+
25.0°C " " " "	150+	150+	150+	150+	150+	150+
30.0°C " " " "	140	150	142	150+	150+	150+
Sol. CCl_4, %	99.99	99.97	99.95	99.82	99.88	99.99
Oliensis spot test	Neg	Neg	Neg	Neg	Neg	Neg
Matter insoluble in hexane, %	17.25	21.44	17.43	15.50	15.33	21.94
Visc., Saybolt Furol, at 275°F, sec	192.0	313.0	197.4	217.0	276.0	337.0
300°F, sec	101.4	169.6	105.0	128.0	150.0	172.0
325°F, sec	61.0	100.0	61.0	83.8	91.0	93.0
1/8-in. Thin film method:						
L. on H. at 163°C, 1 hr, 50 g, %	0.019	0.006	0.082	0.054	0.021	0.009
Pen. res., 25°C, 100 g, 5 sec, dmm	54	54	55	52	54	55
Ductility, 25°C, 5 cm/min, cm	150+	150+	150+	150+	150+	150+
L. on H. at 163°C, 3 hr, 50 g, %	0.010	0.057	0.073	0.052	0.056	0.004
Pen. res., 25°C, 100 g, 5 sec, dmm	47	45	45	46	45	53
Ductility, 25°C, 5 cm/min, cm	150+	150+	150+	150+	150+	150+

Section	1	2	3	4	5	6
Source of Crude	Wyo.	Venez.	Wyo.	Wink.	Smack	Talco
Laboratory No.	1716	1640	1641	1485	1443	1299
Course	top	top	top	top	top	top
L. on H. at 163°C, 5 hr, 50 g, %	0.022	0.132	0.079	0.091	0.092	0.016
Pen. res., 25°C, 100 g, 5 sec, dmm	36	38	40	42	39	45
Ductility, 25°C, 5 cm/min, cm	150+	150+	150+	150+	150+	77
L. on H. at 163°C, 7 hr, 50 g, %	0.026	0.142	0.025	0.050	0.105	0.054
Pen. res., 25°C, 100 g, 5 sec, dmm	31	34	34	38	35	37
Ductility, 25°C, 5 cm/min, cm	150+	150+	150+	150+	111	33
L. on H., 163°C, 24 hr, 50 g, %	0.048	1.541	0.046	0.114	0.239	0.151
Pen. res., 25°C, 100 g, 5 sec, dmm	16	16	17	22	21	22
Ductility, 25°C, 5 cm/min, cm	6	4	6	7	6	4
Heat stability test, 100 g, 500°F, 2 hr:						
Pen. at 25°C, 100 g, 5 sec, dmm	58	57	66	63	56	61
Visc., Saybolt Furol, at 275°F, sec	215	337	205	192.8	284	333
at 325°F, sec	68	108	61.4	58.6	88.2	109.0
Heat stability test, 100 g, 600°F, 2 hr:						
Pen. at 25°C, 100 g, 5 sec, dmm	62	65	70	98	65	61
Visc., Saybolt Furol, at 275°F, sec	206	321	186.2	151.6	266	316
at 325°F, sec	70	103	57.6	50	71.5	95
Shattuck pen. test, 25°C, 100 g, 5 sec	29	28	29	38	34	36
Ductility, 25°C, 5 cm/min, cm	136+	69	150+	150+	137	26

Note: Underlined values in above table are reported as (+) in the Michigan progress report.

PLANT MIXING TEMPERATURE DATA

The records for the mixing temperatures at the plant were included in the progress report. As reproduced below, they indicate the average temperatures of test-road bituminous-concrete wearing course mixtures.

		Temperature—°F		
Sect.	Lane	Design	Plant	Street
1A	1	295	300	300
	2	295	300	295
	3	295	300	295
	4	295	290	285

		Temperature—°F		
Sect.	Lane	Design	Plant	Street
1B	1	315	315	310
	2	315	315	310
	3	275	290	285
	4	275	290	285

Sect.	Lane	Temperature—°F Design	Plant	Street
2A	1	310	315	310
	2	310	300	300
	3	310	320	320
	4	310	325	325
2B	1	330	340	335
	2	330	325	325
	3	290	295	290
	4	290	295	290
3A	1	310	305	300
	2	310	315	310
	3	310	315	310
	4	310	305	300
3B	1	315	320	315
	2	315	310	305
	3	275	285	285
	4	275	290	285
4A	1	300	300	295
	2	300	295	295
	3	300	300	300
	4	300	300	300

Sect.	Lane	Temperature—°F Design	Plant	Street
4B	1	275	275	265
	2	275	285	285
	3	315	310	310
	4	315	315	315
5A	1	310	305	305
	2	310	300	295
	3	310	310	310
	4	310	310	305
5B	1	330	320	320
	2	330	325	320
	3	290	295	295
	4	290	295	295
6A	1	305	300	295
	2	305	305	295
	3	305	300	290
	4	305	305	300
6B	1	330	330	320
	2	330	330	320
	3	290	300	290
	4	290	300	290

The design temperatures shown in the preceding tabulation were based upon an investigation of the Saybolt Furol viscosity seconds versus temperature. The relationship as found has been extracted from the progress report and is tabulated below:

Section and Asphalt No.	Source of Asphalt	Temperature at Saybolt Furol of 75 sec °F	200 sec °F
1	Wyoming—Trumbull	315	273
2	Venezuelan—American Bitumuls Co.	341	293
3	Wyoming—Leonard	316	274
4	Texas Winkler—Standard Oil Co., Ind.	332	278
5	Arkansas Smackover—Lion Oil Co.	335	287
6	East Texas Talco—Amer. Lib. Oil Co.	336	294

Plant mixing control temperature was quite satisfactory, as indicated by the narrow variations reported from design requirements. The maximum high occurred in Section 1B, which showed an average excess of 30°F. The maximum average low is observed in Section 5A and was 15°F below design requirements.

In contrast to the apparently careful regulation of plant mixing temperature, the records of the aggregate temperatures indicate considerable

variation. Such data has been extracted from the progress report and is tabulated below:

APPROXIMATE AGGREGATE TEMPERATURES
AS TAKEN FROM TEMPERATURE RECORDS

Sect. and Sub-sect.	Lane 1, °F		Lane 2, °F		Lane 3, °F		Lane 4, °F	
	Max	Avg	Max	Avg	Max	Avg	Max	Avg
1A	370	335	338	325	350	320	343	320
1B	380	340	360	345	335	310	352	315
2A	390	330	374	335	392	360	381	360
2B	400	375	380	360	343	320	356	325
3A	364	330	364	345	363	340	353	330
3B	380	360	360	335	327	305	331	300
4A	346	330	343	325	345	325	345	325
4B	350	325	362	295	362	340	370	345
5A	345	330	362	330	370	340	351	330
5B	383	340	380	360	369	330	368	320
6A	350	330	345	330	350	330	370	330
6B	395	370	375	360	360	320	345	320

In the preceding investigation an attempt has been made to correlate standard tests on asphalt with service behavior. The penetration and softening point tests are the two which have been employed for this purpose. The relationship between the two test results has been expressed as a ratio of softening point/penetration. Comparison between the ratio of the original material and the same asphalt after service exposure indicates that the asphalt in paving exhibiting greater deterioration usually had a much higher ratio value than that in paving having more favorable appearance. Furthermore, it appeared that the asphalt exhibiting the least change in ratio value was least affected by mixing operations and subsequent effects of aging or weathering in service. As it has been recognized that the effect of temperature tends to produce change in asphalt, the influence of both plant mixing and aggregate temperatures will be explored and the several asphalts rated upon the basis of least change from the original material.

In order to employ this method of analysis, the test data relative to penetration and softening point will be extracted from the progress report and used as the basis for further investigation.

SOFTENING POINT AND PENETRATION TEST DATA

Asphalt and Section	1	2	3	4	5	6
Source of Crude	Wyo.	Venez.	Wyo.	Wink	Smack	Talco
Laboratory No.	1716	1640	1641	1485	1443	1299
Original Asphalt						
Penetration*	63	60	67	60	61	65
Softening point—°F	120.0	125.2	118.6	123.3	120.2	124.2
S. pt./pen. ratio	1.905	2.087	1.770	2.055	1.970	1.911
Asphalt recovered from cores taken November, 1954 (Average values for asphalt)						
Sub-section A						
Penetration*	42	38	44	43	46	44
Softening point—°F	126.9	137.3	145.4	133.3	126.7	137.7
S. pt./pen. ratio	3.021	3.613	3.305	3.100	2.754	3.130
Sub-section B						
Penetration*	44	38	43	43	42	42
Softening point	127.4	135.7	123.4	129.2	132.4	136.8
S. pt./pen. ratio	2.895	3.571	2.870	3.005	3.152	3.257

When rating the performance of the different asphalts upon the basis of least change in the softening point/penetration ratio between the original and recovered material, the following is indicated.

SOFTENING POINT/PENETRATION RATIO VALUES

Asphalt	1	2	3	4	5	6
Original	1.905	2.087	1.770	2.055	1.970	1.911
Recovered						
From A	3.021	3.613	3.305	3.100	2.754	3.130
Change	1.116	1.526	1.535	1.045	0.784	1.219
Rating	3	5	6	2	1	4
From B	2.895	3.571	2.870	3.005	3.152	3.257
Change	1.990	1.484	1.100	0.950	1.182	1.346
Rating	6	5	2	1	3	4

*Penetration test: 100 gr, 5 sec, 77°F. Surface course material only.

Ratings for the different asphalts based upon least change by other test criteria are tabulated below for comparative purposes.

Asphalt No.	1	2	3	4	5	6
Penetration—100 gr, 5 sec						
Original asphalt						
At 95°F	173	154	186	151	144	141
At 77°F	63	60	67	60	61	65
Change	110	94	119	91	83	76
Rating	5	4	6	3	2	(1)
Recovered asphalt from mix used in A and B sub-sections - 77°F						
From A	45	42	46	45	46	46
Change	-18	-18	-21	-15	-15	-19
Rating	2	2	4	(1)	(1)	3
From B	44	43	44	48	45	46
Change	-19	-17	-23	-12	-16	-19
Rating	4	3	5	(1)	2	4
Recovered asphalt from cores taken from A and B sub-sections -77°F						
From A	42	38	44	43	46	44
Change	-21	-22	-23	-17	-15	-21
Rating	3	4	5	2	1	3
From B	44	38	43	43	42	42
Change	-19	-22	-24	-17	-19	-23
Rating	2	3	5	(1)	2	4
Ductility, 5 cm per min						
Original asphalt						
At 77°F	150+	150+	150+	150+	150+	150+
At 39.2°F	0	1	0	5	5	5
Change	150	149	150	145	145	145
Rating	(3)	(2)	(3)	(1)	(1)	(1)
Recovered asphalt from mix used in A and B sub-sections						
From A	150+	150+	150+	150+	150+	Avg-133
Change	0	0	0	0	0	-17
Rating	(1)	(1)	(1)	(1)	(1)	(6)
From B	150+	150+	150+	150+	150+	Avg-141
Change	0	0	0	0	0	-9
Rating	(1)	(1)	(1)	(1)	(1)	(6)

Asphalt No.	1	2	3	4	5	6
Recovered asphalt from cores taken from A and B sub-sections						
From A	150+	150+	150+	150+	150+	Avg-123
Change	0	0	0	0	0	-27
Rating	(1)	(1)	(1)	(1)	(1)	(6)
From B	150+	150+	150+	150+	150+	Avg-112
Change	0	0	0	0	0	-38
Rating	(1)	(1)	(1)	(1)	(1)	(6)
Saybolt Furol seconds viscosity						
Original asphalt:						
At 275°F (a)	192.0	313.0	197.4	217.0	276.0	337.0
At 300°F (b)	101.4	169.6	105.0	128.0	150.0	172.0
At 325°F (c)	61.0	100.0	61.0	83.8	91.0	93.0
Change a-b	-90.6	-143.4	-92.4	-89.0	-126.0	-165.0
Rating	2	5	3	(1)	(4)	(6)
Change a-c	-131.0	-213.0	-136.4	-133.2	-185.0	-144.0
Rating	(1)	(6)	(3)	2	5	4
Recovered asphalt: no comparable data						
Oliensis spot test data						
Original asphalt	neg	neg	neg	neg	neg	neg
Rcvd asph. from mix. during construction	pos	neg	pos	neg	neg	neg
Rcvd asph. from cores taken from A and B sub-sect.	pos	neg	pos	neg	neg	neg
Rcvd asph. from lab. Shattuck mixing test	neg	neg	neg	neg	neg	neg
Rcvd asph. from lab thin-film test	pos	neg	pos	neg	neg	neg

The condensed summary below indicates how the various tests evaluate the acceptability of the asphalt, using the least change from the original material as the basis for rating.

Asphalt No.	1	2	3	4	5	6
S. pt./pen ratio						
Sub-section A	3	5	6	2	(1)	4
Sub-section B	6	5	2	(1)	3	4

Asphalt No.	1	2	3	4	5	6
Penetration						
Original	5	4	6	3	2	(1)
From mix, section A	2	2	4	(1)	(1)	3
From mix, section B	4	3	5	(1)	2	4
From cores, section A	3	4	5	2	(1)	3
From cores, section B	2	3	5	(1)	2	4
Ductility						
Original	3	2	3	(1)	(1)	(1)
From mix, section A	(1)	(1)	(1)	(1)	(1)	(6)
From mix, section B	(1)	(1)	(1)	(1)	(1)	(6)
From cores, section A	(1)	(1)	(1)	(1)	(1)	(6)
From cores, section B	(1)	(1)	(1)	(1)	(1)	(6)
Saybolt Furol viscosity						
Original material:						
Change between 300° and 275°F	2	5	3	(1)	4	6
Change between 325° and 275°F	(1)	6	3	2	5	4

Recovered material: no comparable data

In addition to the foregoing, the following data with respect to susceptibility of asphalt and general discussion have been extracted from the Michigan progress report.

SUSCEPTIBILITY FACTORS

Control Items	Asphalt No.					
	1	2	3	4	5	6
Pen. slope = $\frac{\log P_1 - \log P_2}{T_1 - T_2}$	0.0249	0.0240	0.0258	0.0227	0.0232	0.0219
Viscosity slope = $\frac{\log V_1 - \log V_2}{T_2 - T_1}$	0.0100	0.0099	0.0102	0.0083	0.0096	0.0112

Control Items	Asphalt No. 1	2	3	5	5	6
Viscosity slope = $\frac{\log V_1 - \log V_2}{\log T_2 - \log T_1}$	17.41	17.33	17.83	14.45	16.85	19.55
Penetration index = $\frac{\text{Penetration at } 77°F}{\text{Penetration at } 32°F}$	3.94	3.75	5.15	4.00	4.36	3.42
Penetration ratio = $\frac{\text{Penetration at } 39.2°F}{\text{Penetration at } 77°F}$	33	35	30	40	34	40
1/8 in. BPR thin film test, L. on H. at 325°F, % original penetration after						
1 hr	86	90	82	87	89	85
3 hr	75	75	67	77	74	82
5 hr	57	63	60	70	64	69
7 hr	49	57	51	63	57	57
24 hr	25	27	25	37	34	34
Ductility of residue at 25°C after						
1 hr	150+	150+	150+	150+	150+	150+
3 hr	150+	150+	150+	150+	150+	150+
5 hr	150+	150+	150+	150+	150+	77
7 hr	150+	150+	150+	150+	111	33
24 hr	6	4	6	7	6	4
Shattuck test						
% Original penetration	46	47	43	63	56	55
Ductility at 25°C—cm	136+	69	150+	150+	137	26
Heat stability test, 100 g, 2 hr, 500°F						
% of orig penetration	92	95	99	105	92	94

Excerpts from Michigan "Progress Report":

"The standard specification tests for specific gravity, penetration, loss on heating, ductility, solubility and spot test, etc., do not indicate any significant differences between these various asphalts and therefore the additional tests tabulated were run on each of the asphalts to bring out differences which might relate, in some manner, to the quality or future performance of the asphalts in the pavement test sections.

"It is important to note the variation of test results comparing the penetrations at the temperatures under the same load conditions. At 95°F the penetration ranges from 141 to 186, while the original on the six asphalts at 77°F range only from 60 to 67°. Similarly, there is some variation in the penetration at 32 and 39°F, although the significance of these values is somewhat lost due to the asphalt approaching zero-hardness at the lower temperatures.

"If the penetration slope is determined by plotting the log penetrations at 59, 77 and 95°F, it is found that the penetration curves, for all practical purposes, are straight lines within the temperature range. The slope of the log penetration versus temperature curves for the various asphalts is expressed numerically in Table 2. It will be noted that asphalt No. 6 has the lowest penetration susceptibility, followed by asphalts Nos. 4, 5, 2, 1, and 3, in ascending order.

"Considering, next, the viscosity results made at 275, 300 and 325°F, it will be noted that, although the penetration of these six asphalts was confined to the narrow range 60-70, the viscosity at 275°F ranged from 192 to 337 Saybolt Furol seconds. The viscosity curves were plotted on an ASTM log viscosity chart, illustrated in Fig. 5. It will be noted from this figure that the viscosity curve slopes for asphalt Nos. 1, 3 and 6, are approximately parallel throughout, although the values at specific temperatures show a considerable difference in viscosity. Asphalt No. 4, which is presumed to be partially oxidized, shows the lowest viscosity-temperature slope, while asphalt No. 6 shows the greatest rate in change in viscosity, although the asphalt itself is in the higher viscosity range. The actual slopes of the viscosity curves are tabulated in Table 2 and rank No. 4 least susceptible, with Nos. 5, 2, 1, 3, and 6 following in ascending order. The penetration-temperature susceptibilities of the different asphalts rank in the same order as the viscosity-temperature susceptibilities except No. 6, which ranks highest in viscosity-temperature susceptibility.

"The California Division of Highways has recently proposed a specification in which the viscosity at 275°F is specified for the various penetration grades. Other agencies have the requirement of determining the proper mixing temperature from the asphalt viscosity. The indication from the viscosity curves in Fig. 5 is that asphalts Nos. 2, 5, and 6 would not meet the California viscosity requirements; however, asphalt cements from these three crude sources have been used successfully for the past fifteen years in Michigan. The California Division of Highways has also proposed a penetration ratio determined from the penetrations made at 39.2°F and 77°F and expressed by the following equation:

$$\text{Penetration ratio-percent} = \frac{\text{pen. } 39.2°\text{F, } 200 \text{ g, } 1 \text{ min}}{\text{pen. } 77.0°\text{F, } 100 \text{ g, } 5 \text{ sec}} \times 100 \quad .$$

This is similar to a requirement of the New York State Highway Department and several other agencies. Table 2 gives penetration ratio values of these six asphalts. It will be noted that all of these are well above the minimum of 25 proposed by California and all meet the 30% requirement of New York State.

"Ductility tests were determined on all the asphalts at various temperatures, from 4 to 30°C. The test values noted in Table 1 show all of these asphalts have ductilities of 150+ at 15.6°C, with the exception of No. 6. The ductilities of the asphalts at 10°C vary considerably over a range of from 8 to 25 centimeters. At 4°C asphalts Nos. 4, 5, and 6 show a ductility of 5, while No. 2 shows a ductility of 1, and Nos. 1 and 3 show zero ductility.

"A number of tests have been proposed to measure the resistance of asphalt to hardening. Among these are the Bureau of Public Roads thin-film test, Shattuck test, and the Michigan Highway Department recovery test. All of these were used in this investigation. The thin-film test for the five-hour period is proposed to indicate the relative resistance of the asphalt to hardening. The data on the thin-film tests on these asphalts is summarized in Table 3. From the 5-hour thin-film test noted here, it will be observed that the penetration ranges from 57 to 70 percent of the original asphalt penetration. Other periods of exposure used in this investigation for the thin-film oven-oxidation test were 1, 3, 7, and 24 hours for the purpose of obtaining information on the rate of hardening on this test.

"Noting the ductilities from the thin-film test residues, it is observed that only asphalt No. 6 showed any reduction in ductility up to the 7-hour period, all of the others having 150+ ductility values. Asphalt No. 6 lost ductility at a quite uniform rate and at the end of 24 hours, it was down to 4 centimeters ductility. However, while all of the other asphalts except No. 5 showed 150+ ductility at 7 hours, the 24-hour thin-film residue ductility tests were all of a rather low numerical value.

"The Shattuck test reported in the AAPT Proceedings previously was originated by Mr. Charles Shattuck while in charge of the City of Detroit bituminous paving construction and has been used by other investigators. The Shattuck test was performed in duplicate on all of the asphalts, following a procedure noted in the reference, with the exception that a Despatch oven, Style No. V-29-2, with forced circulation was used for the 30-minute curing period after the mixing. The penetration of the recovered asphalt from the Shattuck test varies from 43 to 63 percent of the original penetration, showing quite a wide variation in the resistance to hardening as measured by this test with asphalts Nos. 1, 2, and 3 failing to meet the 50% penetration loss requirement. Similarly the ductility of the recovered asphalt from the Shattuck tests showed variation, with asphalt No. 6, having exceptionally low ductility, and asphalts Nos. 1, 2, and 5, a reduction from the original ductility of 150+. Asphalts 3 and 4 still retained 150+ ductility after the Shattuck test.

"The heat stability test, noted in Table 3, was devised at the Michigan laboratory to determine the stability of the asphalt to softening with heating. At numerous times, it had been observed experimentally, particularly with oxidized asphalt cements, that an increase in penetration occurred when the asphalt was heated at certain elevated temperatures. The test is performed by heating a 100-gram sample of asphalt for a 2-hour period in a closed metal con-

tainer (seamless ointment can) at 500°F. With ordinary straight-run vacuum or steam-refined asphalt cement, a slight reduction of penetration will be observed while with oxidized asphalt, a definite softening or increase in penetration will occur. Other factors beside oxidation, unknown at the present time, may influence such a change or instability with heat. The test results on the heat stability of these six asphalts show all except No. 4 having a slight reduction in penetration while No. 4 shows a 5 percent increase in penetration. Up to 30% increase in penetration was observed in our 1950-54 investigation on some 60-70 penetration asphalt samples.

"The Michigan Highway Department recovery test has been used since 1935 as a part of their specifications and is performed on a sample of mix taken daily from each hot-mix bituminous-concrete project. The requirements specify that, for 60-70 penetration asphalt cement, the penetration of the recovered asphalt be at least 60% of the original penetration and that the ductility of the recovered asphalt be not less than 50 centimeters. Table 4 summarizes the average test results on all of the samples taken from the various test sections, both at the time of construction and at the time of coring after the paving had been in use approximately three months. The average mix temperature for the various sections has been noted. It will be observed that the average penetration of the samples taken at the time of construction range from 66 to 78 percent of the original penetration of the asphalt. These test values are an average of results from 17 to 21 samples taken from each test section. The asphalt in the pavement has continued to harden as shown by the penetration test results of analyses made on the cores taken three months after construction. The penetration noted at this time ranged from 63 to 72% of the original penetration, while the drop in penetration for the individual asphalts, expressed as a difference in percents of the penetration immediately after construction and that of the core, vary from 2 to 9 percent. Asphalt No. 2 shows the most loss in penetration during th 3-month period, while asphalt No. 5 shows the least. The ductility of the recovered asphalt from both the sample taken immediately after recovery and those from the cores taken in November show 150+ centimeters ductility, with the exception of asphalt No. 6 which had some ductility values below the 150+, as noted by the average figures 140 and 116.

"A significant fact was observed when the Oliensis spot test was made on the recovered asphalts from the various sections. In all cases, positive spot-test results were obtained with the recovered asphalt from Sections 1 and 3, while all other asphalts recovered showed negative spot-test results. This led to further investigation of the spot test on the other heat residues reported previously. A similar relationship was found with spot tests on the residue of the 24 hour 1/8-in. film tests with asphalts Nos. 1 and 3 showing positive spots when subjected to these test conditions, while other asphalts showed negative spot-test results. The Shattuck test, however, gave residues with negative Oliensis spots. Figure 6 (not included in this report) shows photographs of the spot test described for these asphalts. The spot test is well known for its ability to differentiate between cracked and uncracked asphalt, but it is recognized that certain crude sources may be inherently positive before refining of the crude oil, due to some component of the crude not

being entirely soluble in the special naphtha used for the standard Oliensis spot test. These results would indicate a certain change, however, in the asphalt causing some of it to become insoluble in the naphtha solvent. This information is recorded here mainly as a matter of record and will be considered very closely in further analysis of the test road, in the light of the durability observed under traffic and climatic conditions."

Throughout the preceding appendices, in which Wyoming asphalts are discussed, it appears that the softening point/penetration ratio may be a test relationship which can be correlated with the service performance of asphalts in paving structures. The temperature susceptibility of an asphalt, as reflected by change in its properties when it is exposed to heated aggregate in thin films during the mixing operation, may be indicated by the change in its softening point/penetration ratio. If the ratio of the original asphalt is employed for control, the actual change in the recovered asphalt should be readily obtainable.

Michigan State Highway Department records for the experimental project under discussion are unusually complete as to aggregate and mixing temperatures. Aggregate temperatures, as tabulated on page 317, will be employed in this discussion. As the B sub-sections were selected to demonstrate the effect of variations in both asphalt content and temperature, they will be chosen for this study.

In the following tabulation the control data are the penetration, softening point, and the softening point/penetration ratio of the original asphalt. They are identified by numbers 1 to 6. The maximum aggregate temperature has been shown, but the averages will be used as being more representative of conditions. From tests on the recovered asphalt, the penetration, softening point, softening point/penetration ratio, and the difference between the original and recovered softening point/penetration ratio have been determined for each lane and each asphalt. For each asphalt, the high and low average temperatures were determined and identified by letter (H) or (L) respectively. The high average temperature for each asphalt has been underlined. The relatively large difference in aggregate temperature between the high and the low produced marked differences in the resulting ratios. When the difference between the high and low aggregate temperature ratio was divided by the difference in temperature, the quotient became the change in softening point/penetration ratio per degree Fahrenheit. This latter value was employed as the rating medium, the material exhibiting the least change being given a rating of (1) and increasing change being denoted in ascending numerical order.

The rating of asphalt performance using averaged plant aggregate temperatures with softening point/penetration ratios are tabulated below:

RATING BASED ON INDIVIDUAL MIXED AGGREGATE TEMPERATURES

Asphalt No.	1	2	3	4	5	6
Rating	4	2	3	6	1	5

COMPARATIVE TEMPERATURE SUSCEPTIBILITY OF ASPHALT
AS DETERMINED BY THE SOFTENING POINT/PENETRATION RATIO

Control Items	Asphalt No. 1	2	3	4	5	6
Original asphalt						
Penetration	63	60	67	60	61	65
Softening point	120.0	125.2	118.6	123.3	120.2	124.2
S. pt./pen. ratio	1.905	2.087	1.770	2.055	1.970	1.911
Sub-section B—individual values						
Lane 1						
Max. agg. temp	380	400	380	350	368	395
Avg agg. temp	340	H373	H343	327	346	H359
Pen. of rcvd asphalt	43	39	43	40	40	43
S. pt. of rcvd asphalt	128.3	136.8	124.2	132.4	133.5	137.8
S. pt./pen. ratio	2.984	3.508	2.888	3.310	3.338	3.205
Rcvd—orig ratio	1.074	1.418	1.118	1.250	1.368	1.295
High avg—low avg temp-°F		+51	+39			+37
Diff. between ratios		-.281	+.025			-.421
Change s.pt./pen. per °F		.0055	.0064			.0114
Rating by least change		(2)	(3)			(5)
Lane 2						
Max agg. temp	360	380	360	362	380	375
Avg agg. temp	H345	358	333	L314	H355	356
Pen. rcvd asphalt	47	37	44	47	44	43
S. pt. rcvd asphalt	126.3		122.7	127.0	133.0	138.0
S. pt./pen. ratio	2.687		2.789	2.702	3.023	3.209
Rcvd—orig ratio	0.777		1.019	0.642	1.053	1.299
High avg—low avg temp-°F	+33				+39	
Diff. between ratios	-.342				-.211	
Change s.pt./pen. per °F	.0104				.0054	
Rating by least change	(4)				(1)	
Lane 3						
Max agg. temp	335	343	327	362	369	328
Avg agg. temp	L312	L322	305	339	318	L322
Pen. rcvd asphalt	42	36	42	45	44	38
S.pt. rcvd asphalt	127.2	136.4	124.0	127.2	130.6	137.8
S.pt./pen. ratio	3.029	3.789	2.953	2.827	2.968	3.626
Rcvd—orig ratio	1.119	1.699	1.183	0.767	0.998	1.716
High avg—low avg temp						
Diff. between ratios						
Change s.pt./pen. per °F						
Rating by least change						

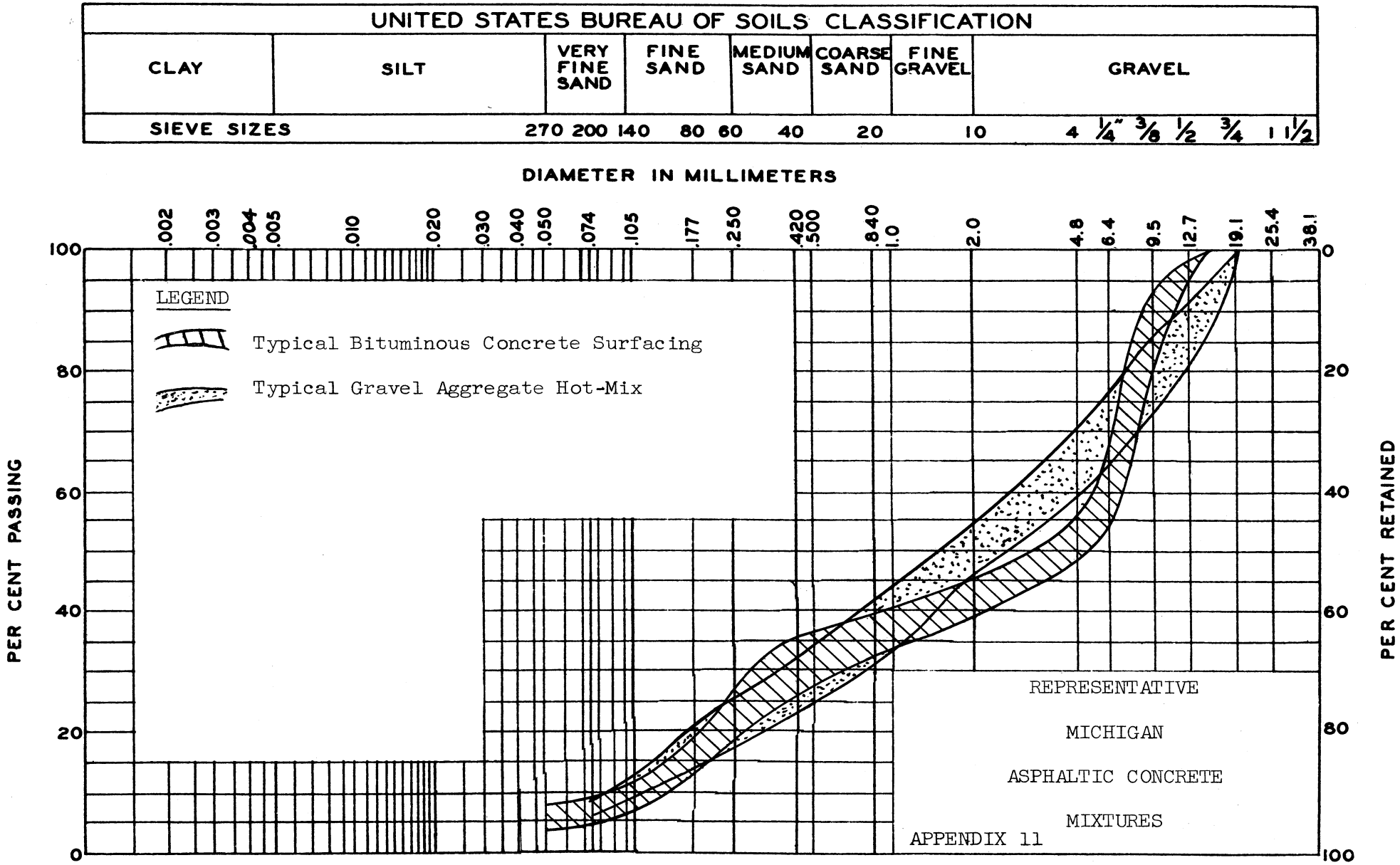
Control Items	Asphalt No.					
	1	2	3	4	5	6
Lane 4						
Max agg. temp	352	356	331	370	368	345
Avg agg. temp	319	323	L304	H350	L316	323
Pen. rcvd asphalt	42	39	43	41	41	44
S. pt. rcvd asphalt	128.4	133.9	123.1	129.7	132.6	133.0
S. pt./pen. ratio	3.057	3.433	2.863	3.163	3.234	3.023
Rcvd—orig ratio	1.147	1.343	1.093	1.103	1.264	1.113
High avg—low avg temp—°F				+36		
Diff. between ratios				+.461		
Change s.pt./pen. per °F				.0128		
Rating by least change				(6)		

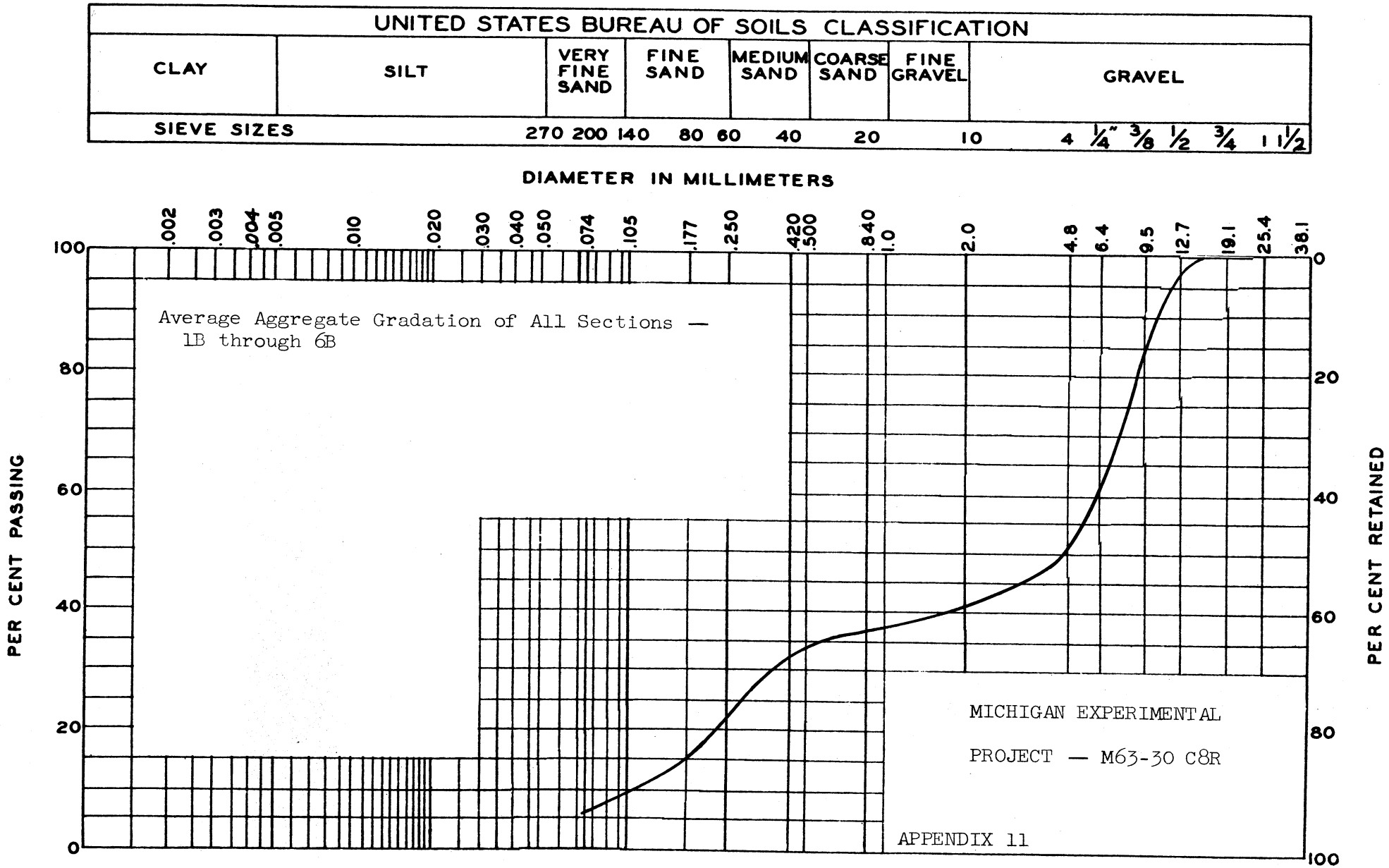
Inspection of the tabular data indicates a departure from the anticipated behavior of asphalt when exposed to relatively high temperature. An increase in softening point and a drop in penetration through thin-film exposure can normally be expected as the temperature of the aggregate increases.

For asphalt No. 1 the high aggregate temperature of 345°F resulted in a recovered penetration and softening point of 47 and 126.3°F, respectively. With the low average temperature of 312°F, the recovered penetration and softening point was 42 and 127.2°, respectively. With asphalts Nos. 2 and 3 this condition was duplicated. For asphalts Nos. 4, 5, and 6 the normally expected trend is followed.

No explanation can be offered for this reversal. It may be due entirely to normal testing inaccuracy or to the relatively short period of time the asphalt has been in service. A longer period of service life may cause subsequent test results to conform to normally expected pattern.

The Michigan investigations reported in this appendix, together with those in appendices 11a and 11b, while not readily comparable with data on the Wyoming asphalt and paving construction inspected in the Western states, are valuable in contributing information relative to the behavior of paving asphalt and bituminous pavements.


UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
PER CENT RETAINED
100 80 60 40 20 0
LEGEND
Typical Bituminous Concrete Surfacing
Typical Gravel Aggregate Hot-Mix
REPRESENTATIVE
MICHIGAN
ASPHALTIC CONCRETE
MIXTURES
APPENDIX 11


UNITED STATES BUREAU OF SOILS CLASSIFICATION
CLAY
SILT
VERY FINE SAND
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
GRAVEL
SIEVE SIZES
270 200 140 80 60 40 20 10 4 1/4" 3/8 1/2 3/4 1 1 1/2
DIAMETER IN MILLIMETERS
.002 .003 .004 .005 .010 .020 .030 .040 .050 .074 .105 .177 .250 .420 .500 .840 1.0 2.0 4.8 6.4 9.5 12.7 19.1 25.4 38.1
PER CENT PASSING
100 80 60 40 20 0
PER CENT RETAINED
0 20 40 60 80 100
Average Aggregate Gradation of All Sections — 1B through 6B
MICHIGAN EXPERIMENTAL
PROJECT — M63-30 C8R
APPENDIX 11

APPENDIX NO. 11a

MICHIGAN STATE HIGHWAY DEPARTMENT
PROJECT F 83-13 C5 and C6
M-55 FROM CADILLAC TO MANISTEE

SPECIAL TEST SECTION
CONSTRUCTED IN 1936
USING
NATURAL, OIL ASPHALT, AND BLENDS FOR
A STUDY OF WEATHERING CHARACTERISTICS

ASPHALTIC CONCRETE PAVING

Michigan State Highway Department
Project F 83-13 C5 and C6, Special Test Section
Location and Scope: On State Route M 55, between Cadillac and Manistee, Michigan, totaling 10.092 miles east of Wexford County line toward Cadillac. This experimental section was provided to study the service behavior of several asphalts and their blends with Trinidad asphalt.

The following asphalts were used:

Barber Asphalt Company----------CNA-T
American Bitumuls Company----------COA
Lion Oil Refining Company----------COA
Standard Oil of Indiana----------COA
Standard Oil of New Jersey----------COA

The crushed gravel was produced by the Grand Rapids Sand and Gravel Company and was combined with local sands. The filler was a limestone dust obtained from the Ohio Hydrate Company, Woodville, Ohio.

Pavement samples have been taken since 1936 and laboratory tests were performed on the recovered asphalt. Results of these tests are shown in both table and graph and indicate the condition of the several asphalts over a period of 17 years, between 1936 and 1953.

The location of the test section is shown in the plan on page 338 of this appendix. The notation on the plan, "bad frost heaves, beginning to ravel," denotes the possible reason for adverse paving performance.

The records and files of the Michigan State Highway Department have been made available for use in connection with ERI Project No. 2249. The information obtainable from this project is a portion of the results of such study of a large number of projects constructed in 1936. This particular section has received detailed attention and provides data relative to several different asphalts in approximately the same location.

Numerous test sections have been resurfaced. The asphalt as employed is quite dissimilar to that investigated in Project 2249. For these reasons no project inspection, sampling, or laboratory testing has been performed. The data are based upon that contained in the Michigan State Highway Department records and are included in Table 1 of this appendix. Original and recovered penetration, ductility, and recovered dust content of the asphalt are the pertinent observations for comparison.

The change in penetration of the different asphalts is tabulated below:

REDUCTION IN PENETRATION WITH TIME

Elapsed Time, Years	a	b	c	d	e	f	g	h	i	j	Max	Min	Ave
0-Orig	0	0	0	0	0	0	0	0	0	0	0	0	0
0-Mix	-12	-12			-1	-9	-14	-18		-9	-18	-1	-9
1	-3	-13	-31		-5	-5	-2	-9	-20	-18	-20	-2	-12
2	-4	-2	-2	-24	-5	-1	-13	-12	-11	-4	-24	-1	-8
3													
4	+3	-4	-4	+1	0	-1	+6	+5	-11	-1	-11	0	-1
5	+2	-4	-1	-3	-3	-2	+2	+5	-3	-4	+5	-1	-1
6	-1	-1	+1	0	+1	-3	-3	-16	-7	+3	-16	0	-3
10	-1	-2	-2	0	-7	-12	0	+12	-5	+1	-12	0	-2
13	+1	+9	-3	0	-3	+3	-10	-1	-4	-9	-10	0	-2
17	-5	-6	0	-2	-7	-4	+5	+3	-7	+4	-7	0	-2

Symbols Identifying Asphalts

(a) Barber Natural Asphalt
(b) Barber-Std. of N.J. Blend
(c) Std. of N.J. Asphalt
(d) Barber-Lion Blend
(e) Std. Oil of Ind. Asphalt
(f) Std. Indiana-Barber Blend
(g) Barber-Amer. Bit. Blend
(h) Amer. Bitumuls Asphalt
(i) Barber-Lion Blend
(j) Lion Oil Co. Asphalt

The ratings of the several asphalts and blends are tabulated below. The least change in penetration is rated as (1) and the greatest as (10).

Elapsed Time, Years	Asphalt (See Legend) a	b	c	d	e	f	g	h	i	j
0-Orig										
0-Mix	3	3			(1)	2	4	10		2
1	2	5	10		3	3	(1)	4	7	6
2	3	2	2	10	4	(1)	7	6	5	3
3										
4	(1)	2	2	(1)	(1)	2	(1)	(1)	10	2
5	(1)	10	2	4	4	3	(1)	(1)	4	10
6	2	2	(1)	(1)	(1)	3	3	10	4	(1)
10	2	3	3	(1)	5	10	(1)	(1)	4	(1)
13	(1)	(1)	3	(1)	3	(1)	10	2	4	5
17	4	5	(1)	2	10	3	(1)	(1)	10	(1)
Ave	2	4	3	2	4	3	3	4	5	3

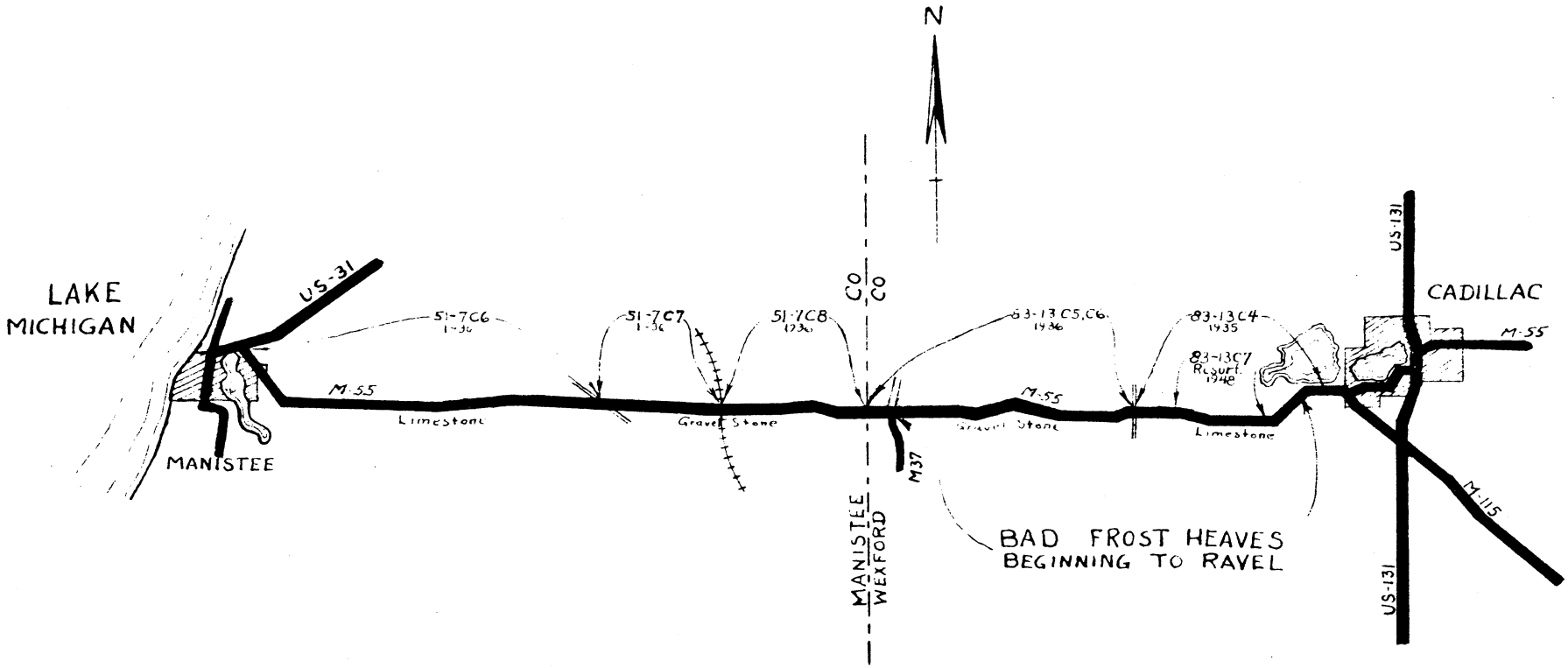


Figure 3. Map of M-55 (Cadillac to Manistee) Showing Projects and Location of Frost Heaves.

APPENDIX NO. 11b

MICHIGAN STATE HIGHWAY DEPARTMENT
ASPHALT TEST DATA FROM
DATA COLLECTED BETWEEN 1934 AND 1949

WEATHERING STUDY

ASPHALTIC CONCRETE PAVING

Michigan State Highway Department
Asphalt Test Data for Period Between 1934 and 1949
Location and Scope: Various locations in Michigan. Standard tests on original and recovered asphalt.

The following material was included in the Highway Department investigation:

Date Const.	Source of Asphalt	Type Asph.	Type Paving	Proj. No.	Location	Plot*	Source
1934	Std. of New Jersey-Barber Blend	CNO	Sh	NRHM81-16C4	US12,A. Arbor	(C)	(k)
1934	Texas Co.	COA	AC	NRH47-17C6	US16,Howell	(E)	(s)
1934	Texas Co.	COA	AC	NRH59-34C1	Greenville	(E)	(t)
1935	Warner-Quinlan	CIA	AC	F10-16C3	Frankfort	(B)	(y)
1935	S.O.N.J.-Barber	CNO	Sh	NRM39-29C2	Kalamazoo	(C)	(l)
1935	S.O. Ind.	COA	AC	NRS28-26C3	Traverse City	(H)	(u)
1935	S.O. Ind.	COA	AC	NRH47-17C6	US16,Howell	(H)	(v)
1935	Texas Co-Barber	CNO	AC	NRS30-19C6	Osseo	(E)	(r)
1936	Am.Bit.Co.-Barber	CNO	Sh	WPMS9-30C2	Bay City	(A)	(f)
1936	S.O.N.J.-Barber	CNO	Sh	F50-32C1	Mt. Clemens	(C)	(m)
1936	Lion Oil Co.-Barber	CNO	SH	F77-53C3	Port Huron	(D)	(h)
1937	Lion-Barber	CNO	Sh	F38-41C8	US12,Jackson	(D)	(g)
1940	Lion	SOA	AC	M39-1C4	Schoolcraft	(F)	(i)
1940	Barber	SOA	AC	M41-54C2	US37, N.G.Rpd	(G)	(a)
1940	Barber	SOA	AC	M63-8C6	US16,New Hdsn	(G)	(b)
1940	S.O.N.J.	SOA	AC	M25-14C2	M21,E. of M13	(I)	(n)
1940	S.O.N.J.	SOA	AC	M33-8C3	US127, Leslie	(I)	(o)
1940	S.O.N.J.	SOA	AC	M81-20C5	US12 A. Arbor	(I)	(p)
1941	Lion	SOA	AC	M9-15C3	M24, Bay City	(F)	(j)
1941	Barber	SOA	AC	M13-32C3	Albion-Marshl	(G)	(c)
1941	Barber	SOA	AC	M61-20C4	M46, Muskegon	(G)	(d)
1941	Barber	SOA	AC	M63-37C3	M59,E. Pontiac	(G)	(e)
1941	S.O.N.J.	SOA	AC	F58-25C7	US25, S. Erie	(I)	(q)
1944	S.O. Ind.	SOA	AC	F11-22C7	US12, Coloma	(H)	(w)
1945	S.O. Ind.	SOA	AC	Main St.	Traverse City	(H)	(x)

* Graph 1 and Table 1 identification.

All available data has been tabulated in Table 1, this appendix. It consists of original and recovered penetration and ductility, original specific gravity and the dust content of the recovered asphalt. In addition, the penetrations of the original and recovered asphalt are plotted on Graph 1, this appendix. This presentation facilitates comparison of the several asphalts over the period of this investigation. The symbol "S" in the table indicates the pavement has failed and testing was discontinued, and a seal coat applied in the year noted.

The asphalts included in this appendix are not readily comparable with those reported from Wyoming crudes discussed in Appendices 1 to 11. Softening point values, necessary to the determination of the softening point penetration ratio have not been obtained. Following the procedure in Appendix 11a, the change in penetration will be tabulated and the asphalts rated, using least change in penetration as the criteria for service performance.

As indicated by the averaged rating over the years of record, asphalts from (f), American Bitumuls-Barber blend, (h), Lion-Barber blend, and (l) Standard Oil of New Jersey-Barber blend, have the highest rating. Asphalt (g), Lion-Barber blend, (u), Standard Oil of Indiana, (k), Standard Oil of New Jersey-Barber blend, and (y), Warner-Quinlan Mexican asphalts are grouped in the second position. The intermediate material having ratings ranging from 6 to 8 and consisting of Standard Oil of Indiana, Barber, Lion, Standard of New Jersey, and Standard of Indiana were straight unblended materials. The poorest ratings, from 9 to 11, include Barber SOA and Standard Oil of New Jersey SOA.

REDUCTION IN PENETRATION WITH TIME

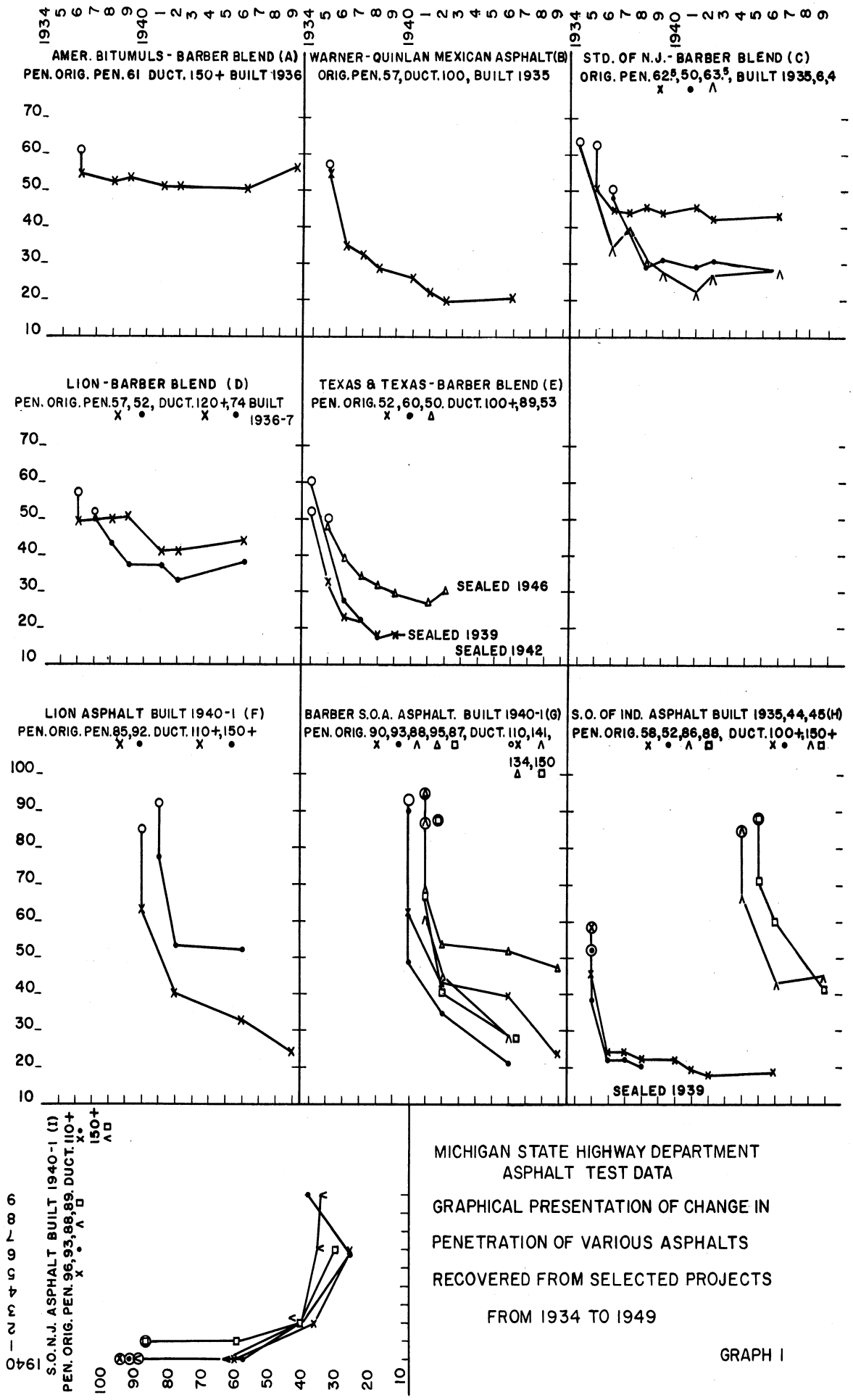
Elapsed Time, Years	Source Symbol for Asphaltic Material																								
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)	(r)	(s)	(t)	(u)	(v)	(w)	(x)	(y)
0-Orig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-Mix	-28	-44	-30	-29	-20	- 7	- 2	- 8	-21	-15		-13	- 3	-34	-34	-26	-28	-12	-20		-12	-14	-19	-17	- 3
1			-13	-12	-26		- 7			-24		- 6					-19	-13	-10		-22	-16		-11	-20
2	-19	-14				- 2	- 6	+ 1	-24		-30	0	-20	-23	-18	-24		- 4	- 1	-33	+ 1	0	-24		- 2
3						+ 1		0			+ 6	+ 1	+ 3					- 3	- 2	- 5	- 3	- 2			- 4
4							0				- 9	- 1						- 3	0	- 5		S		-18	
5			-16	- 2	-13	- 2	- 4	- 9		- 1	- 4		- 2				-10		S	+ 1	0		+ 2		- 2
6	- 3	-14				0		0	- 7			+ 1	+ 2	-11	-14	- 4		- 2			- 3				- 4
7				- 5							- 5	- 3						+ 3		0	- 1				- 3
8											+ 5									- 2					
9	-17						+ 5		- 9						+13	- 1				S					
10						- 1		+ 3					- 3												
11												+ 1						S			+ 1				+ 1
12											+ 1														
13						+ 6																			
14																									
15																									

Note: The symbols representing various asphalts are shown in the table on page 1, of this appendix. "S" indicates year in which seal was applied. Failure may have been due to inadequate support or to frost action.

The ratings of the several asphalts or blends, based upon the least change rating of (1) for the best or first, with greater changes designated in ascending order, are tabulated below:

PERFORMANCE RATING BASED ON PENETRATION CHANGE

Elapsed Time, Years	Source Symbol for Asphaltic Material																								
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)	(r)	(s)	(t)	(u)	(v)	(w)	(x)	(y)
0-Orig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-Mix	14	18	16	15	11	3	(1)	4	12	8		6	2	17	17	13	14	5	10		5	7	10	9	2
1			6	5	12		2			11		(1)					8	6	3		10	7		4	9
2	9	7				4	6	(1)	12		13	2	10	11	8	12		5	3	14	(1)	2	12		4
3						3		4			(1)	3	2					6	5	8	6	5			7
4							(1)				5	2						3	(1)	4		S		6	
5			11	5	10	5	6	7		4	6		5				8		S	2	3		(1)		6
6	5	9				3		3	7			2	(1)	8	9	6		4			5				5
7				5							5	4						(1)		2	3				6
8											(1)									2					
9	5						2		4						(1)	3				S					
10						2		(1)					3												
11												(1)						S			(1)				(1)
12											(1)														
13						(1)																			
14																									
15																									
Avg	8	11	11	8	8	3	3	3	9	8	5	3	4	12	9	9	10	S	S	S	4	S	8	6	5



MICHIGAN STATE HIGHWAY DEPARTMENT
ASPHALT TEST DATA

GRAPHICAL PRESENTATION OF CHANGE IN PENETRATION OF VARIOUS ASPHALTS RECOVERED FROM SELECTED PROJECTS FROM 1934 TO 1949

GRAPH I

APPENDIX NO. 12

MIGHIGAN STATE HIGHWAY DEPARTMENT

SERVICE BEHAVIOR OF ASPHALT

VARIOUS PAVING PROJECTS

CONSTRUCTED BETWEEN 1948 AND 1952

BITUMINOUS AGGREGATE PAVING

FIELD INSPECTION REPORT

Project CS 77-73-C2, Marine City Highway. 11.113 miles west of Marine City, Michigan, to St. Clair-Macomb County Line.
Asphalt LOA-150-175 Pen., American Liberty Oil Co., Mt. Pleasant, Texas. Constructed in 1950.

This paving was inspected and sampled on April 11, 1955. Pictures 300 to 307 supplement this inspection report.

The bituminous surfacing was placed over old concrete. The design thickness was 2 in., laid in two courses. The paving mixture was set up to contain 5.12% asphalt, 6.40% filler, 38.48% sand, and 50.0% coarse aggregate for the base and 5.32% asphalt, 6.20% filler, 38.48% sand, and 50.0% coarse aggregate for the top course. All percentages are ased upon the weight of the mixture. The coarse aggregate was Drummond Island dolomitic limestone.

In general, the condition of the paving was very good. There were variably spaced transverse cracks, carried through from the underlying concrete, throughout the length of the project. Isolated cases of longitudinal cracking were observed in the middle portion of the paving, but there was almost continuous longitudinal cracking at a distance of 3.0 ft inward from each edge. There was some heaving or buckling of the surface at a limited number of transverse cracks which were apparently caused by frost action. Only isolated edge failures and patching were in evidence and the edges were in good alignment, although the abutting gravel shoulder was generally below the level of the paving surface. Some abrasion was apparent in the east-bound traffic lane immediately east of the stop sign at the junction of the north-south Macomb-St. Clair county line road, probably caused by acceleration of vehicle wheels. There were no corrugations, raveling, or shoving, and no appreciable rutting throughout the project.

Samples were obtained at Station 496+88 in the westbound traffic lane on the north side of the road. Sample No. 300 was taken from the inner wheel path and sample No. 301 from between wheel paths. Picture No. 306 shows the paving samples and cuts from which they were removed. Comparative data on the original and recovered asphalt is presented in Table 1, this appendix.

Project M 71-20-C8, on U.S. 23 eastward from the junction with M65, a distance of 5.2 miles. Located in Presque Isle county.

Asphalt LOA 150-175 Pen. Between Stations 112+60 to 122+00, 2.13 to 2.30 miles from start of project at junction with M65, the asphalt was supplied by Asphalt Products Co., West Branch, Michigan. The remainder of the asphalt was furnished by the American Liberty Oil Company, Mt. Pleasant, Texas. Constructed in 1952.

This paving was inspected and sampled on April 12, 1955. Pictures 308 to 312 supplement the inspection report.

The bituminous surfacing was placed on gravel base. Construction records indicate that the weight of mixture per square yard of paving surface was approximately 260 pounds. The paving was laid in two courses, and both base and surface course contained 5.5% asphalt, 3.0 to 5.3% filler, 43.4 to 44.7% sand, and 45.8 to 46.8% coarse aggregate. All percentages are based upon the total weight of the mixture. Gravel was used for coarse aggregate.

The paving over the entire project is in excellent condition. The riding qualities are exceptionally good. Paving edges are in excellent alignment. There is no shoving, rutting, raveling, or bleeding of the asphalt. The paving texture and color are uniform. There was no transverse or longitudinal cracking, and only three of four isolated small edge breaks throughout the project.

Samples representative of the paving laid with American Liberty Oil Company asphalt were obtained at Station 211+20, 4.0 miles east of the junction with M65, from the westbound traffic lane. Sample No. 302 was from the inner wheel path and No. 303 from between wheel paths. Picture No. 310 shows these samples and the paving cut from which they were removed. Samples No. 304 and No. 305 were obtained from paving laid with Asphalt Products Company asphalt. They were obtained at Station 116+16, 2.2 miles east of the junction with M65. Sample No. 304 was taken from the inner wheel path and No. 305 from between wheel paths in the westbound traffic lane. Picture No. 312 shows a view of these samples and the paving cut from which they were removed. Comparative data for the original and recovered asphalts will be presented in Table 1, this appendix.

Project SS 57-11-C5, commencing at relocation at the Osceola-Missaukee County line, around curve and then along existing M66, north and west to the east city limits of McBain.

Twenty ft wide, class F-2, bituminous surface course—4.456 miles on gravel base.

Asphalt LOA 150-175 Pen., Lion Oil Company, Eldorado, Arkansas. Constructed 1952.

This paving was inspected and sampled April 12, 1955. Pictures Nos. 313 and 315 supplement this inspection report.

The bituminous surfacing was placed over gravel base at the approximate rate of 130 lb/sq yd for base and 120 lb for top. The mixture proportions were 5.4% asphalt, 5.0% filler, 53.7% sand, and 35.9% coarse aggregate. Gravel was used as the coarse aggregate.

No defects were noted in the paving surface. The original stationing stakes were found on the east side of the road, and sampling was done at Station 1162+85 in the southbound traffic lane. Sample No. 306 was taken from the inner wheel path and No. 307 from between wheel paths. Picture No. 315 shows the samples and the paving cut from which they were taken.

Project M 43-1-C3, from Lakeland Acres in Baldwin, Michigan, thence eastward on U.S. 10 for 1.905 miles to a point just east of the bridge across Sanborn Creek.

One hundred and fifty lb of bituminous aggregate mixture per square yard was placed over old concrete paving.

Asphalt LOA 100-120 Pen., Asphalt Products Company, West Branch, Michigan. Paving constructed in 1949.

This paving was inspected and sampled on April 14, 1955. No pictures were taken because of heavy rain at the time of inspection. Picture No. 314 shows a view of the paving area at point of sampling.

The bituminous surfacing was placed over old concrete paving. It was placed in one course and, where sampled, had a finished thickness of approximately 1 in. The paving mixture consisted of 5.0% asphalt, 5.0% filler, 55.8% sand, and 34.1% coarse aggregate. Gravel was used as the coarse aggregate.

At the start of the project in Baldwin, where the city access road intersects U.S. 10, there has been pronounced abrasion of the surface due to traffic action. Throughout the project the paving surface is extensively pitted due to the breakdown of soft aggregate particles. Transverse cracks carried through from the underlying old concrete are numerous but relatively well maintained. The paving has a dry, lifeless appearance, and picked samples appear to lack cohesion. The rideability of the paving is still good, with no shoving, rutting, raveling or bleeding of asphalt.

Samples M308 and M309 were obtained near Station 78+00 from the inner wheel path and between wheel paths of the westbound traffic lane. This is the intersection of Gray Road with U.S. 10, near the eastern city limits of Baldwin.

Project M 54-27-C6, from Remus, Michigan, east on M20, about 0.2 mile east of the intersection of M66 and M20 in Remus to the east county line of Mecosta County. Length of project 2.90 miles.

Paving consists of plant-mix bituminous aggregate laid on untreated gravel base at the rate of 250-275 lb of mixture per sq yd. Paving laid in two courses.

Asphalt LOA 150-175 Pen., Asphalt Products Co., West Branch, Michigan. Paving constructed in 1949.

This paving was inspected on April 13, 1955. Pictures 315 to 319 supplement this inspection report.

The bituminous surfacing was placed over gravel base. The base course averaged approximately 138 lb/sq yd, and the top 134 lb/sq yd. The paving mixture was set up to contain 5.2% asphalt, 4.2% filler, 38.2% sand, and 52.4% coarse aggregate for the binder, and 5.3% asphalt, 4.3% filler, 46.5% sand, and 43.9% coarse aggregate for the surfacing. All percentages are based upon the total weight of the mixture. The coarse aggregate was gravel.

The general paving condition is quite poor. As shown by picture No. 318, map cracking occurs at closely spaced random intervals inward from the paving edges for a distance of between 3 and 4 ft in both traffic lanes. Surface pitting, due to the breakup of soft aggregate is pronounced and extensive. Samples picked at random from the paving surface indicated the paving was relatively dry and brittle. Where map-cracked material was removed for inspection the gravel base appeared to be somewhat loose and sandy. A composite sample, M312, was obtained from the map-cracked edges in addition to those cut from the paving.

The location of sampling was largely influenced by the necessity for adequate sight distances for traffic. Samples M310 and M311 were obtained from the inner wheel path and from between wheel paths in the westbound traffic lane at Station 132+00, which was 0.4 mile from the Mecosta-Isabella County line, the eastern end of this project. Data relative to the original and recovered asphalt are included in Table 1, this appendix.

Project M 37-12-C11, a distance of 7.90 miles on M20 from the west county line of Isabella County, thence eastward to the beginning of the concrete pavement near the section corner common to sections 16, 17, 20 and 21, T. 14N, R 5 W., Deerfield Township.

Paving consists of plant mixed bituminous aggregate laid on untreated gravel base in two courses at the rate of approximately 275 lb/sq yd

Asphalt LOA 150-175 Pen., Asphalt Products Company, West Branch, Michigan. Paving constructed in 1949.

This paving was inspected and sampled on April 14, 1955. No pictures were obtained because of rain during the time of inspection and sampling.

The bituminous surface was placed over gravel base course. It was laid at an approximate rate of 136 lb/sq yd for base and 132 lb/sq yd for top. The composition of the mixture for binder was 5.2% asphalt, 4.2% filler, 38.2% sand, and 52.4% coarse aggregate. For the top the asphalt was 5.3%, filler 4.3%, sand 46.5%, and coarse aggregate 43.9%. All proportions are based upon the total weight of the paving mixture. Gravel was used as coarse aggregate.

This project is a continuation of the preceding project from Remus to the Mecosta-Isabella County line. The same contractor handled both paving operations and the aggregate sources and asphalt were identical. In general, the highway is located on higher-lying land, appears to have better subgrade soil and drainage conditions. Except for the low-lying swampy areas, there is markedly less cracking in the surfacing than was evident in the preceding project. There is a limited amount of edge map cracking, extending inward for a distance of from 6 to 18 in. in random locations. Pitting of the surface is extensive throughout the job, due to the disintegration of soft aggregate particles. There has been no evident rutting, shoving, raveling, or bleeding of the asphalt. The color and texture of the paving surface is uniform. Except where the road traverses low-lying swampy areas, the riding qualities of the paving are very satisfactory.

Sight distance for traffic influenced the selection of the sampling location. The highway is heavily traveled, requiring careful location of the point of sampling so as to create no traffic hazard. The sampling location was located at Station 419+76, 5 miles east of the Mecosta-Isabella County line at the junction of M20 and a county highway. Samples M313 and M314 were obtained from the inner wheel path and between the wheel paths of the westbound traffic lane. Sample M315 is a composite of map-cracked edges. Comparative data on the original and recovered asphalt are included in Table No. 1, this appendix.

Project CS 11-68-C2, commencing at Sodus and extending a distance of 5.98 miles to Eau Claire, Michigan.

Paving 20 ft wide, approximately 2 in. thick, laid on base consisting of salvaged crushed stone macadam intermixed with gravel and surfaced with approximately 2 in. of crushed gravel.

Asphalt SOA 100-120 Pen., American Liberty Oil Company, Mt. Pleasant, Texas. Paving constructed in 1948 by continuous plant mixer.

This paving was inspected and sampled April 15, 1955. Pictures Nos. 324 to 331 supplement this inspection report.

This surfacing was placed over a base course consisting of salvaged water-bound macadam mixed with crushed gravel. The surfacing was laid to a thickness of approximately 2 in., using approximately 113 lb/sq yd in the base course and 112 lb/sq yd in the surfacing layer. The approximate composition of the base course was 4.6% asphalt, 48.0% retained No. 10, 45.1% P 10-R200

and 2.3% pass No. 200 sieve. This paving was laid between September 13, 1948 and September 29, 1948. By February 1949, this paving had raveled and broken up so badly that an inspection was made by the State Highway Department. It was extensively sampled and the base and surfacing were analyzed in the laboratory. Those inspecting the paving, together with the Berrien County officials, were of the opinion that insufficient asphalt in the mixture was the major source of the trouble. As the paving was rapidly disintegrating, the State Highway Department authorized a resurfacing operation early in 1949. This project is described below.

Project MCS 11-68-C3, consisting of a 1-in.-thick surfacing over the raveled paving constructed under Project CS 11-68-C2. This project started at Sodus and continued to Eau Claire, covering a distance of 5.98 miles.
This surfacing course was plant mixed and trucked to the job.
Asphalt SOAM 100-120 Pen., Lion Oil Company, Eldorado, Arkansas. Paving resurfacing constructed in 1949.

The composition of the resurfacing paving mixture was 5.4% asphalt, 5.0% filler, 37.4% sand, and 52.2% coarse aggregate.

This resurfacing continued in service until the fall of 1954, when the Berrien County Road Commission applied a stone-chip seal between Sodus and the west city limits of Eau Claire. This seal consisted of 0.35 gal of asphalt per sq yd and 30 lb of stone chips. Within the limits of Eau Claire, the resurfacing course applied in 1949 is still in service.

Due to the rolling nature of the terrain traversed by this highway, sight distance to the point of sampling for vehicles using the highway was an important consideration. A favorable location was at the intersection of Evans Road with the Sodus-Eau Claire highway. This was a distance of 3.5 miles from the start of the job in Sodus. The stationing at this point of beginning for the original project was 128+30 which became Station 0+00 on this project, making the point of sampling on this project 184+80, which is identical with 313+10 on the original project. Samples M318, 318a, M319, and 319a were obtained from this location, the first two from the inner wheel path and the others from between the wheel paths. Test data for the original and recovered material are shown in Table No. 1, included in this appendix.

As the paving at Evans Road was covered with the asphalt—stone-chip seal coat, another location was selected within the city of Eau Claire where the existing paving surface consisted of the resurfacing course applied in 1949. The point of sampling was selected in the eastbound traffic lane, 0.1 mile from the end of the project at original stationing 437+10, which equalled 308+80 on the 1949 resurfacing project. Samples M320, 320a, M321, 321a and 20 were obtained from the inner wheel path and between wheel paths respectively. All asphalt test data covering the original and recovered material for both projects are shown in Table No. 1, in this appendix.

Prior to testing the paving samples in the laboratory, the layers of different paving were separated with a masonry saw in order that the composition of the mixtures and asphalt in each layer might be reported separately.

Project M 14-35-C2, commencing at the intersection of M62 and M40, in Dowagiac, thence west on M62 for 4.4 miles.

Twenty-ft-wide bituminous plant mix placed on gravel base in two courses. Binder course mixture at the rate of approximately 125 lb/sq yd and surfacing course at the rate of approximately 125 lb/sq yd.

Asphalt LOA 150-175 Pen., Lion Oil Company, Eldorado, Arkansas. Paving constructed in 1949.

This paving was inspected and sampled on April 14, 1955. Pictures Nos. 320 to 323 supplement this inspection report.

The bituminous surfacing was placed over gravel base. The design thickness was approximately 2-1/2 inches, laid in two courses. The paving mixture was set up to contain 5.2% asphalt, 5.3% filler, 42.0 to 43.0% sand, and 45.5 to 47.5% coarse aggregate for both courses. All percentages are based on the total weight of the mixture. Gravel was used for the coarse aggregate.

The riding qualities of the paving are very good. There is considerable pitting of the paving surface due to the use of soft aggregate particles. Random map cracking, with occasional short transverse or longitudinal cracking is present throughout the length of the project. All such cracking has occurred in the middle half of the roadway with practically none visible near the edges or in the outer wheel path. There has been some maintenance patching of map-cracked areas. Two bridges were constructed on this project in 1953, causing the removal of the original paving at the approaches. The present surfacing on these disturbed areas is of temporary nature and shows some rutting and shoving. Abrasive action from the wheels of vehicles is quite pronounced at the intersection of M62 and M40. Vehicles are required to stop for M40 traffic, and wheel acceleration in the eastbound lane of M62 has caused considerable surface wear. This is shown in picture No. 321. In the original paving, there was no rutting, shoving, corrugation, or bleeding of asphalt. The color and texture of the paving surface is uniform throughout the project.

Samples M316 and M317 were obtained from the westbound traffic lane at Station 161+04, 3 miles west of the start of the project at the junction of M62 and M40 in Dowagiac. Sample M316 was taken from the inner wheel path amd number M317 from between the wheel paths. The tests on the original asphalt, together with those on the recovered material, will be reported in Table No. 1, this appendix.

Project M 23-30-C2, commencing at Station 696+60 on M50, located about 55 ft northwest of the centerline of Potterville Road to Station 916+12, 22 ft south of the intersection of M50 and Maple Street in Charlotte, a distance of approximately 4.16 miles.

Asphalt LOA 150-175 Pen., Lion Oil Company, Eldorado, Arkansas. Paving constructed in 1949.

The paving was inspected and sampled April 16, 1955. Pictures Nos. 333 to 335 supplement this inspection report.

The riding qualities of this paving were very good. The edges were in good alignment and no breakage was evident. There were occasional areas in the central paved width where map cracking was visible throughout the length of the project. There was no displacement of the map-cracked sections and the individual particles could not be readily removed. There was no raveling, stripping, shoving, or rutting.

The sample site was selected with consideration of adequate sight distance for traffic. The highway was very heavily traveled by both passenger cars and commercial vehicles. Sample number M322 was obtained from the inner wheel path and sample number M323 from between the wheel paths of the southbound traffic lane at Station 876+12, 3.4 miles from the point of beginning of the project at Potterville Road.

Test data on the original and recovered asphalt will be included in Table Number 1, this appendix.

Project S 76-30-C4, commencing at Station 470+35.2, the intersection of M47 with Lovejoy Road on the Ingham-Shiawassee County line and extending to Station 641+70, 510.0 ft north of the south city limits of Perry.

The paving was laid over gravel base, to a thickness of approximately 2 in., using about 250 lb of mix per sq yd.

Asphalt LOA 150-175 Pen., American Liberty Oil Co., Mt. Pleasant, Texas. Paving constructed in 1952.

This paving was inspected and sampled on April 16, 1955. Pictures Nos. 336 to 338 supplement this inspection report.

The riding qualities of this paving are very good. There has been some slight amount of surface pitting due to the breakdown of soft aggregate. Limited edge failures occur at intervals and generally extend inward from the edges a distance of 6 in. There was some map cracking observed in the middle portion of the paved width, chiefly in the inner wheel path.

Sampling was done at Station 491+00 in the northbound traffic lane. Sample number M324 was taken from the inner wheel path and number M325 from between the wheel paths.

The test data on the original and recovered asphalt will be included in Table No. 1, this appendix.

Project 81-69-C2, Washtenaw County, Liberty Road, extending from Zeeb to Wagner Road, a distance of 2.045 miles.

The paving mixture was plant-mixed bituminous aggregate, laid to a thickness of 2 in. The mixture was supplied by the State and laid by the County organization. No inspector was provided by the State, and daily job reports showing stationing and job progress are not available. The only data of this nature was obtained by the plant inspector relative to the paving mixture at the time of delivery to the trucks.

Asphalt LOA 150-175 Pen. Supplied from the tank storage at the asphalt plant and appears to be a mixture of Standard Oil Co., Baltimore, and Lion Oil Company, Eldorado, Arkansas. The station location at which the asphalt or mixture was used is not obtainable. Paving was constructed in 1950.

This paving was inspected and sampled on April 16, 1955. Picture Nos. 339 to 341 supplement this inspection report.

The paving is in good serviceable condition with no irregularities noted.

Samples were obtained at Station 47+61 in the eastbound traffic lane at the intersection of Knight and Liberty Road. Number M326 was taken from the inner wheel path and M327 from between the wheel paths. In addition to these samples, members of the State Highway organization were desirous of seeing the masonry saw perform a typical sampling operation. This sampling demonstration provided an additional sample at Station 103+24 from near the center line in the westbound traffic lane.

The failure to indicate the disposition of the asphalt and mixtures by stations in the highway requires that the data on the original asphalt be obtained from daily plant testing records. These test data and those obtained from the paving samples are included in Table No. 1, this appendix.

SAMPLE INDEX

Sample No.	Year Const.	Asphalt Pen	Asphalt Source	Place of Sampling
M 300	1950	161(B)	Am. Lib.	Project CS 77-73-C2, Marine City highway. Sampled at Station 496+88, westbound traffic lane, IWP.
M 301	1950	163(S)*	Am. Lib.	Same as above except sample obtained from between wheel paths.
M 302	1952	146(B)*	Am. Lib.	Project M 71-20-C8, U.S. 23, east of M65, Presque Isle County. Sampled at Station 211+20, westbound traffic lane, IWP.
M 303	1952	151(S)	Am. Lib.	Same as above except sample obtained from between wheel paths.
M 304	1952	160(B)	Asph. Prod.	Project M 71-20-C8, U.S. 23, east of M65, Presque Isle County. Sampled at Station 116+16, westbound traffic lane, IWP.
M 305	1952	161(S)	Asph. Prod.	Same as above except sample obtained from between wheel paths.
M 306	1952	159(B)	Lion	Project SS 57-11-C5, M66, south of McBain. Sampled at Station 1162+85, IWP.
M 307	1952	159(S)	Lion	Same as above except sample obtained from between wheel paths.
M 308	1949	102(B)	Asph. Prod.	Project M 43-1-C3 on U.S. 10, east of Baldwin. Sampled at Station 78+05, westbound traffic lane, IWP.
M 309	1949	102(S)	Asph. Prod.	Same as above except sample obtained from between wheel paths.
M 310	1949	162(B)	Asph. Prod.	Project M 54-27-C6 on M20, east of Remus. Sampled at Station 132+00, westbound traffic lane, IWP.

*(B) and (S) denote base and surface course.

SAMPLE INDEX (continued)

Sample No.	Year Const.	Asphalt Pen	Asphalt Source	Place of Sampling
M 311	1949	166(S)	Asph. Prod.	Same as above except sample obtained from between wheel paths.
M 312	1949	164	Asph. Prod.	Project M54-27-C6 on M20, east of Remus. This sample was a composite from the map-cracked paving edges over the entire job.
M 313	1949	163(B)	Asph. Prod.	Project M 37-12-C11 on M20, eastward of west county line in Isabella County. Sampled at Station 419+76, westbound traffic lane, IWP.
M 314	1949	171(S)	Asph. Prod.	Same as above except sample was obtained from between wheel paths.
M 315	1949		Asph. Prod.	Same as above except sample was a composite of map-cracked edges taken over the length of the project.
M 316	1949	167(S)	Lion	Project M 14-35-C2 on M62, west of Dowagiac. Sampled at Station 161+04, westbound traffic lane, IWP.
M 317	1949	163(B)	Lion	Same as above but from between the wheel paths.
M 318	1948	113(B)	Am. Lib.	Project CS 11-68-C2, Berrien County, Sodus to Eau Claire. Sampled at Station 313+10, eastbound traffic lane, IWP.
M 319	1948	114(S)	Am. Lib.	Same as above except sample obtained from between wheel paths.
M 320	1948	115(B)	Am. Lib.	Same as above except sample obtained from Station 437+10, eastbound traffic lane, IWP.
M 321	1948	111(S)	Am. Lib.	Same as for M320 except sample obtained from between wheel paths.

SAMPLE INDEX (continued)

Sample No.	Year Const.	Asphalt Pen	Asphalt Source	Place of Sampling
M 318a	1949	93(S)	Lion	Project MCS 11-68-C3, Berrien County, Sodus to Eau Claire. Sampled at Station 184+80 (equals 313+10 of preceding project), eastbound traffic lane, IWP.
M 319a	1949	93(S)	Lion	Same as above except sample obtained from between wheel paths.
M 320a	1949	111(S)	Lion	Same as above except that sample obtained at Station 308+72 (equals 437+10 of preceding project), eastbound lane, IWP.
M 321a	1949	111(S)	Lion	Same as for M320a, except that sample was obtained from between wheel paths.
M 322	1949	168(B)	Lion	Project M23-30-C2 on M50, northwest of Charlotte. Sampled at Station 876+12, southbound traffic lane, IWP.
M 323	1949	161(B)	Lion	Same as above except that sample obtained from between wheel paths.
M 324	1952	159(B)	Am. Lib.	Project S 76-30-C4 on M47, south of Perry. Sampled at Station 491+00, northbound traffic lane, IWP.
M 325	1952	159(S)	Am. Lib.	Same as above except that sample was obtained from between wheel paths.
M 326	1950	158(S)	Lion and Std.	Project 81-69-C2 on Liberty Road, Washtenaw County, west of Ann Arbor. Sampled at Station 47+61, eastbound traffic lane, IWP.
M 327	1950	158(S)	Lion and Std.	Same as above except sample obtained from between wheel paths.
M 327	1950	158(S)	Lion and Std.	Same as above except sample obtained at Station 103+24 from the center line of the paving.

SUMMATION OF PAVING MATERIAL TEST DATA

The bituminous aggregate paving inspected, sampled, and tested in Michigan consisted of 12 projects involving paving constructed between 1948 and 1952 in the southern peninsula. Samples M300 to M328, inclusive, a total of 33 samples, were obtained.

Bituminous aggregate paving similar to the mixtures used in the western states, using penetration grade asphalt, was not extensively used in Michigan prior to 1948, and these 12 projects represent the majority of this type laid between 1948 and 1952 in which a single source of asphalt was used. Pertinent information relative to the paving mixtures, asphalt content, properties of the paving, and asphalt test data are presented in Table No. 1, this appendix.

In order to introduce the discussion of Michigan paving and to provide a basis for comparison, the data have been averaged and maximum and minimum values shown. These values are from tests on the paving samples. Twenty-seven of the paving samples were obtained from paving regarded as satisfactory. Six were taken from paving regarded as defective. The two groups are separated in the following table. The summary of the averaged results will be tabulated in a later table to indicate the characteristics of paving built in accordance with Michigan practice.

MICHIGAN BITUMINOUS AGGREGATE PAVING

Gradation of the Aggregate	Ret. No.10 %	P10-R200 %	P-200 %	% Crushed Ret. No.4	% Rcvd Asph	Theor. S.G.	Act. S.G.	Voids Pavg	Voids M.A.	Voids Filled % AC
Normal Appearance and Performance—Average of 27 Samples										
Avg	47.2	39.8	7.9	59.2	5.3	2.490	2.360	5.24	17.44	70.3
Max	52.1	45.0	9.4	99.2	6.0	2.528	2.407	8.59	20.10	79.01
Min	42.7	34.8	6.0	36.7	4.8	2.460	2.287	3.29	15.41	57.26
Defective Appearance and Performance—Average of 6 samples										
Avg	45.3	44.7	5.6	54.7	4.3	2.527	2.198	12.96	22.31	42.68
Max	50.5	51.8	8.5	85.1	5.5	2.548	2.320	16.13	24.27	65.50
Min	39.3	36.5	3.8	39.6	3.4	2.486	2.137	6.68	19.36	30.50

The six defective paving samples consist of two made up of fragments from map-cracked paving edges and four from paving laid in 1949 which was deficient in asphalt, low in density, and which raveled badly immediately after being laid. It is believed that the asphalt was not directly responsible for the adverse paving condition on these projects. It is quite apparent that paving composition, inadequate compaction and subgrade support contributed materially to the adverse changes in the asphalt.

Information relative to the asphalt is presented with the specific data for each project and its performance is correlated and discussed with respect to the averaged paving composition and properties appearing in the foregoing table.

In general, all the normal Michigan paving was quite similar in appearance and performance. The range of gradation of the aggregate was within narrow limits, the percentage of asphalt varied only slightly. Density, voids in mineral aggregate, and voids filled with asphalt were very similar. This close similarity indicates good control of mixture composition and construction.

Project CS 77-73-C2, Marine City Highway
Asphalt supplied by American Liberty Oil Company. Constructed 1950.
ERI paving samples M300, inner wheel path and M301, between wheel paths, as obtained from the westbound traffic lane, Station 496+88.
(Picture Reference 300 to 307.)

This paving was laid to a thickness of approximately 2 inches over old concrete. All cracking was apparently due to faulting of the concrete base. Aggregate gradation closely approached the average, asphalt content was slightly above average, and density was better than average with voids in the paving being the lowest observed in the survey.

The original asphalt penetration was 161 and 163 adjacent to the point of sampling. State records indicated an average drop in penetration to 120 after mixing. Recovered asphalt from the ERI samples had a penetration of 59 for sample M300 and 50 for M301, recovered ductility of 150+ and 82, softening point 125 and 129°F, respectively. The average s. pt./pen. ratio of the asphalt after 4 years service life was 2.315, which is well within the range of such values for asphalts giving satisfactory paving performance. The Oliensis spot test on the original asphalt and the ERI and 15% Xylene-85% Naphtha spot tests on the recovered material resulted in negative spots. There were no detrimental paving conditions on this project which could be attributed to the service performance of the asphalt.

Project M 71-20-C8. U.S. 23 east of M65, Presque Isle County.
Asphalt supplied by American Liberty Oil Co. and the Asphalt Products Company. Constructed 1952.
ERI paving samples M302 and M303, and M304 and M305, respectively represent paving in which asphalt was supplied by these two producers. Samples M302 and M303 were obtained from the inner wheel path and between paths at Station 211+20, and M304 and 305 from the same locations at Station 116+16. All samples were taken from the westbound traffic lane.
(Picture Reference Nos. 308 to 312.)

This paving was laid to an approximate thickness of 2-1/4 in. over gravel base. The paving surface was in excellent condition, with no visible cracking in the interior or edge sections. Edges were in perfect alignment. In all samples the paving density was slightly below average for normal Michigan paving. The aggregate gradation was slightly finer than average, asphalt content slightly higher, approximately 1% more voids in the paving, and normal voids in mineral aggregate with voids filled with asphalt were approximately 2% less than average.

With reference to the original asphalt supplied by the American Liberty Oil Company and used at the point of sampling, the penetration was approximately 149. State records indicate an average drop in penetration to 109 after mixing. Recovered asphalt from ERI samples M302 and M303 had an average penetration of 64. The average softening point was 122°F. The resultant s. pt./pen. ratio of the asphalt after 2 years of service life was 1.909, indicating a value well within limits observed for satisfactory performance. The Oliensis spot test on the original material was negative, and the ERI and 15%-85% xylene and naphtha tests showed the same result on the recovered asphalt.

The original asphalt supplied by the Asphalt Products Company was 161 penetration. State records indicate a penetration drop after mixing to an average value of 101. Recovered asphalt from ERI samples M304 and M305 had a penetration of 60. The average softening point was 124°F. The resultant s. pt./pen. ratio of the asphalt after 2 years of service life was 2.073, which is well within the range for satisfactory performance, although slightly higher than that of the American Liberty Oil Company asphalt. The Oliensis spot test on the original material was negative, and both the ERI and 15% xylene-85% naphtha tests showed the same results on the recovered material.

Project SS 57-11-C5. M66 south and east of McBain.
Asphalt supplied by Lion Oil Company. Constructed 1952.
ERI paving samples M306 and M307 obtained from inner wheel path and between wheel paths, respectively, of the southbound traffic lane, Station 1162+85.
(Picture Reference Nos. 313 to 315.)

This paving was laid to a thickness of approximately 3 in. over gravel base. No defects were observed in the paving surface throughout the

project. Aggregate gradation closely bracketed the average for normal paving, the filler content being 1.5 to 2.0 percent lower. The asphalt content was normal and the paving density slightly above average, with lower voids and slightly more asphalt by volume.

The original asphalt penetration was 159 as used adjacent to the point of sampling. State records indicate an average penetration of the recovered asphalt after mixing of 117. Recovered asphalt from ERI samples M306 and M307 had an average penetration of 109. The average softening point on the recovered material was 110°F. The resultant s. pt./pen. ratio on the asphalt after 2 years of service was 1.014, indicating very little change under service conditions. The Oliensis spot test on the original material was negative, as was the recovered asphalt when subjected to the ERI and 15% xylene-85% naphtha spot tests.

Project M43-1-C3. U.S. 10 east of Baldwin.
Asphalt supplied by Asphalt Products Company. Constructed 1949.
ERI paving samples M308 and M309 obtained from the inner wheel path and between wheel paths, respectively, of the westbound traffic lane, Station 78+05, at the intersection of U.S. 10 with Gray Road, immediately east of Baldwin.

Rain during inspection prevented the usual picture taking; one was obtained at the site of sampling, (see picture No. 314). This bituminous aggregate paving was placed over old concrete to a thickness of approximately 1 in. It is unusual to find such thin bituminous aggregate paving laid over old, cracked concrete paving, and this undoubtedly contributed to its condition at the time of inspection. Transverse cracks were numerous, apparently being carried through from the old concrete base. There was extensive pitting of the surface, probably due to the soft aggregate. The general appearance of the paving was dry and lifeless. Numerous samples lacked cohesion. Considerable traffic abrasion was observed.

The aggregate gradation as obtained from the samples was almost identical with the average for normal Michigan paving, the asphalt content approximately 0.5 percent low, and density slightly higher, with lower voids and higher percentage by volume filled with asphalt.

The original asphalt penetration was 102 in the paving adjacent to the point of sampling. State records indicate an average penetration of the recovered asphalt after mixing of 50. Asphalt recovered from samples ERI M308 and M309 had an average penetration of 29. The average softening point was 152°F. The resultant s. pt./pen. ratio of the asphalt after 5 years of service life was 5.241. Based on the extensive inspection of paving throughout this survey, this value indicates appreciable change from the original asphalt, although definite information is not available due to the absence of softening point data on the original material. The Oliensis spot test on the original

material had not been obtained; however, both the ERI and 15% xylene-85% naphtha spot tests on the recovered material showed negative.

Project M54-27-C6. M20 east of Remus to Mecosta-Isabella County line. Asphalt supplied by the Asphalt Products Company. Constructed 1949. ERI paving samples M310 and M311 were obtained from the inner wheel path and between wheel paths, respectively, of the westbound traffic lane at Station 132+00. ERI sample M312 is a collection of paving particles taken from the map-cracked edges throughout the length of the project. (Picture Reference Nos. 315 to 319. Picture 318 is of special interest as it shows map-cracked edges.)

This paving was laid over gravel base course to an approximate thickness of 2 in. The general paving condition is quite poor. Extensive map cracking occurs at closely spaced random intervals in the middle section of the paved width, and extensive map cracking extends inward from the paving edge for a distance of 3 to 4 ft. All such failures appear to be due to subgrade or base deficiencies, although such cracking has materially affected the properties of the asphalt. Surface pitting due to the use of soft coarse aggregate is uniformly in evidence throughout the length of the project. Samples picked at random from the paving surface indicate that the mixture is somewhat dry and brittle. In locations where map-cracked paving was removed, the underlying base appeared to be quite friable and sandy, with apparent low density and stability. The aggregate gradation indicates appreciably higher percentage of retained No. 10, less pass No. 10 retained 200, and normal pass No. 200, as compared with the average Michigan normal paving. The percentage of asphalt in the mixture is nearly identical with normal as are densities for samples M310 and M311. Density of sample M312, the composite map-cracked sample, is appreciably less than normal. There is an appreciable increase in voids, voids filled with asphalt and volume of asphalt in the map-cracked composite sample as referred to normal Michigan conditions. The regular samples M310 and M311 are in good agreement in this respect.

The original asphalt penetration averaged 164. State records indicate that the penetration of the asphalt recovered after mixing averaged 98. The asphalt recovered from the regular paving samples, M310 and M311, averaged 68, while that from the composite sample, M312, was only 39. The average softening point on the asphalt recovered from the regular paving samples was 129°F, while that from the map-cracked composite sample was 143°F. The average resultant s. pt./pen. ratios are 1.893 for the regular paving samples and 3.656 for the map-cracked composite sample. The conditions noted on this project indicate that paving breakup, due to inadequate base, contributed greatly to asphalt deterioration by exposing more surface area to weathering action. Even the severely map-cracked paving edges had a s. pt./pen. ratio no greater than that observed in relatively satisfactory paving at other locations covered by this survey. The Oliensis spot test for the original asphalt was not included in the State data; however, both the ERI and 15% xylene-85% naphtha spot tests made on the recovered material showed negative spots.

Project M 37-12-C11, M20 east of west Isabella County line
Asphalt supplied by Asphalt Products Co. Constructed 1949.
ERI paving samples M313, M314, and M315 obtained from inner wheel path, between wheel paths, and composite sample of map-cracked edge were taken at Station 419+76 for the first two and from broken edges throughout the job for the latter. Samples obtained from the westbound wheel path.

No pictures were obtained on account of rain during inspection and sampling. This paving was laid to a thickness of approximately 2-1/2 in. over gravel base. The location of this paving was much better drained than that covered by the preceding project, M54-27-C6. Both these projects were a continuous job in adjacent counties. There is a limited amount of edge cracking at random locations extending inward from the edges approximately 18 in. Pitting of the surface was extensive, due to the prevalence of soft aggregate. There are no marked defects in the paving surface except for numerous transverse cracks, apparently caused by fill settlement or subgrade consolidation. Except where the road traverses low-lying swampy areas, the riding qualities of the paving are very good.

The gradation of the aggregate recovered from the paving samples checks with the normal average for Michigan paving. The percent of asphalt used is closely identical with the normal, although the average density of the three samples is somewhat lower, and particularly so with respect to the material recovered from the broken-edge samples. Voids in the paving and in the mineral aggregate approach the normal maximum while the voids filled with asphalt are nearly 5% less.

The original asphalt used in the paving adjacent to the point of sampling, Station 419+76, westbound lane, had an original penetration of approximately 167. State records indicate that the material recovered after mixing averaged 99 penetration. Recovered asphalt from regular paving samples, M313 and M314, had a penetration of 80 and 61, respectively, an average of 71. The material recovered from the composite failed edge, sample No. 315, shows a recovered penetration of 31. The softening point for the three samples was 123, 132 and 150°F, respectively. The average s. pt./pen. ratio for the regular paving samples was 1.797 and for the composite sample, 4.853. The former indicates satisfactory asphalt, whereas the latter indicates that the material has deteriorated sufficiently to require replacement. It is hardly possible that the map-cracked edge material was damaged during paving operations and the cause of the deterioration of the asphalt may be logically attributed to the increased surface area of the broken paving exposed to weathering action.

No Oliensis spot test data were reported on the original material, but both ERI and 15% xylene-naphtha spot tests indicated the recovered asphalt was negative.

Project CS 11-68-C2. Sodus to Eau Claire, Berrien County
Asphalt supplied by American Liberty Oil Co. Constructed in 1948.
ERI samples M318, 319, 320, and 321 represent typical present paving from two locations. All were obtained from the eastbound traffic lane, the first two from Station 313+10, junction of this highway with Evans Road and the last two in the city of Eau Claire, Station 437+10.
(Picture Reference Nos. 324 to 331.)

This project provides the principal source of defective paving samples, comprising four of the six test results tabulated on the first page of this section. The paving surface was laid to an approximate thickness of 2 in. over a newly prepared base of combined crushed rock and gravel. The paving mixture was processed in a continuous mixer and was reported to have been extremely variable. Either due to erroneous calculation or uncertain mechanical action, the percentage of asphalt used in the initial mixture was unusually low by Michigan standards. Inadequate asphalt, insufficient compaction, and high voids resulted in almost immediate raveling after laying and practically complete breakup during the first winter. In the spring of 1949, a 1-in.-thick resurfacing course was constructed. This paving is described in the section immediately following.

The gradation of the aggregate recovered from the paving samples is quite variable. For M318 and M319 the retained No. 10 sieve material is approximately 7% below normal average, the pass 10-retained 200 is about 11% more and the pass 200 is 3.7% less. The percentage of asphalt is slightly more than 1% less than normal. High voids in the paving, averaging about 15% with only about 36% of the voids filled with asphalt show a very apparent reason for paving failure. Samples M320 and M321 contained aggregate having a gradation with about 2% less of retained 10 mesh, 7% greater of pass 10-retained 200, and 3.4% less pass 200 than normal grading. The percent by weight of asphalt was 1.8% less than normal. The paving was definitely undercompacted, having about 15% voids, of which only approximately 32% were filled with asphalt.

The original asphalt had a penetration of 113. State records indicate that the penetration of the recovered material after mixing was 53. For some unknown reason the asphalt recovered from ERI samples M318 and M319 averaged only 43. The softening point on the recovered asphalt was 138°F. The resultant s. pt./pen. ratio was approximately 3.219, which does not indicate an excessive change, presuming that the ratio of the original material was in the order of 1.00 to 1.50. In contrast, the asphalt recovered from ERI samples M320 and M321 had a penetration of 56 with a softening point value of 130°F. The resultant s. pt./pen. ratio was 2.326, which is a quite favorable value after more than 6 years of service life. The Oliensis spot tests on the original material were negative as were the ERI and 15% xylene-85% naphtha spot tests on the recovered asphalt. There is little doubt that the immediate application of the resurfacing layer in the spring of 1949 contributed to the preservation of the asphalt in the initial paving, as every opportunity for weathering action would have been available because of the open nature of the paving structure.

Project MCS 11-68-C3, Sodus to Eau Claire, Berrien County.
Asphalt was supplied by Lion Oil Company. Constructed in 1949 as 1-in. resurfacing over the initial raveled paving constructed in 1948.
ERI samples M318a, 319a, 320a, 321a were taken at the same locations as indicated in the report on the preceding project. The stationing of sampling at 184+80 and 308+72, eastbound traffic lane as shown in Table 1, are equivalent to Stations 313+10 and 437+10 in the preceding project.
(Picture Reference Nos. 324 to 331)

Picture 326 shows a measurement of the thin surface layer. The line of demarcation between the respective layers is quite evident. Prior to testing the two layers were separated.

Aggregate gradation and asphalt content closely approach normal Michigan practice. The density is slightly below normal, which may be attributed to the open nature of the initial paving layers which may have failed to provide adequate reaction to rolling.

There is some question about the original penetration of the asphalt. At one location it is reported as 93, believed to be in error, and in the other 111. Penetration on the recovered material after mixing is reported as approximately 88. There is also a difference between the penetration of the asphalt recovered from ERI samples M318a and M319a, taken at Station 184+80, equivalent to Station 313+10 in Project CS 11-68-C2, and from ERI samples M320a and M321a from Project Station 308+72, equivalent to Station 437+10 on project CS 11-68-C2. The former penetration averages 44, whereas the latter average is 54. Approximately the same difference in penetration may be noted in the asphalt recovered at these identical locations from samples 318-319 and 320-321. The reason is not apparent from study of the data.

The original asphalt spot test data was not entered in the State job reports or records. The ERI spot test indicates that the asphalt recovered from samples M319a and 321a were slightly positive and that the other two samples were negative. All were negative when tested by the 15% xylene-85% naphtha solution.

Project M 14-35-C2, M62 from the junction with M40 in Dowagiac then westward a distance of 4.4 miles.
Asphalt was supplied by Lion Oil Co. Constructed in 1949.
ERI samples M316 and M317 were obtained at Station 161+04, from the inner wheel path and between wheel paths, westbound traffic lane.
(Picture Reference Nos. 320 to 323.)

This paving was laid over gravel base to an approximate thickness of 3 in. Random map cracking, practically all confined to the middle portion of the paved width, is present throughout the length of the project. No irregularities were observed at the edges or in the outer wheel path. This unusual condition may be caused by inadequate thickness of the gravel base course in

the central paved area, which sometimes occurs when it is necessary to blade off high crown in the old gravel base course during construction. There is considerable pitting of the surface, due to disintegration of large particles of soft aggregate. Traffic abrasion is quite pronounced at the intersection of M62 and M40, where it is necessary that eastbound vehicles on M62 stop before entering traffic on M40.

The aggregate gradation is approximately 5% below normal for retained No. 10 sieve, 5 to 6% above normal for pass No. 10-retained No. 200, and normal for the pass 200 material. Asphalt content by weight is only 0.2% below normal. Paving density is slightly low, with voids in mineral aggregate approaching maximum for Michigan normal paving.

The penetration of the original asphalt was approximately 165. According to State data, the penetration of the asphalt recovered from the mix at the time of construction was 119 average. Asphalt recovered from ERI sample M316 was 42 and from M317 was 60. This large difference between samples taken in the same location was rechecked, with approximately the same values being obtained. The average penetration value of 51 will be used in this discussion. The average softening point was 126°F. The resultant s. pt./pen. value is 2.466, indicating satisfactory condition of the asphalt based upon field performance criteria employed in this investigation.

No Oliensis spot test results were recorded for the original asphalt. Under the ERI and 15%-xylene-85% naphtha spot tests, the recovered asphalt was negative.

Project M 23-30-C2, M50 northwest of Charlotte.
Asphalt was supplied by Lion Oil Company. Constructed 1949.
ERI samples M322 and M323 were obtained from the southbound traffic lane at Station 876+12.
(Picture Reference Nos. 333 to 335.)

This paving was laid over gravel base to an approximate thickness of 2 in. Map cracking occurred at random locations in the central portion of the paved width throughout the length of the projects. Few limited edges failures were observed.

The gradation of the aggregate obtained from the ERI paving samples and the percent of asphalt by weight were practically identical with the average normal Michigan paving. Paving density and other characteristics were also close to normal standards.

The penetration of the original asphalt was 165. Recovered material after mixing was 115. Asphalt recovered from ERI samples had a penetration of 55. The softening point value was 124°F. The resultant s. pt./pen. ratio for the recovered asphalt from ERI samples is 2.261, which is within a favorable bracket of values and indicates only a minor change with service life.

The Oliensis spot test on the original asphalt and the ERI and 15% xylene-85% naphtha spot tests on the recovered material all resulted in negative spot.

Project S 76-30-C4, M47 south of Perry to the Shiawassee-Ingham County line.
Asphalt supplied by American Liberty Oil Co. Constructed 1952.
ERI samples M324 from the inner wheel path and M325 from between wheel paths were taken from the northbound traffic lane at Station 491+00.
(Picture Reference Nos. 336 to 338.)

This paving was laid on gravel base to an approximate thickness of 2-1/4 in. There was a slight amount of surface pitting due to the breakdown of soft coarse aggregate. Limited edge failures had occurred, extending inward a distance of approximately 6 in. There was some map cracking in the central portion of the paved width, apparently due to base or subgrade difficulty.

The gradation of the aggregate and the percentage by weight of asphalt conformed closely to the average Michigan normal gradation. Paving density was slightly greater than normal.

The penetration of the original asphalt was 159. After mixing, the penetration was 110. Asphalt recovered from ERI samples had an average penetration of 75, and a softening point of 121. The resultant s. pt./pen. ratio is 1.613, which indicates very favorable conditions after slightly more than 2 years of service life.

The Oliensis spot test on the original asphalt as well as the ERI and 15% xylene-85% naphtha spot tests were all negative.

Project 81-69-C2. Liberty Road, Washtenaw County, west of Ann Arbor.
Asphalt was supplied from tank storage at asphalt plant and was presumed to consist of both Standard Oil Co., Baltimore, and Lion Oil Co. material Constructed 1950.
ERI samples M326, from the inner wheel path, and M327 from between wheel paths, were obtained from the eastbound traffic lane at Station 47+61, at the junction of Knight and Liberty Road. Sample M328 was obtained from the approximate centerline of the paving at Station 103+24.
(Picture Reference Nos. 339 to 341.)

This paving was laid over gravel base to an approximate thickness of 2 in. There were no serious irregularities observed over the length of the project.

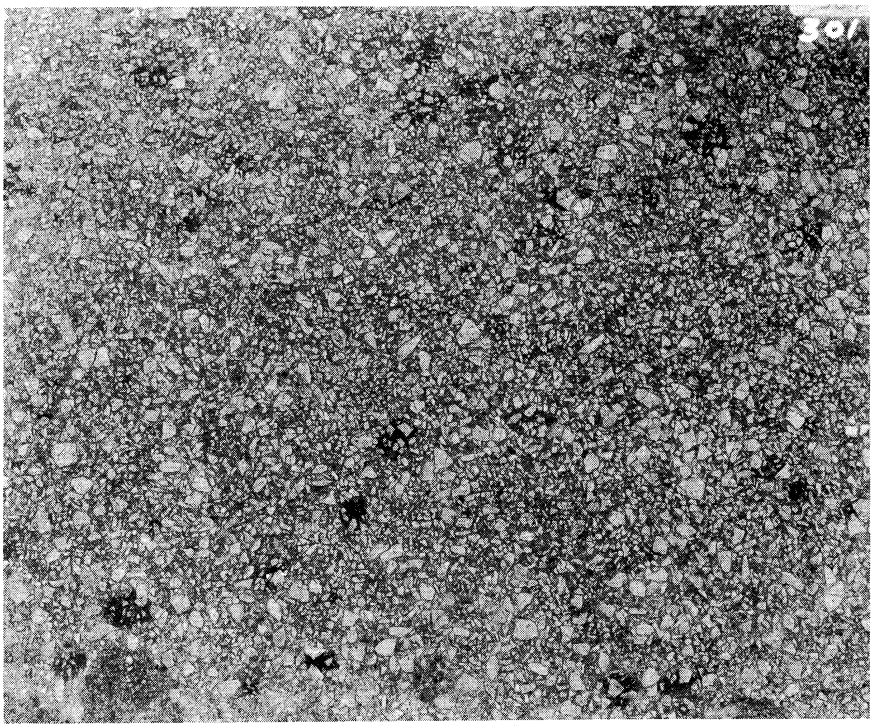
The gradation of the aggregate closely approximates that of the average for Michigan normal paving. The percentage of asphalt by weight is closely

identical. The properties of the paving structure conform to average conditions for normal paving.

Data relative to the original penetration of the asphalt shows a value of 158 and, as recovered from mix at the asphalt plant, a penetration of 110. The penetration of the asphalt recovered from the three ERI samples averaged 87. The average softening point of the recovered material was 117°F. The resultant s. pt./pen. ratio is 1.347, indicating very little change from the normal original asphalt.

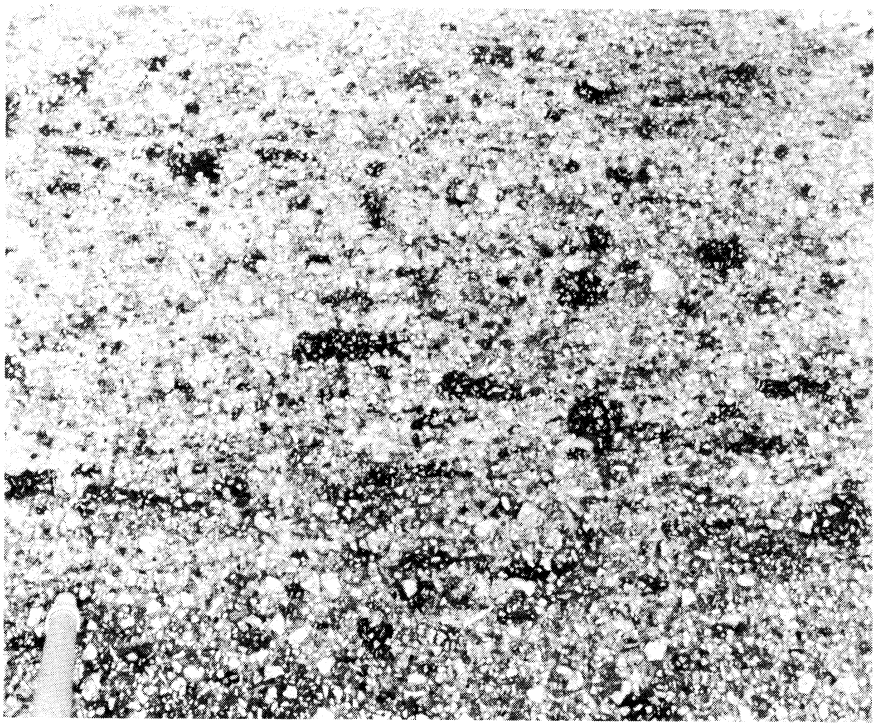
The Oliensis spot test on the original material, and the ERI and 15% xylene-85% naphtha spot tests on the recovered asphalt all gave negative results.

Picture 300. General view of Marine City Highway looking east toward Marine City from St. Clair-Macomb county line highway.



Picture 301. Paving texture in the eastbound traffic lane just beyond the St. Clair-Macomb county line highway. Acceleration of vehicles after stopping at the county line road has produced some abrasion to the surface in the wheel paths.

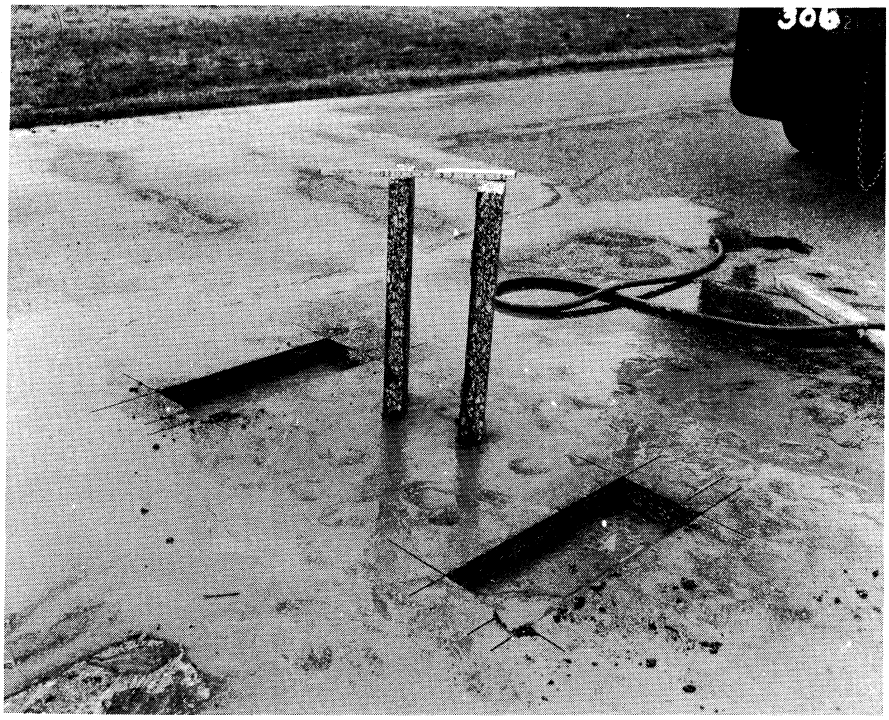
Picture 302. Crack pattern carried through from old underlying concrete paving which is typical throughout project.



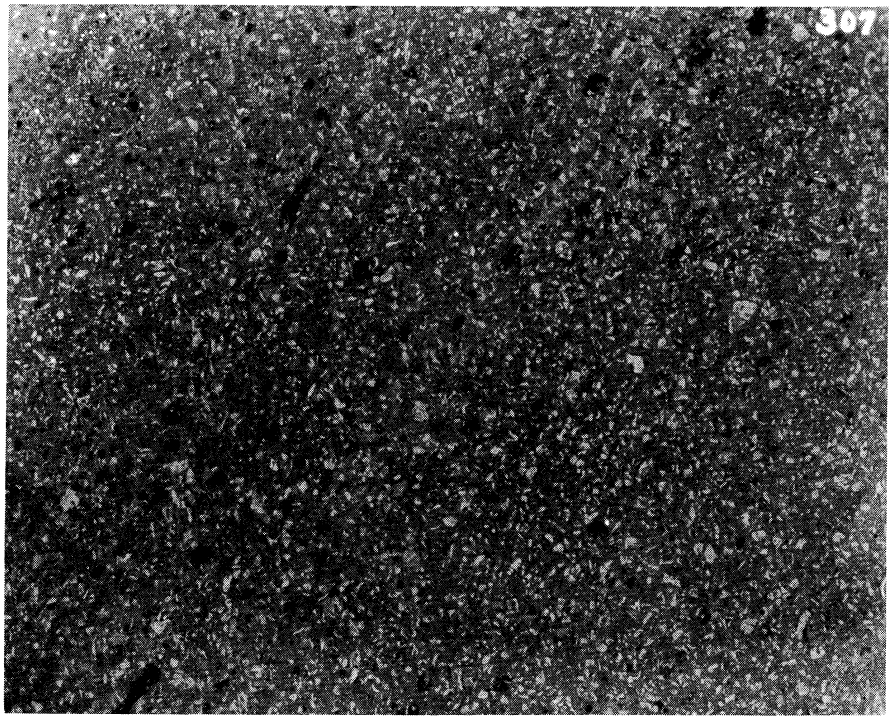
Picture 303. Close-up view of the exposed aggregate in the eastbound wheel paths just east of the stop sign at Macomb-St. Clair county line road. Abrasive action of wheels caused this condition.

Picture 304. Close-up view of typical paving damage at raised joint in the underlying old concrete paving. Appears to have been due to accumulated frost action.

Picture 305. Typical edge patching in the southbound traffic lane.

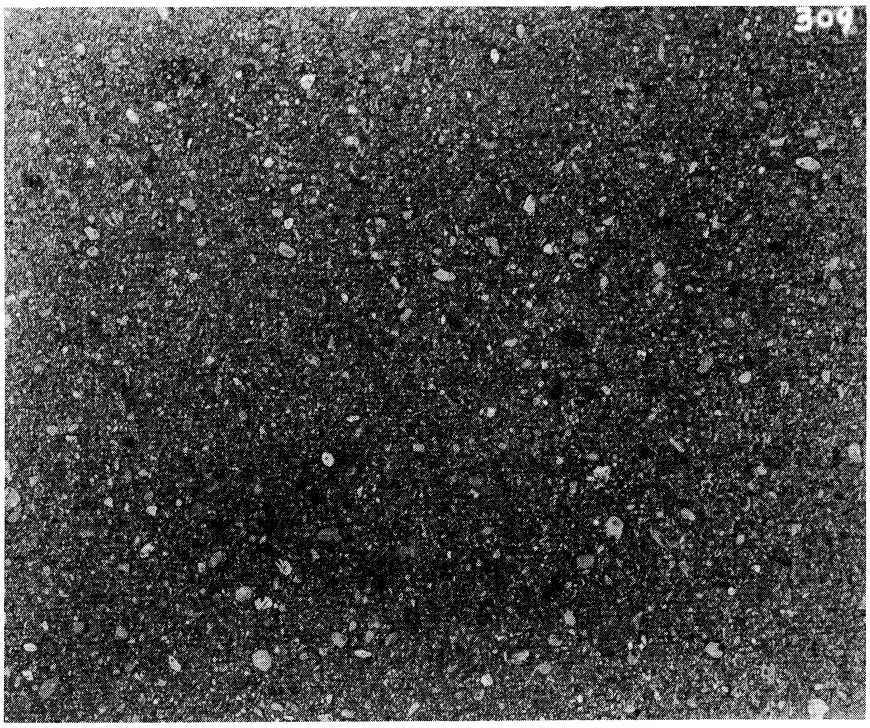


Picture 306. View of paving samples 1 and 2 and the paving cuts from which they were obtained.

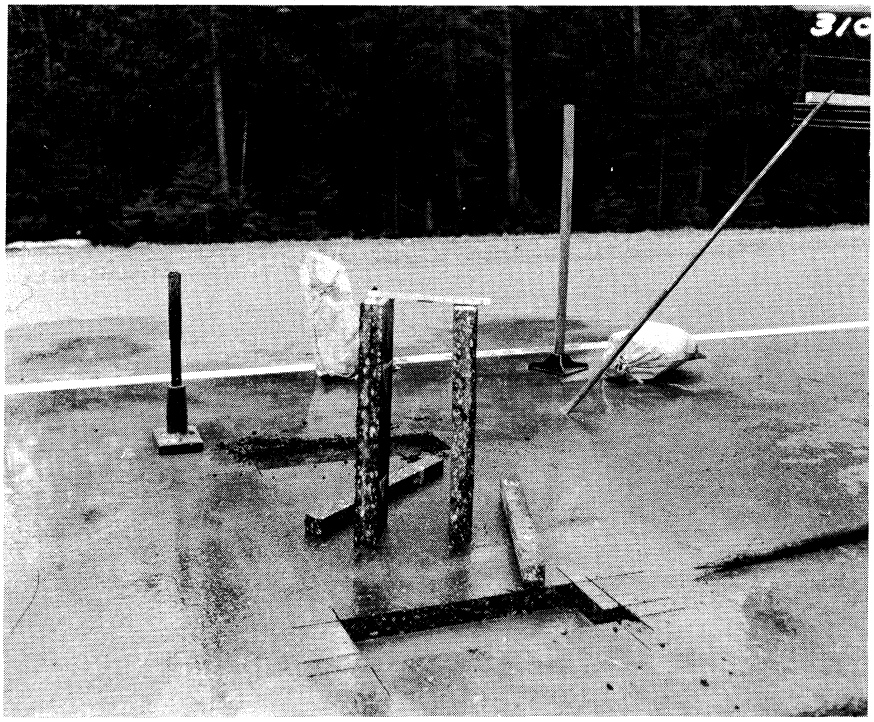


Picture 307. Close-up view of the paving surface at the point of sampling, Station 496+88 in the westbound traffic lane.

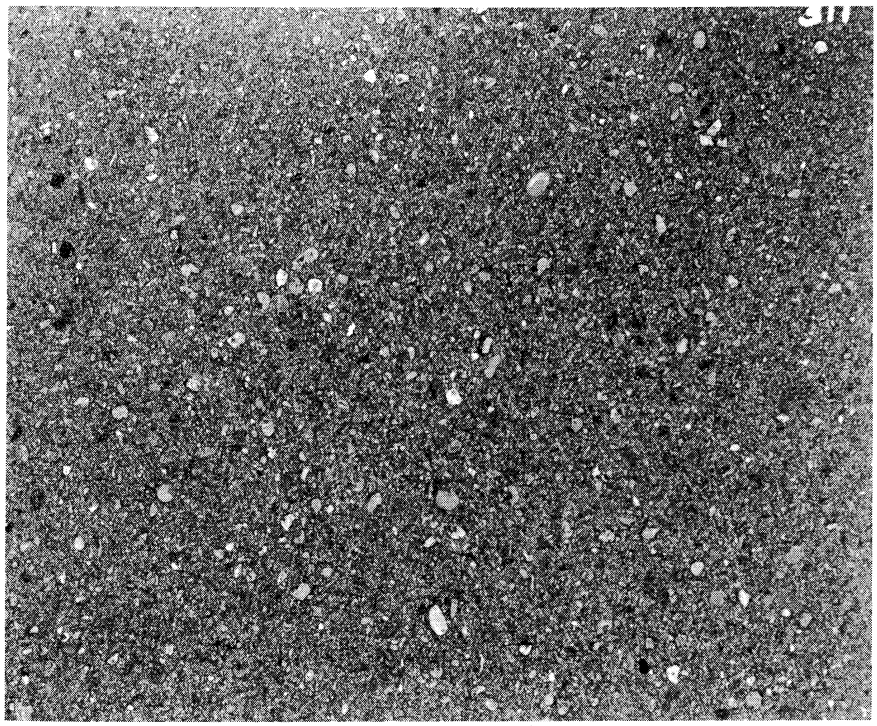
Picture 308. General view of U.S. 23 at the junction with M65, Presque Isle County.



Picture 309. Close-up view of the paving surface at the point of sampling of specimens Nos. 3 and 4.

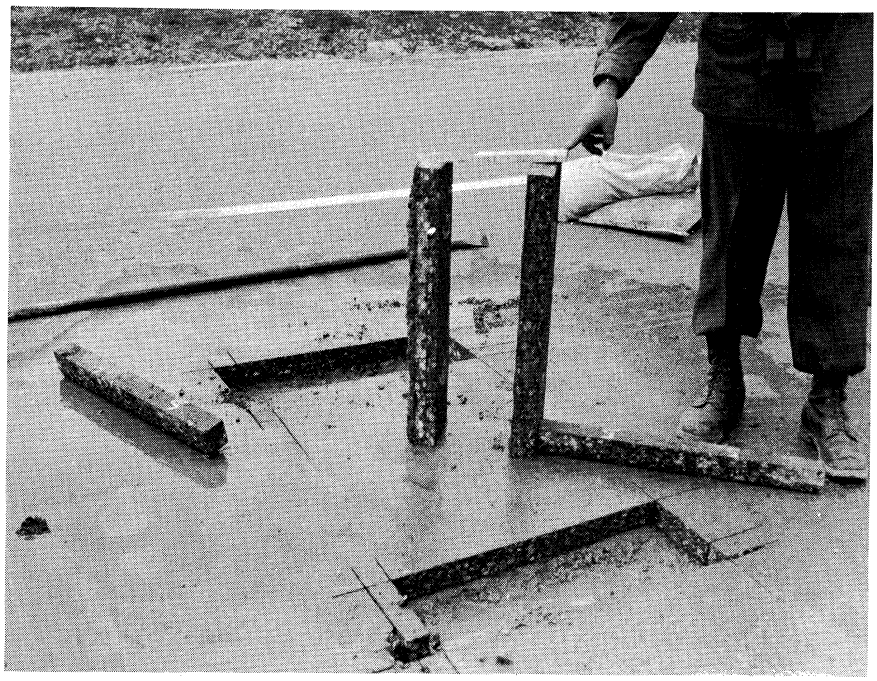


Picture 310. View of samples Nos. 3 and 4, sample cuts at point of sampling of paving made from American Liberty Oil Company asphalt.



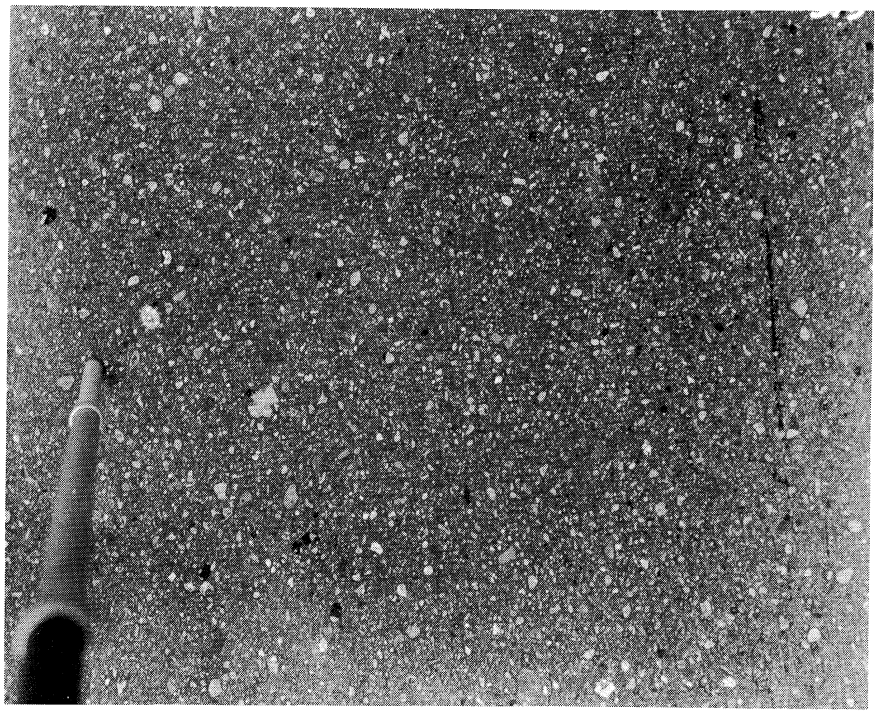
Picture 311. View of the paving surface at site of samples Nos. 5 and 6, made from asphalt obtained from Asphalt Products Company, West Branch, Michigan.

Project M 71-20-C8, U.S. 23, Presque Isle County



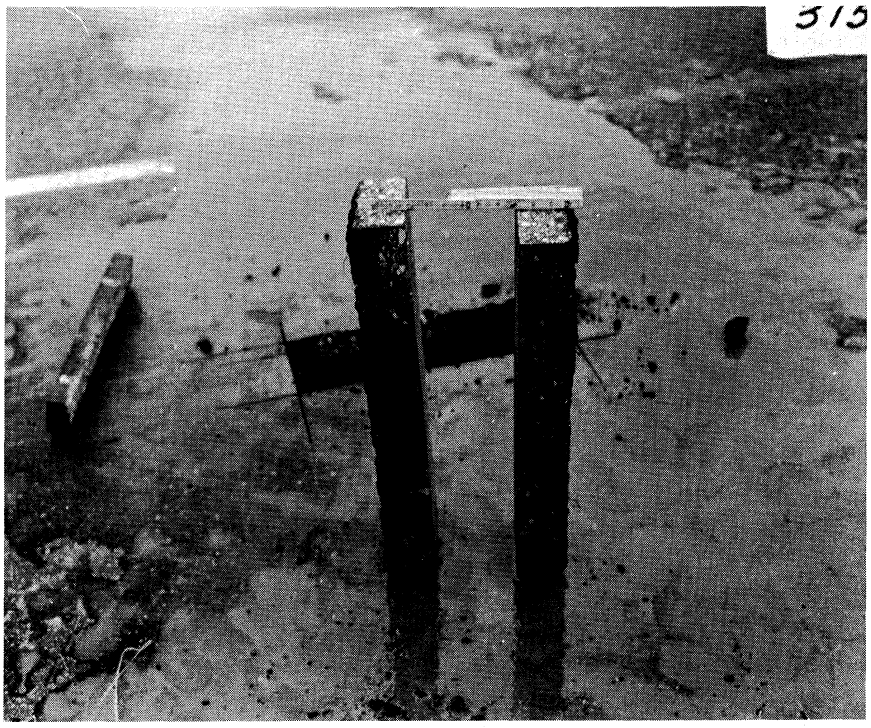
Picture 312. View of paving samples Nos. 5 and 6, taken from the northbound traffic lane 2.2 miles east of junction with M65. Paving made from asphalt supplied by Asphalt Products Co., West Branch, Michigan.

Project SS 57-11-C5, on M66 South of McBain



Picture 313. Surface and paving texture at Station 1162+85, in southbound traffic lane, site of sampling specimens 7 and 8.

Project SS 57-11-C5, on M66 South of McBain

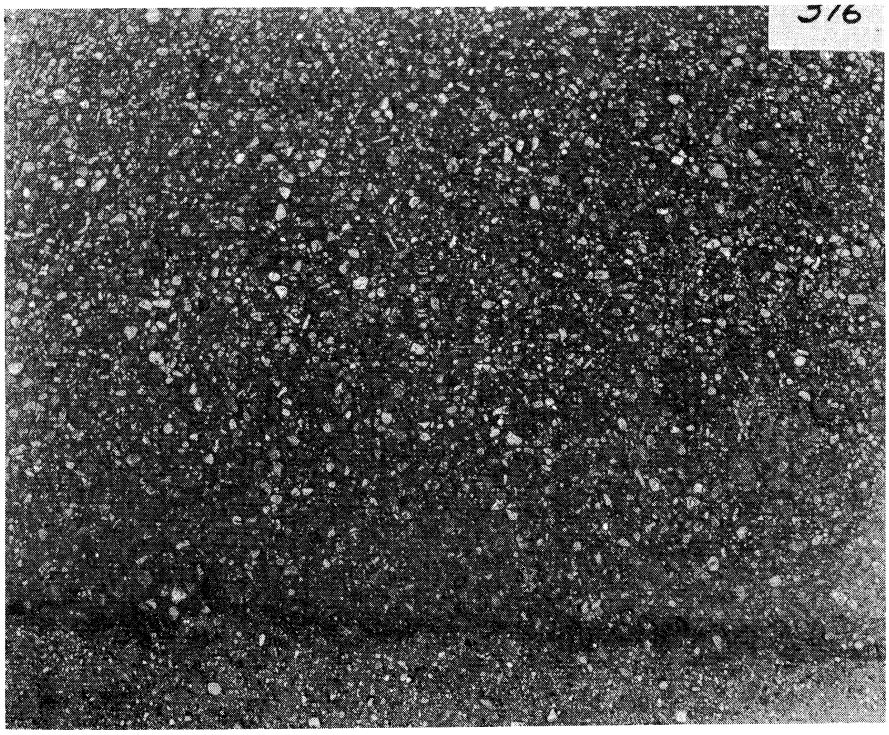


Picture 315. View of samples 7 and 8 and paving cuts from which they were obtained.

Project M 43-1-C3, U.S. 10 East of Baldwin

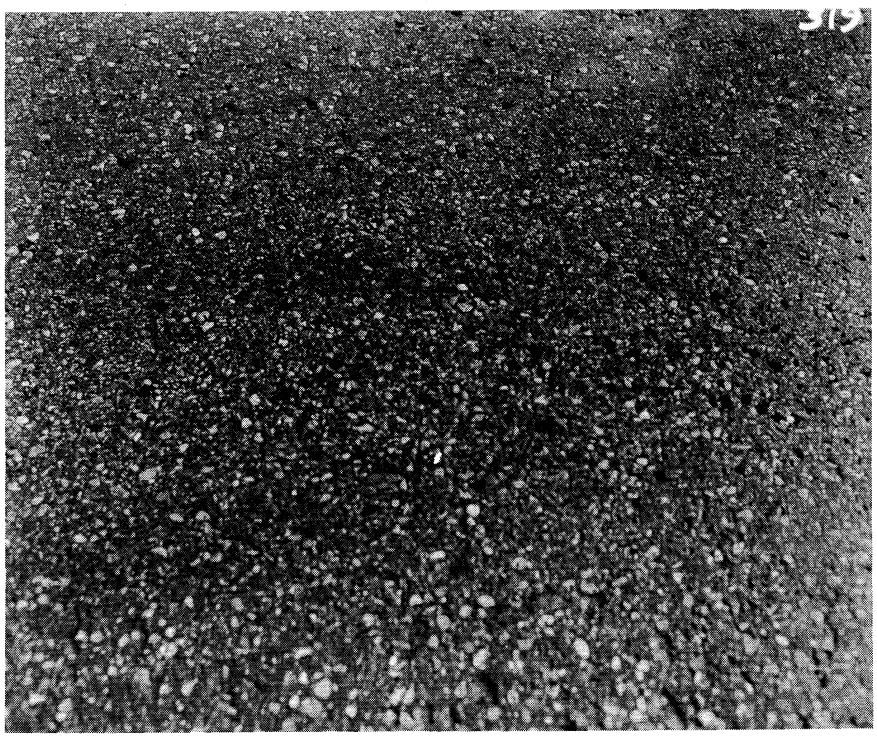
Picture 314. View of paving surface, texture, and patches at location from which samples 9 and 10 were obtained.

Picture 315a. General view of Route M20 at the start of the project, looking eastward toward the Mecosta-Isabella county line.

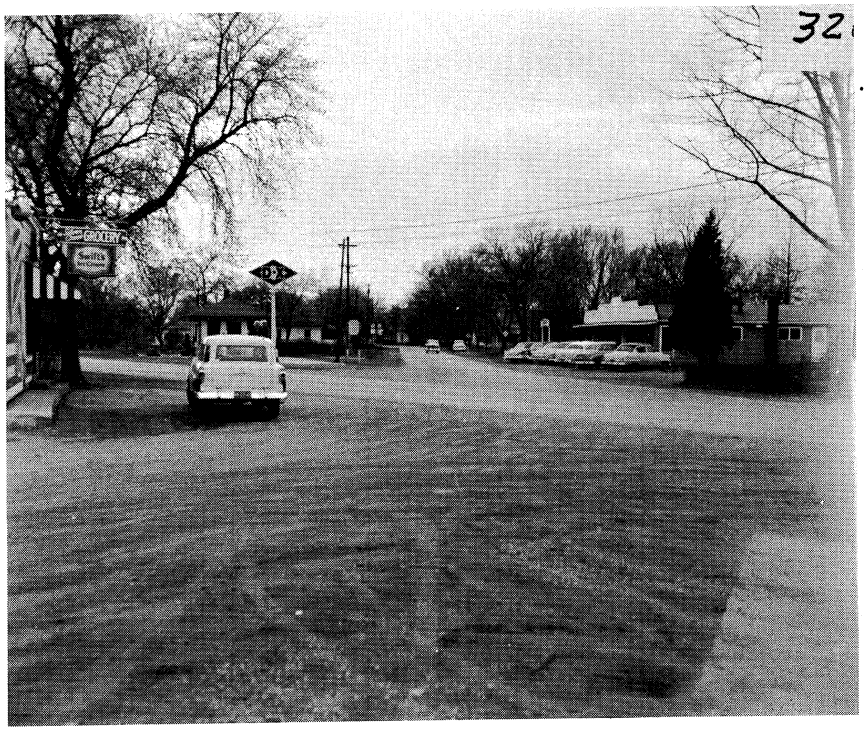


Picture 316. Close-up view of paving surface and texture at the start of the project, Station 0+00.

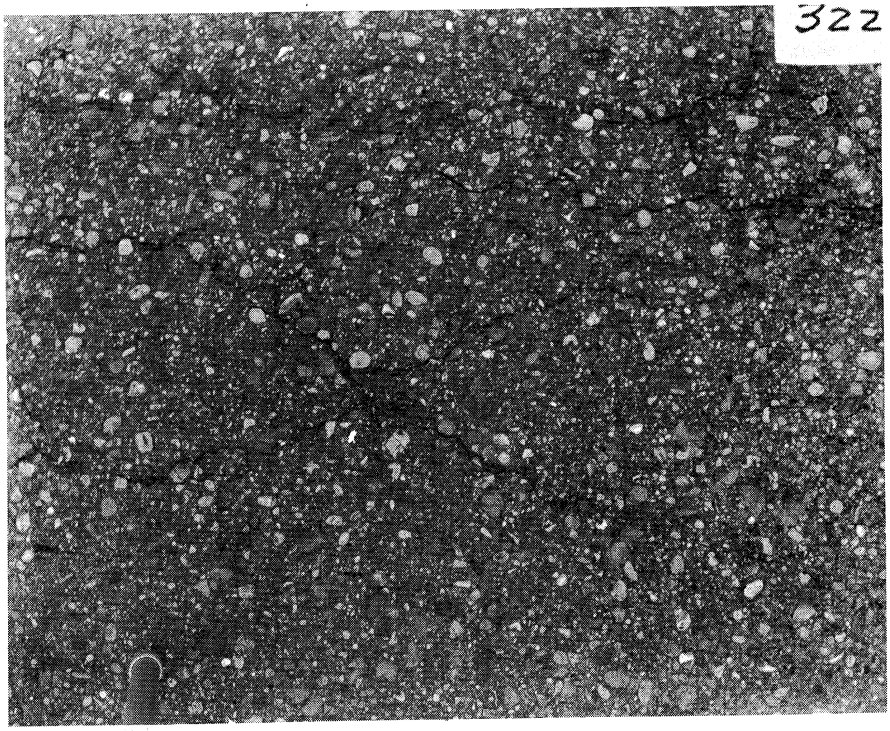
Picture 318. View of typical map cracking occurring at closely spaced random intervals and extending from 3 to 4 ft from the edges of the paving in both traffic lanes. Composite sample from these areas obtained for testing.



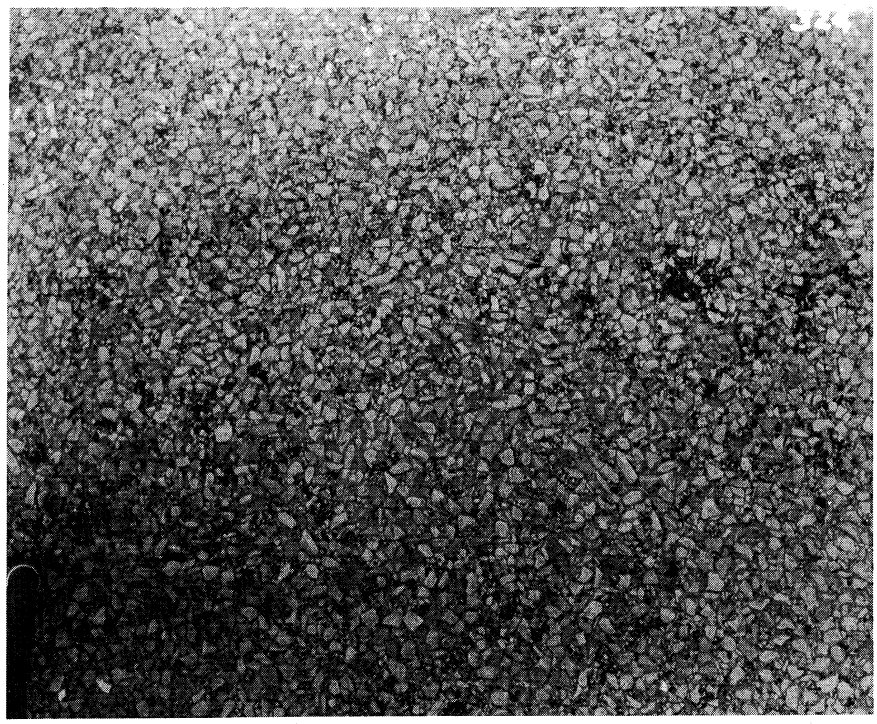
Picture 319. View of typical surface pitting common to the entire project.



Picture 320. General view of M62 at junction with M40 in Dowagiac, Michigan.

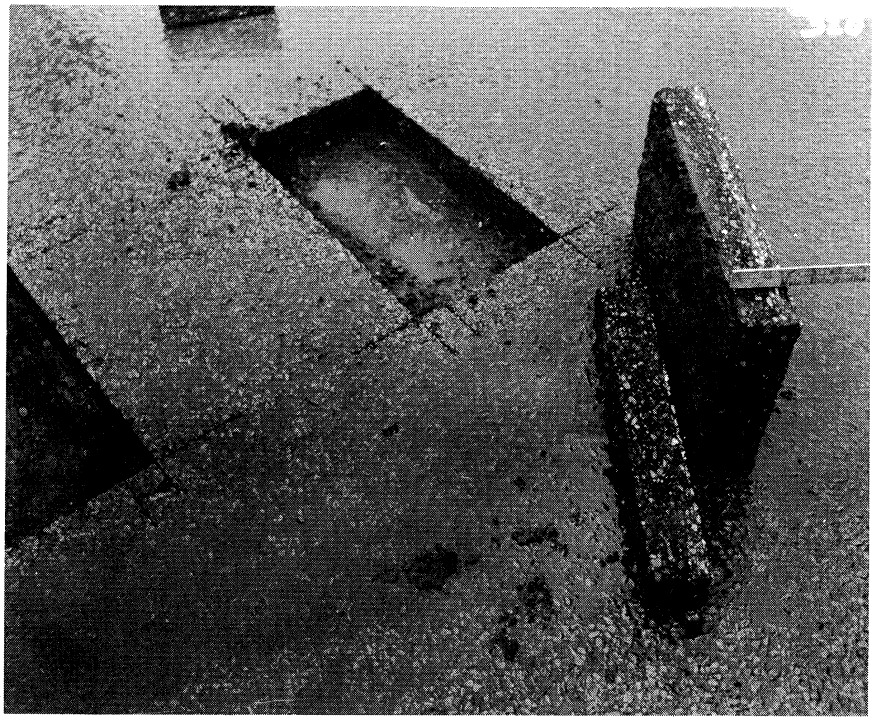


Picture 322. View of typical map-cracked areas located in the middle half of the paving. None evident at edges or rarely in the outer wheel paths.

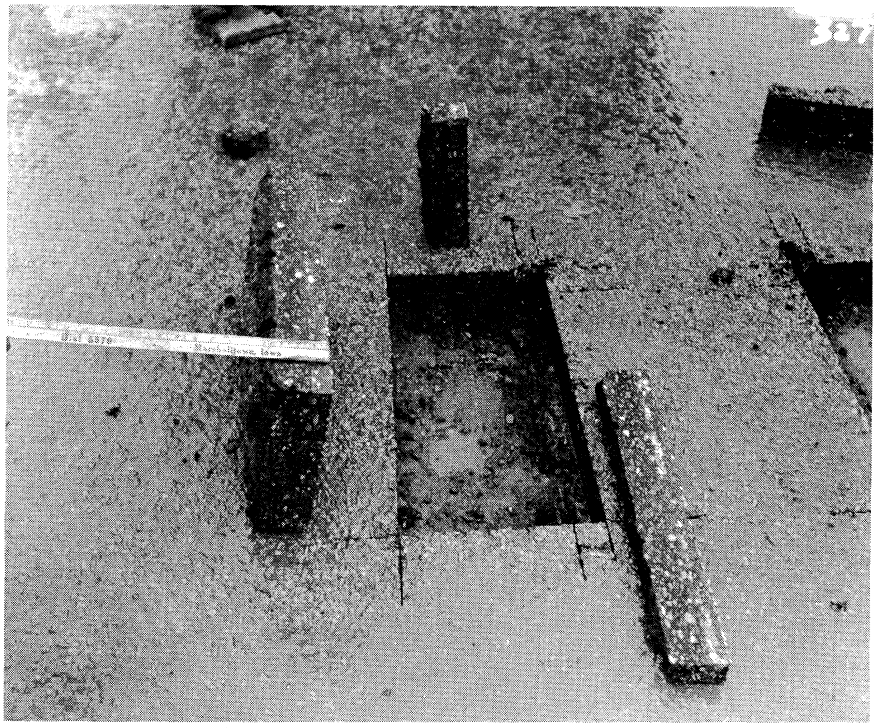


Picture 324. View of typical stone-chip seal coat applied in the fall of 1954 by the county, between Sodus and the west city limits of Eau Claire.

Picture 325. General view of highway looking westward from Evans Road intersection, where samples 17 and 18 were taken.

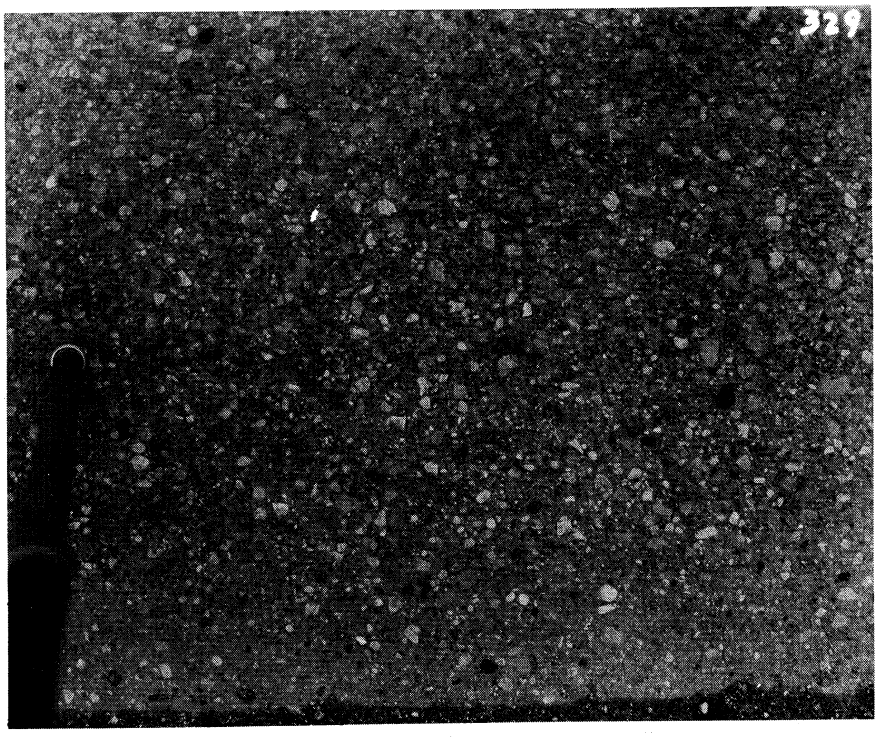


Picture 326. View of sample No. 17 and sample cut. The plane between the original 2-in.-thick original paving, laid in 1948, and the 1-in.-thick resurfacing, laid in 1949, is visible in the view of the sample cross section.



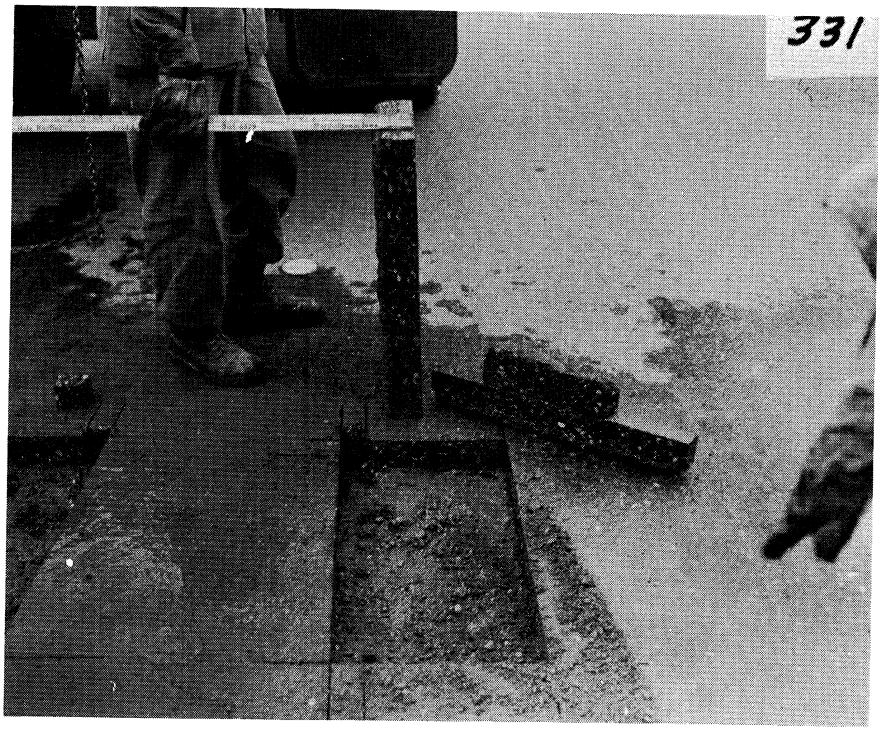
Picture No. 327. View of sample No. 18 and sample cut showing underlying gravel base. The line between the original paving, laid in 1948, and the 1-in. resurfacing, laid in 1949, is readily visible.

Picture 328. View of roadway taken at the west city limits of Eau Claire. In the foreground the paving surface has been stone chipped. In the background, where the color darkens, is the uncovered 1-in. resurfacing laid in 1949.

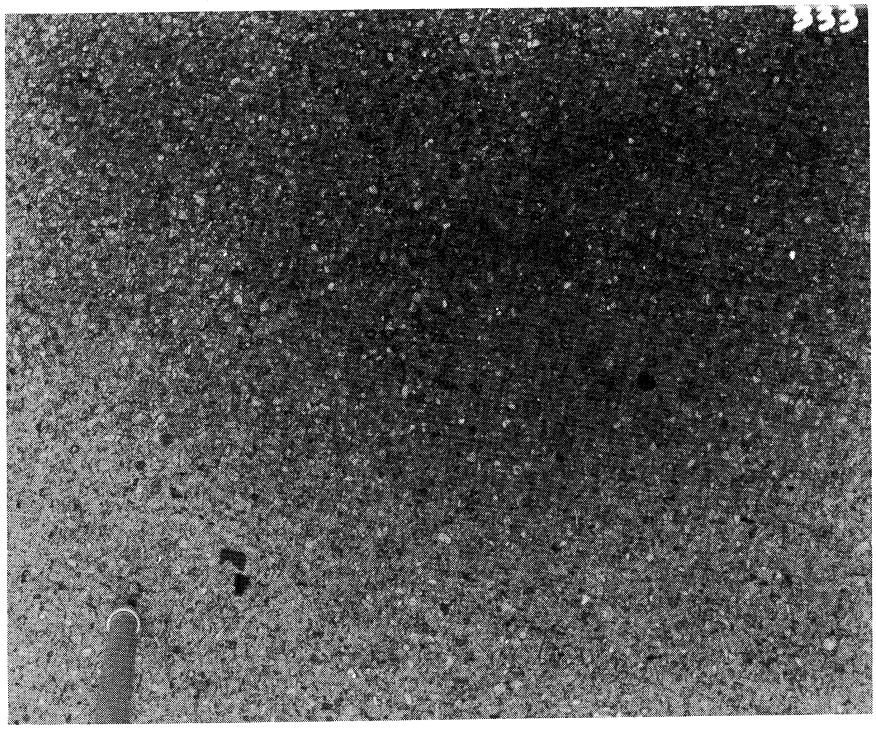


Picture 329. Close-up view of the surface of the 1-in. resurfacing laid in 1949 and still in use within the city limits of Eau Claire.

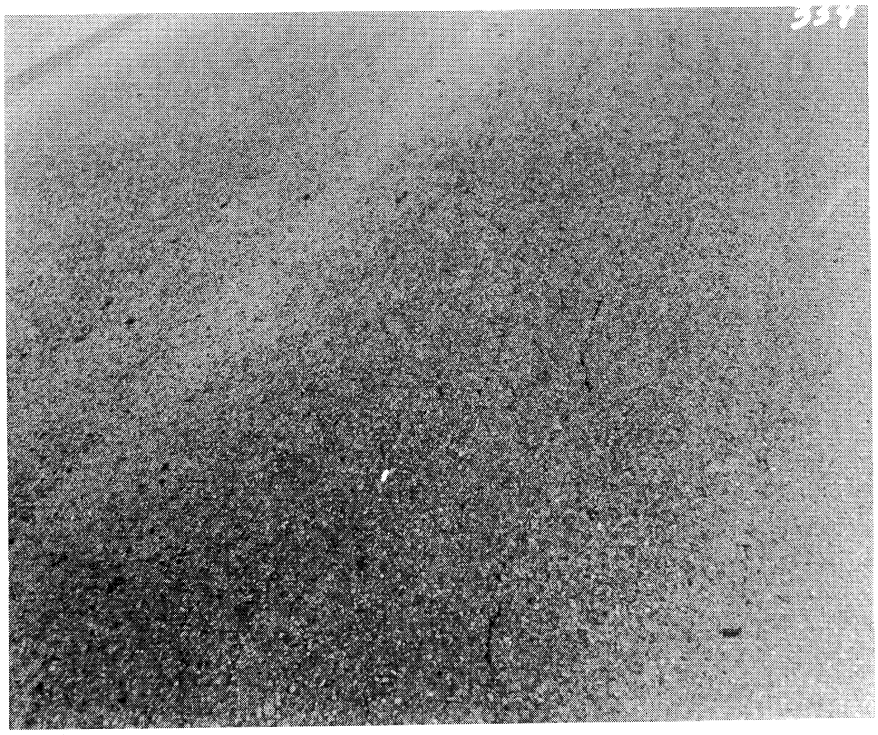
Picture 330. View of sample No. 20, taken from the eastbound traffic lane between the wheel paths at Station 437+40 in Eau Claire.



Picture 331. View of sample No. 19, taken from the inner wheel path of the eastbound traffic lane at Station 437+40 in Eau Claire.

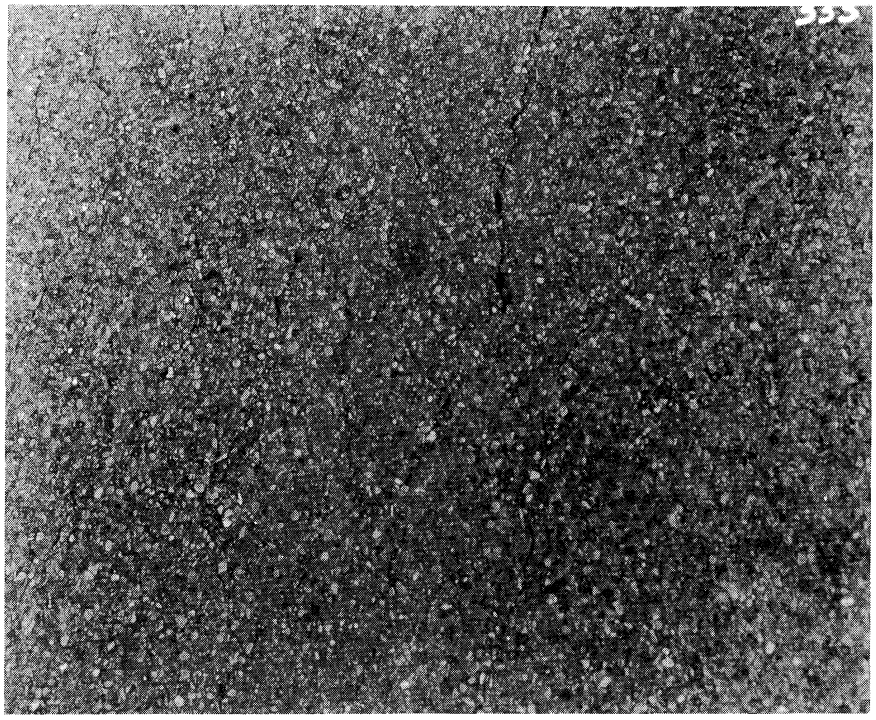


Picture 333. Typical view of the paving surface and texture.



Picture 334. Typical outer-wheel-path map cracking at random intervals, observed in both traffic lanes.

Project M 23-30-C2. M50 Between Potterville Road and Maple Street, Charlotte, Michigan, Eaton County

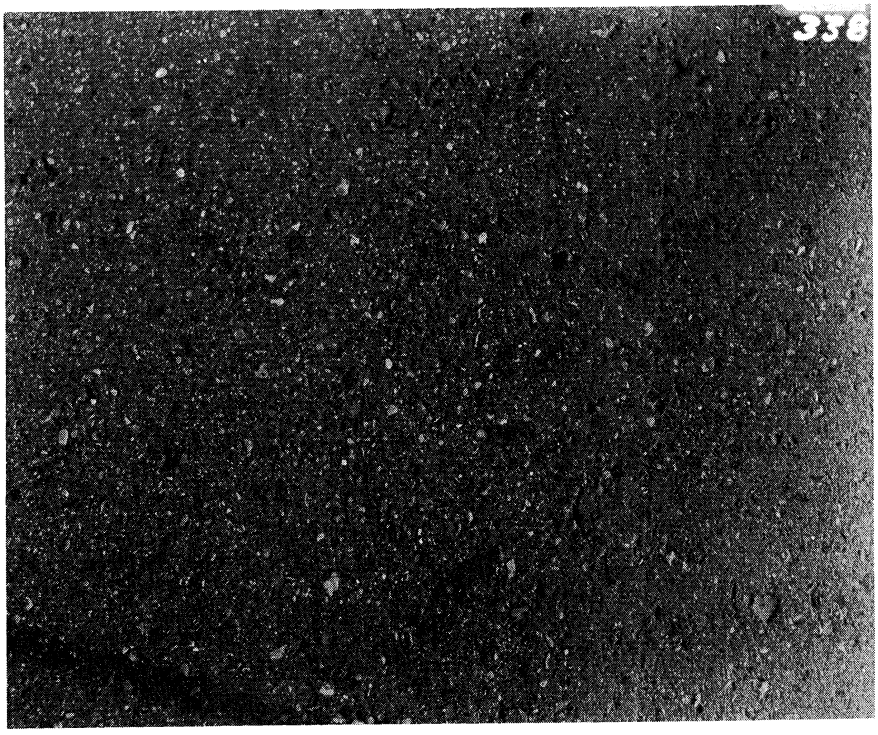


Picture 335. Typical close-up view of map cracking observed at random intervals throughout the length of this project.

Project S 76-30-C4. M47 from Ingham-Shiawassee County Line to Perry

Picture 336. General view of the highway taken at the Ingham-Shiawassee county line, looking northward toward Perry, Michigan.

Picture 337. View of the limited edge cracking observed over the length of the project. This view was taken at 300 ft north of Ingham county line, Lovejoy Road.



Picture 338. View of the typical paving surface. This picture was taken at the point of sampling, Station 491+00, in the northbound traffic lane.

Picture 339. View taken at intersection of Liberty and Knight Roads, the point of sampling for specimens Nos. 25 and 26, showing ERI equipment and State Highway Department personnel who assisted in the sampling operations.

Picture 340. Sample cuts, samples, and masonry saw used to obtain samples.

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