LABORATORY RESEARCH ON MATERIALS USED FOR BITUMINOUS MAT SURFACES

By Harold Allen
Engineer of Materials
AND
W E Gibson
Engineer of Tests, Kansas State Highway Commission

SYNOPSIS

Since 1930, large mileages of sand-gravel or chat roads on the Kansas State Highway system have been treated with oil to form a bituminous mat from 1 to 1 5 in in thickness Difficulties encountered in construction showed the necessity for research on both bituminous materials and aggregates. This paper describes the research undertaken to determine the physical characteristics of mixtures of aggregates and road oil and the effect upon those characteristics of variations in the source of supply of the bituminous materials, the effect of changes in gradation of the aggregates, the relative values of different types of fines, and the results obtained by variations in the amount of road oil used in the mixture

It was found that for best results with the materials in question, 5 to 7 per cent of oil is required and 5 to 15 per cent of the mineral aggregate must pass a 200 mesh sieve The percentage of asphaltic oil soluble in carbon tetrachloride was found to be an important index of quality, and the ductility test at 77 F on 15 to 25 penetration residue was found to be a better indication of quality than on 100 penetration Viscosity should be determined at constant temperature and the size of the orifice should be such that the time will fall between 40 and 400 seconds

INTRODUCTION

Prior to 1930 a large portion of the State Highway System of Kansas was surfaced with sand-gravel or chat Sand-gravel consists of sand having a fineness modulus of 4 00 or more. Chat consists of the tailings from the zinc and lead mines of southern Kansas, and has about the same gradation as sand-gravel These materials were windrowed along the shoulder of the road and spread over the surface by means of patrol graders as needed

Public demand made it necessary to develop road surfaces which were free from dust in dry weather and from sloppiness in wet weather The efforts to develop such a surface resulted in bituminous mats and related types. The one finally developed as most practical for our conditions and finances consisted of a mixture of aggregate and road oil placed on the road surface to form a mat one to one and one-half inches in thickness, hence the name bituminous mat surface

The aggregates for the mats are the dense graded type and due to local conditions must be built up by using three and sometimes four materials of different gradations The coarse material consists of sand and gravel, chat or crushed stone, and the fines or material passing the 200 mesh sieve consist of volcanic ash, river silt, chat sludge or limestone dust Top soil was used in the early construction but due to mechanical difficulties involved in pulverizing it was abandoned

The bituminous materials consist of road oil which is a residual product of the refineries located in Kansas and neighboring states

The difficulties encountered in the first year of construction showed the necessity for research on both bituminous materials and aggregates It was thought to be necessary to determine the physical characteristics of mixtures of aggregate and road oil and the effects upon those characteristics of variations in the source of supply of the bituminous materials, the effects of changes in gradation of the aggregates, the relative values of different types of fines, and the results obtained by variations in the percentage of road oil used in the mixture Verification of the formula used for calculating the quantity of bituminous material necessary in a mat surface was also deemed important

INVESTIGATIONS OF MIXTURES

With these needs in mind, tests were started to get some information on road oil and aggregate mixtures which could be used as a guide in future construction work After preliminary experiments, the swell, stability and impact tests were chosen as most suitable for the work which we wished to do

The swell test specimen was made by placing 160 grams of the mixture of oil and aggregate in a cylindrical mold $2\frac{3}{8}$ in inside diameter and compressing it under a load of 2000 lb per sq in This amount of material produced a cylinder one inch in thickness and $2\frac{3}{8}$ in in diameter. The piston end of the mold was sealed with wax and the specimen and mold immersed in water after a zero reading was taken on an instrument which recorded to one ten thousandths of an inch (See Fig 1) The specimen was removed from the water at the end of 24 hours and the swell recorded in inches The bituminous mixture was then removed from the mold and a water extraction made to determine the absorption The apparatus for the swell test, used by the United States Bureau of Public Roads (Fig 2) consisted of a heavy brass mold four inches inside diameter and having a $\frac{9}{16}$ in wall The material was compressed in the mold by means of a piston A perforated cap and screen was placed over the end opposite the piston after the specimen was molded The mold was then immersed in water at 70°F to such a depth that the surface of the water was $1\frac{1}{2}$ in above the top of the specimen This method approximated field conditions presuming that the water came up through the material in the same way that it would on the road surface.

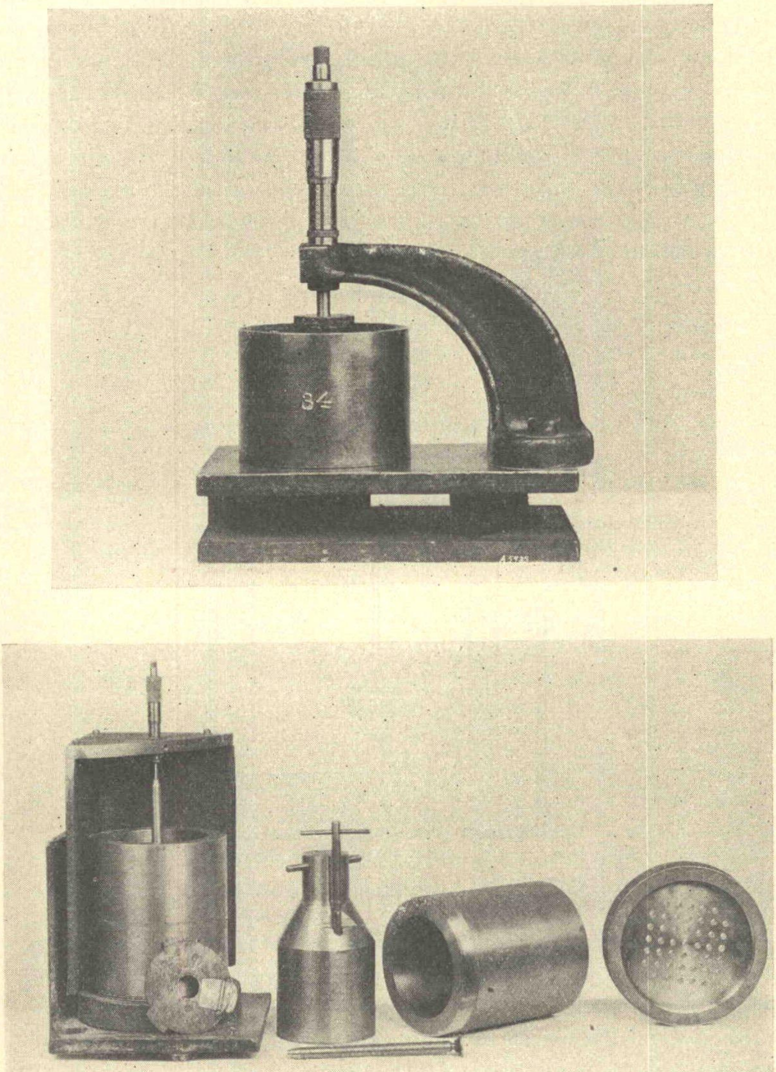

Figure 1. Apparatus for Making Swell Test

The stability test was made by forcing a compacted bituminous mixture through an orifice of given diameter and recording the load necessary to cause complete failure. (See Fig. 3). A specimen $2\frac{3}{8}$ in. in diameter and one inch thick was used for this test. The orifice used was $1\frac{3}{4}$ in in diameter and was tapered out to a thin edge The specimen was molded by placing 160 grams of the bituminous mixture in a cylinder and compressing it under a load of 2000 lb per sq in The solid plate was then removed and the orifice plate and collar or drum were placed in the testing machine on the end of the cylindrical mold. The load was then applied to failure This test was only partially successful, since it was found that aggregates larger than the four mesh sieve caught on the edge of the orifice and the test then measured the shearing strength of the aggregate and not the stability of the mixture. The results of the early tests were erratic, but after the material above the No 4 sieve was removed the results for the sand mix and oil were fairly constant

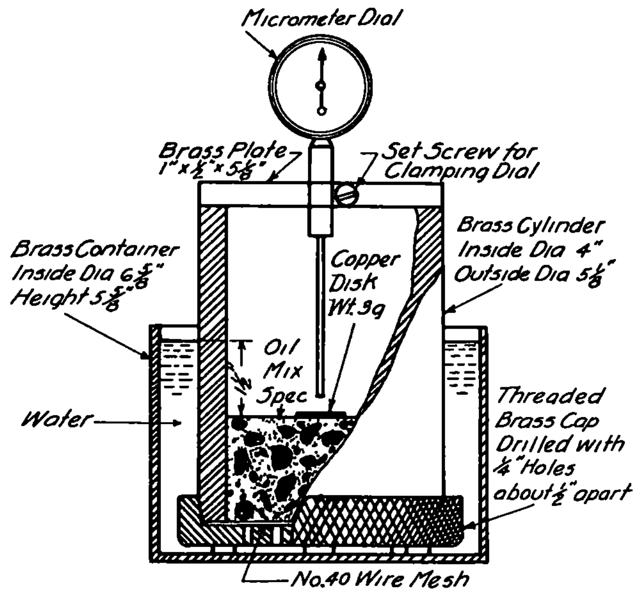

Figure 2. Apparatus for Swell Test

The impact test was made on a cylindrical specimen $2\frac{3}{8}$ in in diameter and one inch in height (See Fig 4) The specimen was made by molding the material under a pressure of 2000 pounds per sq in The specimen was then placed in a standard Page impact toughness machine between two $\frac{3}{4}$ in. plates and the hammer allowed to fall with an increasing drop of one centimeter per blow The height of the hammer for the blow causing failure was recorded as the "impact" Failure was the point at which the first flake or chip sloughed off of the specimen or the deformation exceeded 0 4 in This test has proved very satisfactory and is a very good method for measuring the stability and resistance to impact of bituminous mixtures. In the investigation of the New Mexico formula for amount of oil (Series 5) the deformations were measured.

In addition to the above tests, the percentage of voids and the percentage of absorption of the compressed bituminous mixtures were determined from the data recorded in making the impact and swell tests.

The percentage of absorption was obtained by extracting the water as described in "Standard Methods of Test For Water In Petroleum

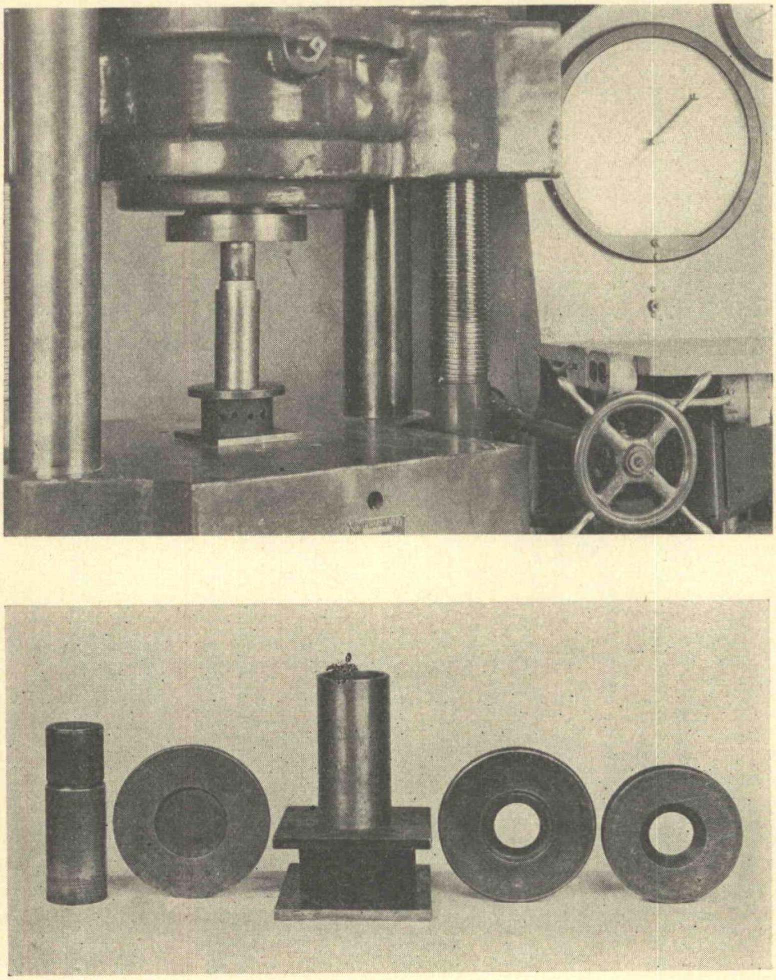

Figure 3. Apparatus for Stability Test

Products and Other Bituminous Materials" A. S. T. M. Designation D 95–30. The percentage of voids was calculated from the absolute volumes of the materials used in cylinders $2\frac{3}{8}$ in. in diameter and one inch in height. The swell test, stability test, impact test, and absorption test were all made at 70°F. plus or minus 5°F.

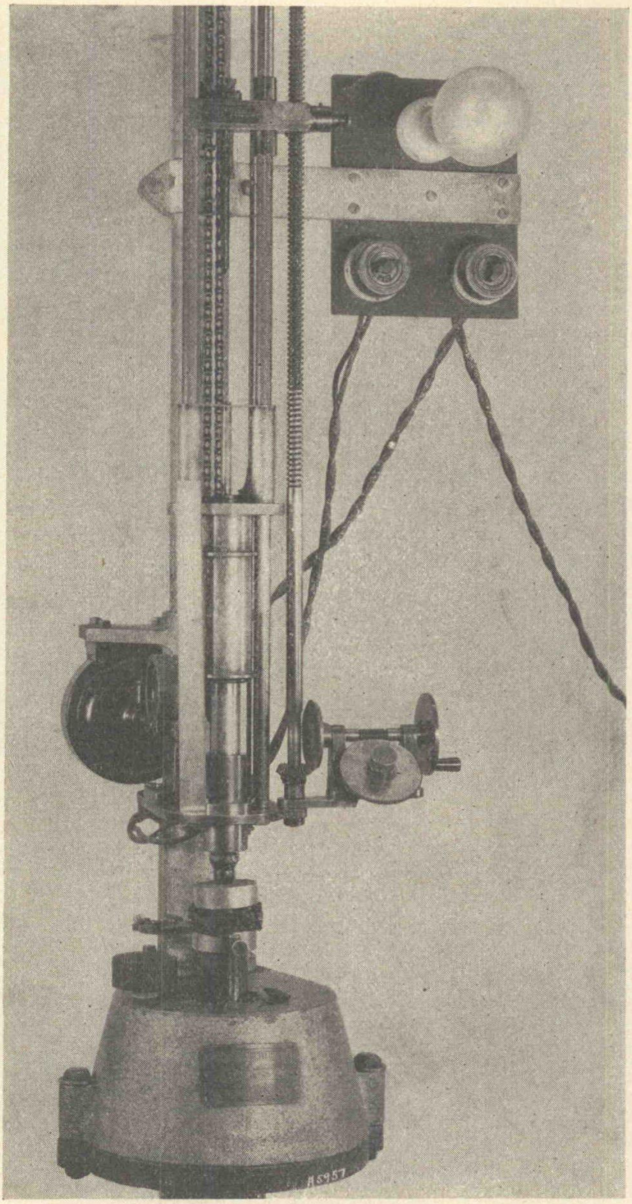

Figure 4. Impact Test

The following combinations of aggregates and oils were chosen as the most likely to give the information desired:

Series 1. Oil content and gradation of aggregate constant. Brand of oil and type of fines variable.

Aggregate—Uniformly graded.

Oil Content—5 and 6 per cent by weight.

Types of Fines

1 Rock Dust 4 Chat Sludge
2 Cement 5 Silt
3 Silica 6 Top Soil

Each brand of oil was combined with each type of fines Six per cent of oil was not used for 60–70 oil

Series 2 Oil content variable with the gradation of aggregate and type of fines constant

Series 3 Percentage of fines variable and gradation of aggregate above the 200 mesh sieve uniform on each sieve Oil content was calculated from the New Mexico formula

TABLE I

CHARACTERISTICS OF ROAD OILS SUBMITTED FOR INVESTIGATION OF MIXTURES—1931

Source of Oil	Specific Gravity at 77°F	Flash C O Deg F	Viscosity		Solubility %		Insoluble in 86° API Naphtha %	Water Sediment %	Loss 50–5–325 %	100 Penetration Asphaltic Residue %	Ductility Cm 77°F
			Saybolt 122°F	Furol 210°F	In CS_2	In CCl_4					
					60–70 Per cent Asphaltic Residue						
A	1 0076	295	148	18 5	99 887	99 705	12 197	0 8	4 801	67 70	100+
B	1 0425	285	103	15 0	99 656	99 915	12 674	0 3	3 666	63 50	100+
C	1 0400	305	129	15 0	99 800	99 633	23 140	0 3	3 309	67 10	100+
D	1 0193	300	138	16 0	99 583	99 590	13 639	0 6	5 807	66 20	100+
E	1 0355	285	179	17 0	99 825	99 550	14 996	0 5	6 355	68 30	100+
F	1 0431	310	126	14 5	99 828	99 758	13 908	0 3	1 967	66 40	100+
					70–80 Per cent Asphaltic Residue						
A	1 0237	310	313	22 3	99 859	99 745	14 675	0 8	3 160	74 20	100+
B	1 0480	275	292	19 3	99 948	99 789	16 224	0 2	3 870	74 10	100+
C	1 0523	340	332	21 0	99 685	99 435	21 364	1 4	1 502	73 40	100+
D	1 0001	325	303	21 5	99 613	99 591	17 293	0 4	3 884	71 30	100+
E	1 0435	280	318	21 0	99 781	99 700	17 087	0 6	4 997	74 00	100+
F	1 0457	345	340	20 5	99 744	99 360	16 541	0 4	1 227	72 05	100+

Series 4. Tests of mixtures taken from construction work

Series 5 Tests designed to study the New Mexico formula

The object of Series 1 was to provide data for the comparison of mixtures of aggregates and road oils available in Kansas

The object of Series 2 was to study the effect of the oil content on the characteristics of the bituminous mixtures of aggregate

The object of Series 3 was to study the effect of the percentage passing the 200 mesh sieve on the physical characteristics of bituminous mixtures.

The object of Series 4 was to study the characteristics of field mixtures.

The object of Series 5 was to study the characteristics of the New Mexico formula.

The oil for this work was obtained from the six refineries which supplied oil for the 1931 construction work A 20 gal. sample of each grade of oil representative of that producer's product was submitted by each refiner The tests of the oils used are shown in Table I. Comparison of these data with the average test results of samples tested by Kansas inspectors at the refineries show that the samples submitted were representative of the oils used in construction

The aggregates used (Table II) were composed of siliceous and granitic particles obtained from the sand-gravel by sieving out each size. The exact amount of each size was weighed separately for each set of specimens so as to avoid any segregation which might result in making up larger batches. In Series 1 and 2, the grading corresponded exactly to that shown in Fig 5.

In making the specimens, the oil and each separate size of aggregate were weighed The oil and aggregates were heated separately to 150°F, combined and hand mixed until a uniform color was obtained, and all particles were completely coated Eighteen pounds of aggregate and the corresponding quantity of oil were mixed in each batch. Extraction tests were made on samples from occasional batches to check the oil content and the gradation of the aggregates The specimens were then molded from the mixture and tests made as described. The values shown in the tables in this paper are the average results of ten tests

TABLE II

CHARACTERISTICS OF AGGREGATES

Type of Fines	Specific Gravity of Fines	Specific Gravity of Aggregates	Wt per cu ft of Straight Line Gradation Aggregate	Absolute Volume Straight Line Gradation Aggregate	Specific Gravity of Combined Fines and Sand
Rock Dust	2 68	2 62	126	77	2 61
Cement	3 14	2 62	130	78	2 66
Silica	2 38	2 62	123	76	2 57
Chat Sludge	2 77	2 62	126	77	2 62
Silt	2 65	2 62	127	78	2 61

SERIES 1

The data obtained from Series 1 are shown in Tables III and IV The values in these tables indicate that there is very little difference in the results obtained with the oils from the six refineries.

All of the test results for the impact test in which six per cent of oil was used were higher than for the specimens containing five per cent of oil. No comparison of the stability tests for the 5 and 6 per cent oil mixes could be made, because the aggregate retained on the No 4 sieve was removed before the specimen was molded This increased the oil content of the test specimens to 6 and 7 per cent. This increase was determined by extraction tests.

The data in Tables III and IV show wide variations in results of the impact and stability test obtained for different types of fines. The stability and impact tests for the rock dust specimens were uniformly higher than for the other fines. The average results on both the impact

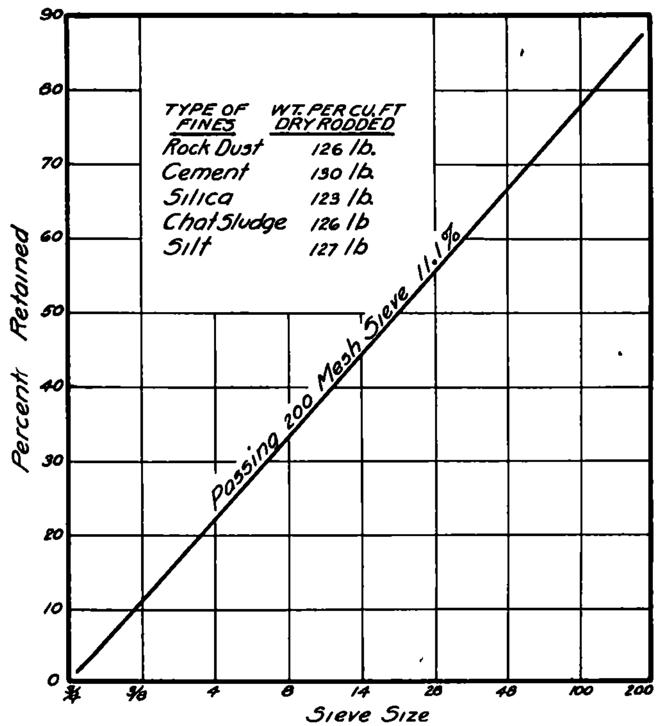

Figure 5. Maximum Density Gradation Curve for Combined Mineral Aggregate

and stability tests show that the fines used may be placed in the following order of relative value in producing a satisfactory mat surface.

1. Rock Dust
2 Volcanic Ash (Silica)
3 River Silt
4 Chat Sludge

The values obtained from the swell tests in this series indicate that with the aggregates and oil used, the increases in volume of the specimens were well within the maximum permissible limits reported by other States The maximum swell permitted in States using this test is reported as .003 in after immersion of the specimen for 24 hrs.

TABLE III

Data on Mixtures of Uniformly Graded Aggregate and 5 Per Cent of Road Oil

Kind and Source of Oil	Type of Fines	Swell in Inches	Stability in Pounds Material Passing No 4 Sieve	Impact Cm Drop	Water A S T M D 95-30	Voids in Compressed Specimen
					%	%
60-70-A	Rock Dust	0009	1372	20 7	0 59	10 11
	Cement	0012	851	11 4	0 70	11 42
	Silica	0015	1170	7 2	1 22	8 99
	Chat Sludge	0013	714	8 6	0 67	10 40
	Silt	0013	761	7 9	1 02	10 01
70-80-A	Rock Dust	0011	1295	41 1	0 77	10 29
	Cement	0009	749	30 6	1 24	11 59
	Silica	0019	1159	19 9	1 19	9 16
	Chat Sludge	0010	734	20 5	1 18	10 58
	Silt	0006	606	13 3	0 93	10 19
60-70-B	Rock Dust	0010	1161	17 6	0 88	10 48
	Cement	0004	717	12 8	0 97	11 79
	Silica	0017	1157	9 4	1 20	9 36
	Chat Sludge	0005	611	7 4	0 94	10 77
	Silt	0001	475	8 8	0 75	10 38
70-80-B	Rock Dust	0009	1204	39 4	0 51	10 54
	Cement	0009	569	29 4	0 89	11 84
	Silica	0013	1110	20 4	1 13	9 41
	Chat Sludge	0009	368	24 0	0 96	10 83
	Silt	0015	714	22 7	0 80	12 25
60-70-C	Rock Dust	0010	1094	18 9	0 79	10 46
	Cement	0007	525	18 1	1 31	11 76
	Silica	0006	913	13 7	1 17	9 34
	Chat Sludge	0008	487	11 1	1 10	10 74
	Silt	0006	511	10 4	0 71	10 36
70-80-C	Rock Dust	0011	1852	21 1	0 91	10 58
	Cement	0009	1394	15 7	1 02	11 88
	Silica	0020	1760	12 4	1 47	9 45
	Chat Sludge	0013	1140	14 6	1 10	10 87
	Silt	0005	675	16 4	0 65	10 48
60-70-D	Rock Dust	0001	1223	25 9	0 74	10 25
	Cement	0009	552	12 9	0 96	11 55
	Silica	0015	1107	9 5	1 11	9 12
	Chat Sludge	0003	413	6 8	0 90	10 54
	Silt	0018	713	14 1	0 41	13 06
70-80-D	Rock Dust	0013	1206	28 0	0 45	10 04
	Cement	0007	932	22 1	0 62	11 34
	Silica	0012	1005	16 5	1 14	8 91
	Chat Sludge	0014	829	13 7	0 65	10 33
	Silt	0012	719	18 9	0 55	9 94

TABLE III—*Concluded*

Kind and Source of Oil	Type of Fines	Swell in Inches	Stability in Pounds Material Passing No 4 Sieve	Impact Cm Drop	Water A S T M D 95–30	Voids in Compressed Specimen
					%	%
	Rock Dust	0009	1466	17 3	0 47	10 41
	Cement	0013	781	13 9	0 83	11 72
60–70–E	Silica	0028	1055	10 5	0 90	9 29
	Chat Sludge	0010	992	13 9	0 52	10 70
	Silt	0012	1006	11 0	0 63	12 12
	Rock Dust	0006	1755	26 4	0 26	10 49
	Cement	0014	1101	22 6	0 61	11 80
70–80–E	Silica	0054	1875	18 8	0 98	9 36
	Chat Sludge	0017	1299	18 7	0 60	10 78
	Silt	0012	996	24 1	0 94	12 20
	Rock Dust	0015	1693	17 0	0 44	11 00
	Cement	0017	1097	15 0	0 53	12 50
60–70–F	Silica	0045	1811	12 0	0 97	10 09
	Chat Sludge	0017	1066	10 5	0 67	11 49
	Silt	0017	467	8 7	0 70	12 20
	Rock Dust	0003	1744	27 6	0 57	10 51
	Cement	0009	829	16 4	0 53	13 60
70–80–F	Silica	0017	1555	30 0	0 73	11 22
	Chat Sludge	0042	928	19 8	0 52	12 60
	Silt	0004	543	18 4	0 45	12 22

SERIES 2

In Tables V and VI are shown the effects of varying the quality of oil in a bituminous mixture and keeping the other factors constant The results of Table V indicate that good stability is obtained when the oil content of the mixture passing a No 4 sieve is from 5 to 7 per cent for aggregates having the same gradation as was used in these tests The data of Table V are shown graphically in Fig 6

SERIES 3

Table VII shows the data obtained by varying the percentage of material passing the 200 mesh sieve It was necessary in this series of tests to vary the percentage of oil with the fines in order to produce a workable mix The New Mexico formula, which is as follows, was used in calculating the quantity of oil used

$P = 0\ 02A + 0\ 07B + 0\ 15C + 0\ 20D$, in which

P = Percentage of oil by weight

A = Percentage of material retained on 48 mesh sieve

B = Percentage of material between the 48 and 100 mesh sieves

C = Percentage of material between 100 and 200 mesh sieves

D = Percentage of material passing 200 mesh sieve

TABLE IV

DATA ON MIXTURE OF UNIFORMLY GRADED AGGREGATE AND 6 PER CENT OF 70-80 ROAD OIL

Source of Oil	Type of Fines	Swell in Inches	Stability in Pounds Material Passing No 4 Sieve	Impact Cm Drop	Water A S T M D 95-30	Voids in Compressed Specimen
					%	%
A	Rock Dust	0004	1247	38 9	0 23	5 37
	Silica	0010	1257	28 1	0 40	11 52
	Chat Sludge	0014	691	26 7	0 47	12 02
	Silt	0007	770	29 2	0 47	10 73
B	Rock Dust	0023	2062	62 5	0 25	6 64
	Silica	0009	1372	27 0	0 67	10 95
	Chat Sludge	0016	746	26 7	0 65	10 59
	Silt	0010	892	30 3	0 40	10 21
C	Rock Dust	0024	1875	44 4	0 51	10 36
	Silica	0020	1459	23 7	0 71	13 50
	Chat Sludge	0007	940	19 3	0 40	11 45
	Silt	0010	1068	25 9	0 60	11 08
D	Rock Dust	0004	1175	49 4	0 18	6 03
	Silica	0008	1039	26 4	0 48	11 23
	Chat Sludge	0011	689	27 3	0 35	9 99
	Silt	0006	951	30 0	0 63	9 62
E	Rock Dust	0017	1331	40 6	0 17	8 45
	Silica	0014	1225	27 2	0 79	10 90
	Chat Sludge	0013	739	25 8	0 40	10 53
	Silt	0016	863	32 1	0 51	10 15
F	Rock Dust	0005	1271	37 6	0 09	8 48
	Silica	0019	999	25 1	1 13	12 61
	Chat Sludge	0011	796	20 9	0 60	13 12
	Silt	0016	1116	28 1	0 70	11 91

TABLE V

EFFECTS OF VARIABLE OIL CONTENT ON MIXTURES OF ROAD OIL AND UNIFORMLY GRADED AGGREGATE

Oil—70-80 "C," Fines—Rock Dust

Oil Per Cent	Swell in Inches	Stability in Pounds Material Passing No 4 Sieve	Impact Cm Drop	Water A S T M D 95-30	Voids in Compressed Specimen
				%	%
4	0030	483	20 7	0 45	12 82
5	0011	1852	21 1	0 91	10 58
6	0024	1875	44 4	0 51	10 36
7	0004	1483	49 1	0 14	5 34
8	0077	*	*	0 17	5 10

* Specimens could not be tested satisfactorily due to excess oil

TABLE VI

EFFECTS OF VARIABLE OIL CONTENT ON MIXTURE OF ROAD OIL AND UNIFORMLY GRADED AGGREGATES

70–80 Oil "C," Fines—Various

Oil %	Type of Fines	Swell in Inches	Stability in Pounds Material Passing No 4 Sieve	Impact Cm Drop	Water A S T M D 95–30	Voids in Compressed Specimen
					%	%
5	Rock Dust	0011	1852	21 1	0 91	10 58
	Silica	0020	1760	12 4	1 47	9 45
	Chat Sludge	0013	1140	14 6	1 10	10 87
	Silt	0005	675	16 4	0 65	10 48
6	Rock Dust	0024	1875	44 4	0 51	10 36
	Silica	0020	1459	23 7	0 71	13 50
	Chat Sludge	0007	940	19 3	0 40	11 45
	Silt	0010	1068	25 9	0 60	11 08
7	Rock Dust	0004	1483	49 1	0 14	5 34
	Silica	0011	1015	36 7	0 54	9 74
	Chat Sludge	0008	771	30 1	0 20	9 33
	Silt	0004	1210	40 4	0 32	7 13

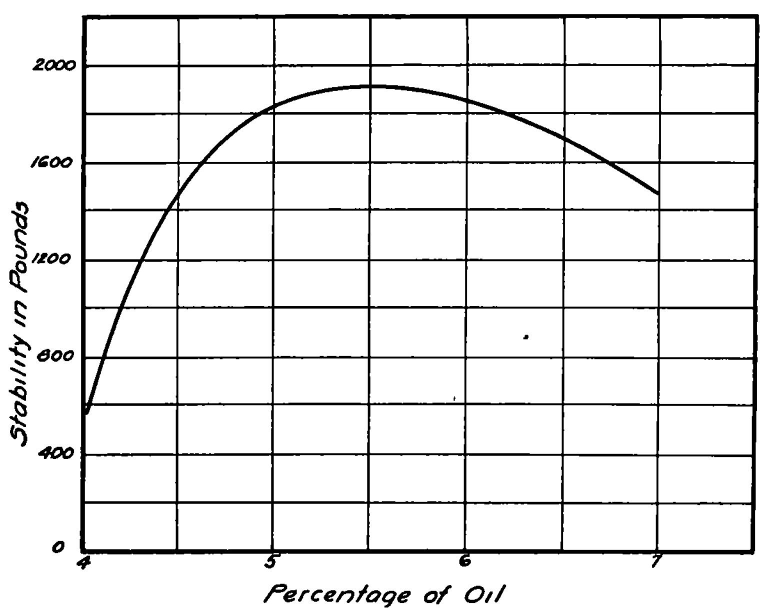

Figure 6. Relation Between Stability and Percentage of Oil. 70-80 Road Oil C. Fines, Rock Dust. Aggregate, Straight Line Gradation Material Passing No. 4 Sieve.

The values ın Table VII ındıcate that for sılıca or rock dust the most satısfactory results are obtaıned when the bıtumınous mıxture contaıns from 10 to 20 per cent of mıneral aggregate passıng the 200 mesh sıeve The results of the swell test on mıxtures contaınıng no 200 mesh materıal ındıcate that a hıgh voıd content ın a bıtumınous mıx tends to produce a large volume change

TABLE VII

Data on Mixtures of Road Oils and Aggregate Variable Percentage Passing 200 Mesh Sieve Per Cent of Oil Calculated by New Mexico Formula

70–80 Oıl "C"

Oıl %	Swell ın Inches	Stabılıty ın Pounds Materıal Passıng No 4 Sıeve	Impact Cm Drop	Water A S T M D 95–30 %	Voıds ın Compressed Specımen %	Gradatıon Per Cent Retaıned on ⅜	4	8	14	28	48	100	G F	Pass 100 Ret 200	Pass 200
Sılıca Fınes															
4 26	0041	766	12 2	0 56	17 18	12 5	25 0	37 5	50 0	62 5	75 0	87 5	3 50	12 5	0
5 01	0035	829	19 2	2 10	13 52	11 8	23 6	35 4	47 2	59 0	70 8	82 6	3 30	12 4	5
5 82	0021	1094	40 1	0 27	7 79	11 2	22 4	33 6	44 8	56 0	67 2	78 4	3 14	11 6	10
6 60	0009	2048	28 9	0 70	10 01	10 6	21 2	31 8	42 4	53 0	63 6	74 2	2 97	10 8	15
7 40	0022	2015	28 5	1 05	12 07	10 0	20 0	30 0	40 0	50 0	60 0	70 0	2 80	10 0	20
Rock Dust Fınes															
4 26	0041	766	12 2	0 56	17 18	12 5	25 0	37 5	50 0	62 5	75 0	87 5	3 50	12 5	0
5 01	0007	813	26 2	0 33	11 45	11 8	23 6	35 4	47 2	59 0	70 8	82 6	3 30	12 4	5
5 80	0003	1711	44 1	0 24	8 79	11 2	22 4	33 6	44 8	56 0	67 2	78 4	3 14	11 6	10
6 60	0008	1819	50 8	0 13	5 99	10 6	21 2	31 8	42 4	53 0	63 6	74 2	2 97	10 8	15
7 40	0008	2453	48 4	0 02	5 05	10 0	20 0	30 0	40 0	50 0	60 0	70 0	2 80	10 0	20

SERIES 4

Table VIII shows the results of tests on specımens made from bıtumınous mıxtures taken from the wındrow of mıxed materıals durıng constructıon The samples taken from the road surface were shıpped to the laboratory and stored ın sealed mason ȷars untıl the tests were made. The percentage of oıl was determıned by the rotarex method of extractıon. The percentage of fines was determıned by sıeve analysıs of the aggregate after the bıtumen had been extracted Consıderable dıfficulty was experıenced ın gettıng the amount passıng the 200 mesh sıeve as determıned by extractıon to check the percentage found by analysıs of the dry aggregate made ın the field The extractıon test value was usually about 50 per cent of the field analysıs value It was concluded that a large amount of 200 mesh materıal was lost durıng dryıng

TABLE VIII

Test Results on Oiled Aggregate Samples

Submitted to the Laboratory by Resident Engineers

Project	County	Division	Fines Passing 200 Mesh	Oil	G F	Stability in Pounds Material Passing No 4 Mesh	Swell In	Impact Cm Drop	Type of Fines
			%	%					
11–14–7351	Lyon	1	6 59	5 32	3 68	3290		27	Soil
30–3–7353	Jefferson	1	7 80	6 35	3 42	2455		56*	Soil
75–28–K1180	Jackson	1	5 32	5 66	3 06	3330		19	Soil
75–27–K1179	Jackson	1	7 98	6 47	3 04	3825	0024	27	Soil
50N–32–K1184	Osage	1	9 02	7 95	3 30	2870	0082	61*	Soil
75–22–K1186	Osage	1	9 54	7 95	3 30	3795	0029	29	Soil
50N–17–7364	McPherson	2	5 68	6 15	3 62	2310	0117	42	Soil
50N–18–7369	McPherson	2	3 49	5 33	3 46	1498	0036	17	Soil
15–19–K1215	Clay	2	13 4	6 88	2 79	2193		14	Soil
81–19–7367	Ottawa	2	5 58	5 79	3 36	2715	0037	30	Soil
40N–20–7366	Cloud	2	9 25	7 30	3 55	3025		45	Soil
81–20–7365	Cloud	2	8 35	6 01	3 61	3862		36	Soil
40N–20–7366	Cloud	2	8 8	6 38	3 24	2025	0149	31	Soil
50N–22–K1198	Marion	2	9 04	6 78	3 51	4474		38	Soil
50N–23–K1199	Dickinson	2	8 65	5 71	3 44	2552		24	Soil
40S–6–7275	Gove	3	13 4	6 48	3 21	4910	0056	46	Soil
40S–5–7274	Gove	3	17 4	6 05	3 09	6210		48	Soil
40S–7–K1201	Gove	3	11 2	5 85	3 27	3585		27	Soil
40S–1–7270	Wallace	3	13 6	6 60	3 09	3390	0038	44	Soil
1–14–FA269B	Ellis	3	13 8	5 96	3 27	5080		73*	Soil
40N–2–7290	Sherman	3	12 3	7 30	3 18	3450		60*	Soil
40N–4–7283	Thomas	3	10 7	7 35	3 33	3470		75*	Soil
54–30–K1193	Greenwood	4	5 64	5 57	3 99	11050	0222	47	Lime Stone
54–31–K1194	Greenwood	4	7 80	6 24	4 03	9590	0077	59*	Lime Stone
75–8–7387	Wilson	4	6 34	5 50	4 32	4500	0002	37	Chat Sludge
75–7–7386	Wilson	4	8 08	7 17	3 93	5570	0008	52*	Chat Sludge
6–4–FA 424A	Allen	4	13 1	9 07	3 81	3650		79*	Chat Sludge
50S–15–FA302	Stafford	5	6 76	5 28	3 09	4090	0016	34	Silt
50S–16–FA302	Stafford	5	6 57	5 22	2 83	1189	0049	31	Silt
50S–12–K1208	Edwards	5	9 1	5 61	3 11	2097		31	Silt
166–2–FA 386A	Cowley	5	8 55	5 07	3 24	2940		37	
54–29–K1206	Butler	5	5 0	5 75	4 02	3040		39	Lime Stone
50S–7–FA 56E	Gray	6	8 85	6 21	3 06	2220	0016	35	Soil
50S–8–K1216	Gray	6	14 1	7 11	2 78	3350		35	Soil
50S–11–FA437	Ford	6	8 45	4 59	3 17	2315	0057	14	Silt
50S–9–K1217	Ford	6	10 5	6 12	3 10	2145	0017	31	Soil
21–5–FA 233B	Ford	6	9 12	5 22	3 06	2345	0093	24	Soil
54–5–K 1178	Meade	6	9 56	5 63	3 43	2212	0019	48	Silica
54–5–FA408A	Meade	6	12 8	6 22	2 97	3880	0066	44	Silica
54–4–K1177	Seward	6	8 80	6 97	3 38	3740		56*	Silica
83–4–K1211	Seward	6	9 14	6 27	3 26	2960		39	Silica
21–4–FA 233C	Clark	6	8 34	6 21	3 52	2880		45	Soil
21–1–K1225	Clark	6	10 9	7 83	2 31	1458	0006	25	Silica
83–6 & 7–7415	Haskell	6	10 1	7 36	3 53	3100		62*	Silica
83–5–K1209	Haskell	6	9 77	6 82	3 46	2667	0026	23	Silica

* Excessive deformations

and mixing operations. This lack of agreement was eliminated in the 1933–1934 work by better methods of handling materials and increased experience of operators. Values obtained from the stability and impact tests on these mixes were higher than for laboratory mixes. This was probably due to the fact that the field mixtures were stiffened by exposure to air for several days during mixing operations, thereby

TABLE IX

EFFECTS OF LUMPS ON MIXTURES OF ROAD OIL AND UNIFORMLY GRADED AGGREGATE

70–80 Oil "C"

5 Per Cent of Oil

Type of Fines	Swell in Inches	Stability in Pounds Material Passing No 4 Sieve	Impact Cm Drop	Water A S T M D 95–30	Voids in Compressed Specimen
				%	%
Clay retained on 3/8 with Rock Dust passing 200	0328	1431	21 4	2 77	10 68
Clay passing	0020	1324	18 0	1 02	10 48
Shale retained on 3/8 with Rock Dust passing 200	0056	1515	21 3	0 60	10 68
Shale passing 200	0011	1838	21 2	0 69	10 48
Top Soils of Various Classifications Used as Fines					
Soil A-6	0028	2355	22 1	1 58*	9 62
Soil A-6	0025	2635	20 6	0 67	10 01
Soil A-4	0028	2331	18 0	1 33	10 09
Soil A-3	0025	1145	18 7	1 09	10 09
Soil A-3	0028	1650	13 2	1 58	10 27
Soil A-3	0006	1230	18 2	1 94	9 90
Soil A-3	0014	1379	14 0	2 67	10 34
Soil A-3	0015	774	13 6	1 58	9 70
Soil A-3	0021	860	13 4	2 91	10 05
Soil A-2	0034	1876	16 2	1 52	10 37
Soil A-4	0028	1416	15 2	1 36	10 20
Soil A-4	0046	1310	15 0	1 44	9 94
Soil A-5	0016	3202	10 8	3 76	9 94
Soil A-4	0062	1984	12 6	1 89	10 30
Soil A-1	0054	1616	13 2	1 94	10 37

* Values following indicate per cent absorption by weight

removing some of the most volatile portions of the oil The values for the stability and impact tests on the samples from Division 4 were especially high. This was probably due to the fact that the angular crushed flint or chat used as aggregate on these projects keyed together better than the rounded aggregates.

The values obtained from the swell tests on the field samples were higher than the average of the laboratory tests. This was found to be due to the presence of soil or shale in clods or lumps instead of in pulverized condition. As a check on this conclusion, tests were run using a soil containing clods as fines and the same soil thoroughly pulverized The same tests were repeated using shale containing large particles and the same shale thoroughly pulverized as fines The results of these tests are shown in Table IX The swell of the samples containing pulverized material was very small, while the specimen containing large particles gave values beyond the allowable limit

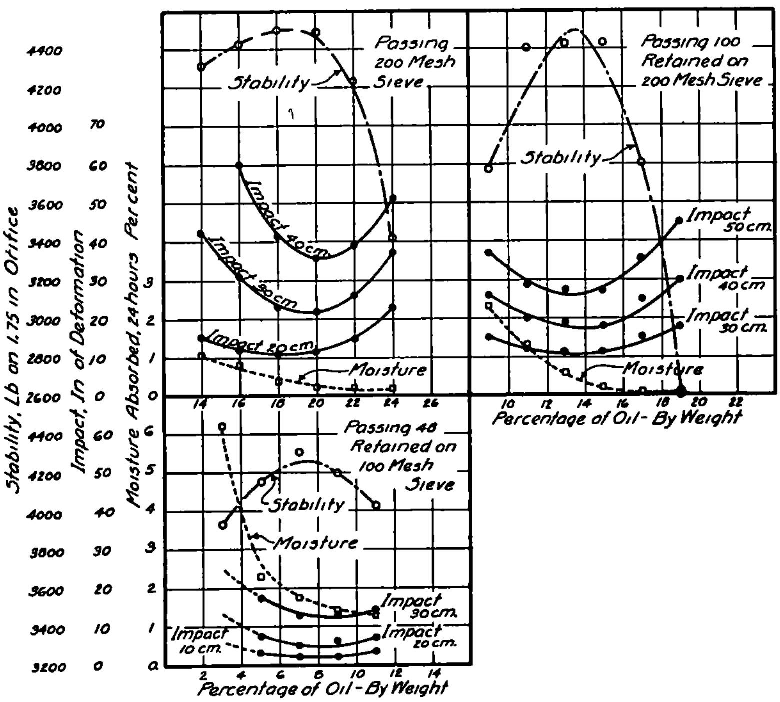

Figure 7. Rock Dust Stability, Impact and Moisture Curves. Size of Specimen $2\frac{3}{8}$ by 1 in. Age 24 hours. 70–80 Oil A. From Table X.

SERIES 5

In Series 5 the New Mexico formula for determining amount of oil was checked by comparing laboratory specimens mixed with the amount of oil given by the formula with mixtures containing other amounts The tests used as criteria of the quality of the mixtures were stability, impact and absorption Fine materials only were used in the mixtures. As it was impossible to mold specimens from the materials coarser than the 48 mesh sieve, the constant in increment A in the formula could not be checked It was found that the silica, silt and chat sludge had approximately 100 per cent passing the 100 mesh sieve so that no results could be obtained on the increment between 48 and 100 mesh sieves for these materials.

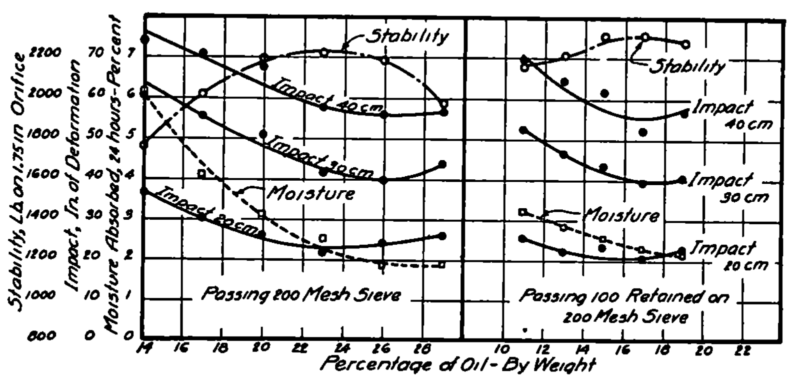

Figure 8. Silica Stability, Impact and Moisture Curves. Size of Specimen 2⅜ by 1 in. Age 24 hours. 70–80 Oil A. From Table XI.

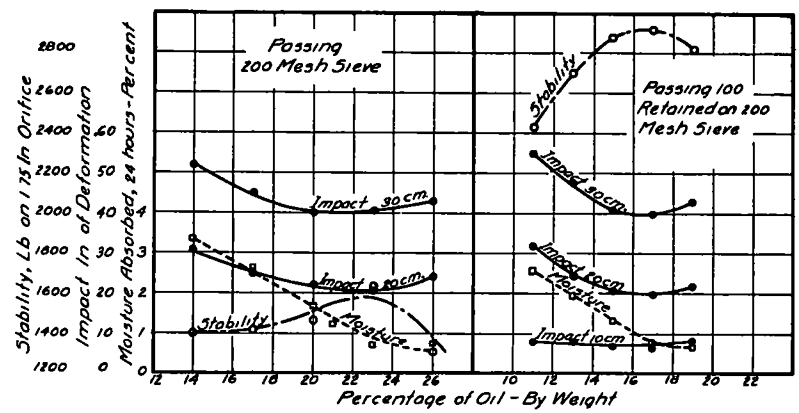

Figure 9. River Silt Stability, Impact and Moisture Curves. Size of Specimen 2⅜ by 1 in. Age 24 hours. 70–80 Oil A. From Table XII.

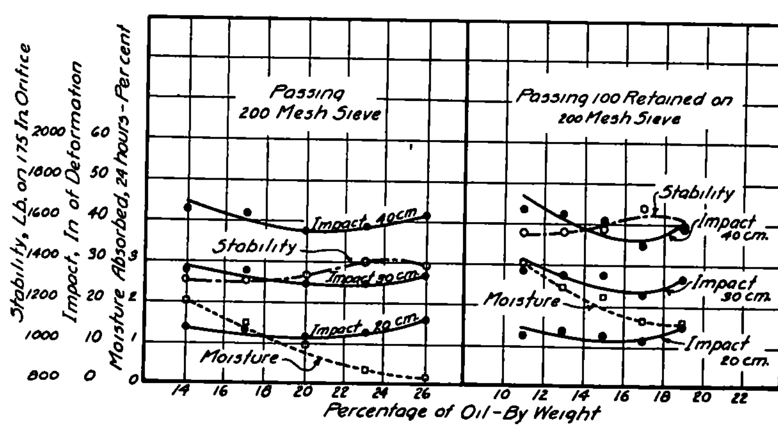

Figure 10. Chat Sludge Stability, Impact and Moisture Curves. Size of Specimen 2⅜ by 1 in. Age 24 hours. 70–80 Oil A From Table XIII.

Figures 7, 8, 9, 10 and Tables X, XI, XII and XIII show the results of these tests It is apparent that the mixtures containing the formula percentages of oil conform closely to the optimum results for the various tests.

TABLE X

EFFECT OF PERCENTAGE OF OIL ON MIXTURES OF ROAD OIL AND ROCK DUST

Percentage of Oil Given by P = 02A + 07B + 15C + 20D Shown in Bold Face Type

70–80 Oil-A

Per Cent Oil	Stability in Pounds	Impact Deformation in Inches at Cm Drop Indicated					Moisture Absorbed 24-Hours
		10	20	30	40	50	
Rock Dust Passing 200 Mesh Sieve P = 0 2D = 0 2 × 100 = 20%							
							%
14	4308	0 06	0 15	0 42	—	—	1 17
16	4430	0 05	0 12	0 31	0 60	—	0 80
18	4500	0 05	0 11	0 23	0 41	0 58	0 36
20	**4492**	**0 05**	**0 12**	**0 22**	**0 36**	**0 52**	**0.21**
22	4225	0 06	0 15	0 26	0 39	0 53	0 20
24	3415	0 11	0 23	0 37	0 51	0 62	0 18
Rock Dust Passing 100 and Retained on 200 Mesh Sieve P = 0 15C = 0 15 × 100 = 15%							
9	3794	0 04	0 08	0 15	0 26	0 37	2 35
11	4400	0 03	0 06	0 12	0 20	0 29	1 23
13	4413	0 02	0 06	0 12	0 19	0 28	0 56
15	**4425**	**0 02**	**0 06**	**0 11**	**0 18**	**0 27**	**0.27**
17	3800	0 02	0 07	0 15	0 25	0 36	0 05
19	2625	0 03	0 09	0 18	0 30	0 45	0 06
Rock Dust Passing 48 and Retained on 100 Mesh Sieve P = 0 07B = 0 07 × 100 = 7%							
3	3930	Too dry for Impact					6 28
5	4150	0 03	0 07	0 17	—	—	2 27
7	**4300**	**0 02**	**0.05**	**0 13**	**0 22**	**0 33**	**1.72**
9	4195	0 02	0 06	0 13	0 21	0 31	1 44
11	4020	0 03	0 07	0 14	0 22	0 32	1 01

Conclusions on Mixtures

Analysis of the data resulting from these series of tests indicates that the following conclusions are justified

1 The oils from the six refineries have equal value as binders
2 The value of the mineral fines may be rated in the following order
    1 Limestone or rock dust (Shale free)
    2. Silica or volcanic ash
    3 River Silt
    4 Chat Sludge

3 The most satisfactory results will be produced by oil contents of 5 to 7 per cent
4 To obtain the best results, 5 to 15 per cent of the mineral aggregate must pass a 200 mesh sieve
5. Top soil and shaley material when finely pulverized and free from clods are satisfactory for use as fines in the mineral aggregate
6. The constants in the New Mexico formula can be confirmed by laboratory tests.

TABLE XI

EFFECT OF PERCENTAGE OF OIL ON MIXTURES OF ROAD OIL AND VOLCANIC ASH (SILICA)

Percentage of Oil Given by P = 02A + 07B + 15C + 20D Shown in Bold Face Type

70–80 Oil-A

Per Cent Oil	Stability in Pounds	Impact at Cm Drop Indicated					Moisture Absorbed 24-Hours
		10	20	30	40	50	
Silica Passing 200 Mesh Sieve P = 0 2D = 20%							
							%
14	1765	0 10	0 36	0 61	0 75	—	6 09
17	2010	0 08	0 30	0 56	0 71	—	4 14
20	**2195**	**0 09**	**0 26**	**0 51**	**0 68**	—	**3 10**
23	2220	0 08	0 22	0 42	0 58	—	2 48
26	2190	0 08	0 24	0 40	0 56	0 66	1 88
29	1969	0 10	0 26	0 44	0 57	0 66	1 89
Silica Passing 100 and Retained on 200 Mesh Sieve P = 0 15C = 15%							
11	2150	0 08	0 25	0 52	0 69	—	3 15
13	2200	0 07	0 22	0 46	0 64	—	2 80
15	**2300**	**0 07**	**0 23**	**0 43**	**0 61**	—	**2 49**
17	2300	0 07	0 20	0 39	0 53	—	2 25
19	2267	0 08	0 22	0 40	0 56	—	2 13

RESEARCH ON BITUMINOUS MATERIALS

During the summer and fall of 1932 some of the bituminous mat surfaces that were constructed in 1931 and early in 1932 began to disintegrate. In some of the surfaces the road oil seemed to have lost its adhesive qualities, causing the mat to become brittle Wherever there was a break in the surface, disintegration was rather rapid In other places the mat would roll and form corrugations These road surfaces were surveyed and analyses of the oils used in them were made in order to determine if possible the cause or causes of these failures

TABLE XII

EFFECT OF PERCENTAGE OF OIL ON MIXTURE OF ROAD OIL AND RIVER SILT
Percentage of Oil Given by P = 02A + 07B + 15C + 20D Shown in Bold Face Type
70–80 Oil-A

Per Cent Oil	Stability in Pounds	Impact at Cm Drop Indicated					Moisture Absorbed 24-Hours
		10	20	30	40	50	
River Silt Passing 200 Mesh Sieve P = 0 2D = 20%							
							%
14	1400	0 09	0 31	0 52	0 65	0 75	3 36
17	1419	0 08	0 25	0 45	0 58	0 68	2 61
20	**1465**	**0.07**	**0 22**	**0 40**	**0 55**	**0 66**	**1.63**
23	1637	0 06	0 21	0 41	0 56	0 68	0 71
26	1317	0 08	0 24	0 43	0 59	0 71	0 72
River Silt Passing 100 and Retained on 200 Mesh Sieve P = 0 15C = 15%							
11	2430	0 08	0 32	0 55	—	—	2 54
13	2712	0 08	0 25	0 48	—	—	1 94
15	**2880**	**0 07**	**0 21**	**0 41**	—	—	**1 33**
17	2920	0 07	0 20	0 40	—	—	0 76
19	2815	0 08	0 22	0 43	—	—	0 76

TABLE XIII

EFFECT OF PERCENTAGE OF OIL ON MIXTURES OF ROAD OIL AND CHAT SLUDGE
Percentage of Oil Given by P = 02A + 07B + 15C + 20D Shown in Bold Face Type
70–80 Oil-A

Per Cent Oil	Stability in Pounds	Impact Deformation in Inches at Cm Drop Indicated					Moisture Absorbed 24-Hours
		10	20	30	40	50	
Chat Sludge Passing 200 Mesh Sieve P = 0 20D = 20%							
							%
14	1314	0 05	0 14	0 28	0 43	0 55	2 00
17	1315	0 04	0 14	0 28	0 42	0 53	1 41
20	**1338**	**0 04**	**0 12**	**0 25**	**0 38**	**0 50**	**0 99**
23	1415	0 05	0 13	0 25	0 39	0 52	0 35
26	1387	0 07	0 16	0 27	0 42	0 55	0 21
Chat Sludge Passing 100 and Retained on 200 Mesh Sieve P = 15C = 15%							
11	1562	0 05	0 13	0 29	0 44	0 56	3 05
13	1569	0 05	0 14	0 28	0 43	0 55	2 49
15	**1581**	**0 04**	**0.13**	**0 28**	**0 41**	**0 52**	**2.24**
17	1680	0 04	0 12	0 23	0 35	0 46	1 66
19	1590	0 06	0 15	0 27	0 39	0 50	1 54

The analyses of the road oils used in these mats showed that in several cases the oils met the requirements for percentage of bitumen soluble in carbon disulphide, but that the percentage soluble in carbon tetrachloride was very low Table No XIV which gives the results of tests of the road oils used in 1932, shows in some oils a variation of from 0 5 to 2 0 per cent in the solubilities in carbon disulphide and carbon tetrachloride In contrast to this the carbon tetrachloride solubility was high in the oils which generally produced good mat surfaces

Samples of the mat surfaces were then taken and the bituminous material in them recovered by dissolving with a mixture of carbon tetrachloride and carbon disulphide After extraction the mixture of carbon tetrachloride and carbon disulphide was allowed to settle for 24 hours, after which it was siphoned off and filtered to remove any mineral filler that might have been carried over in the process The carbon tetrachloride and carbon disulphide solvent was then distilled off at a maximum temperature of 680°F , the residue reduced to various penetrations by the method described in the A S T M Tentative Method of Test For Residue of Specified Penetration, D–243–28T, and complete tests made on the asphaltic residues The results of these tests, as shown in Table No XV, indicate that the asphaltic residue soluble in carbon tetrachloride is considerably less than that soluble in carbon disulphide

No definite conclusion was based on these two series of tests, but the data seemed to indicate that the solubility in carbon tetrachloride would give a better criterion of the quality of a road oil or asphalt than solubility in carbon disulphide With this thought in mind the 1933 specifications included solubility in carbon tetrachloride instead of in carbon disulphide This required a change in practice at some of the refineries The change appeared to be justified in that the oils meeting these requirements have in general produced satisfactory mat surfaces

As previously noted, the bituminous materials reclaimed from the road surfaces were much less soluble in carbon tetrachloride than the original oil, and also the older the mat surface, the lower was the solubility To determine whether this was due to weathering or to a combination of factors, volatization tests were made on the oils and the residues were tested for penetration, solubility and ductility The volatization test was used since it gave the closest approach to an accelerated weathering test that could be devised without expensive equipment Tables XVI and XVII, and Figs 11, 12, and 13 give the results of these tests The amount soluble in carbon tetrachloride given in the tables is corrected to show the percentage of the original oil soluble, not that of the residue from the volatization test These results show a decrease in solubility as the volatization period increases

Table No. XVIII shows that the decreased solubility in carbon tetrachloride is not caused by the oil being mixed with the mineral aggregate and then extracted In these tests the road oil was mixed with the mineral aggregate and then extracted, recovered, and reduced to various penetrations in the manner previously described While these results vary a little from the results obtained when the original oil was reduced to various penetrations, there is insufficient variation to account for any of the weathering of the oil

The brittleness of the mat and the rapidity with which the road surface disintegrates around a break in the surface depend upon the

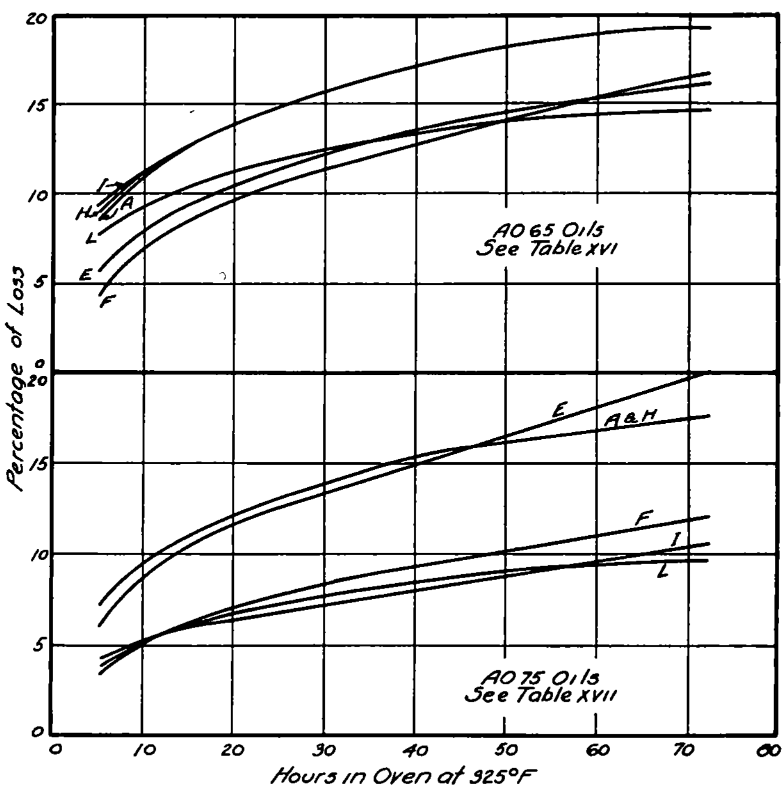

Figure 11. Results of Volatilization, Loss versus Time

adhesive quality of the asphalt The ductility of asphalt is ordinarily accepted as a measure of its adhesion or bonding property Common practice has defined the ductility of road oil as ductility at 77°F. on 100 penetration asphalt resulting from reduction by the A S T M method D-243-28T. It was found that road oil recovered from a mat surface that had been in service for some time had lost some of its volatile material and weathered to such an extent that the penetration was less than 100 (See Table XV) To determine the adhesive properties of the road oils at these lower penetrations, the samples were reduced to

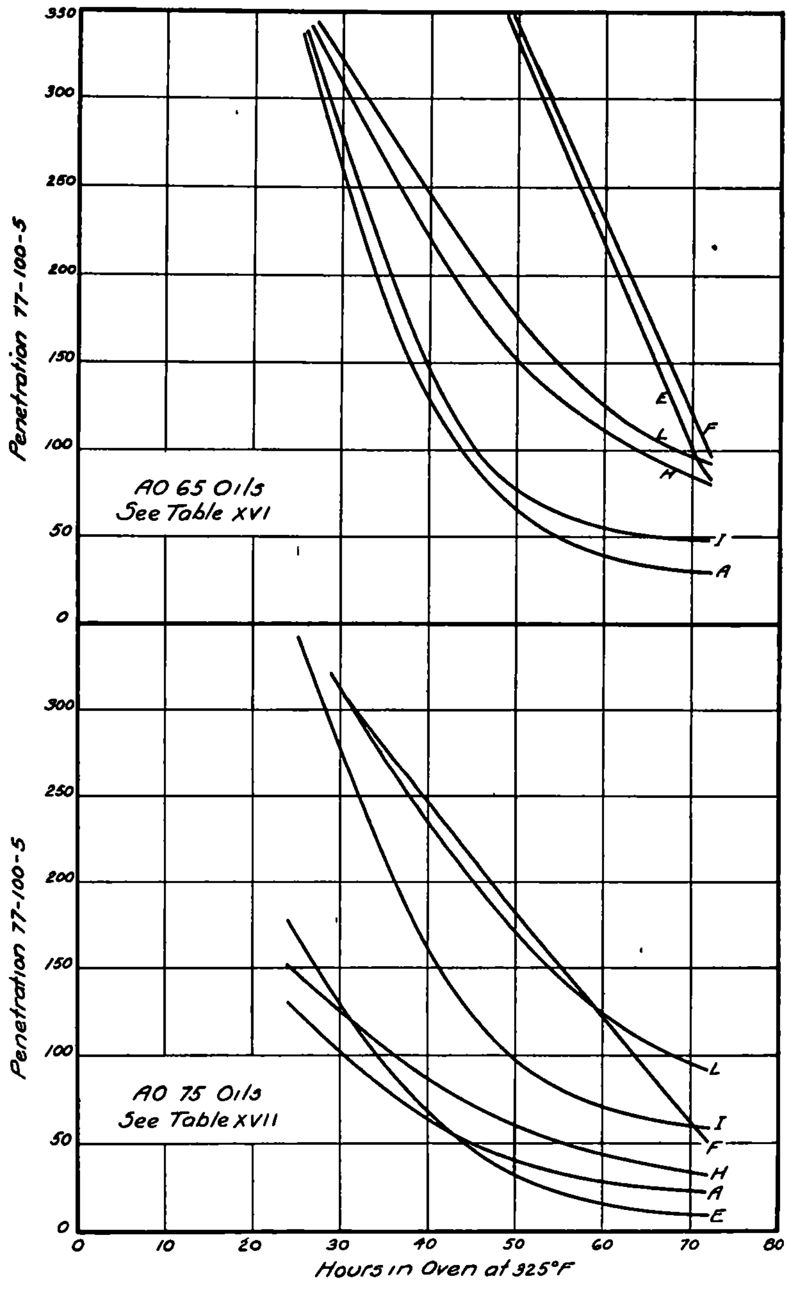

Figure 12. Results of Volatilization, Penetration of Residue versus Time in Oven

various penetrations and the ductility tests made at various temperatures These results are recorded in Tables Nos. XIX and XX These results show that while the asphalt may possess good ductility at 100 penetration at 77° and 39 2°F , the ductility may fall off rapidly at lower penetrations Considerable difficulty was encountered in determining

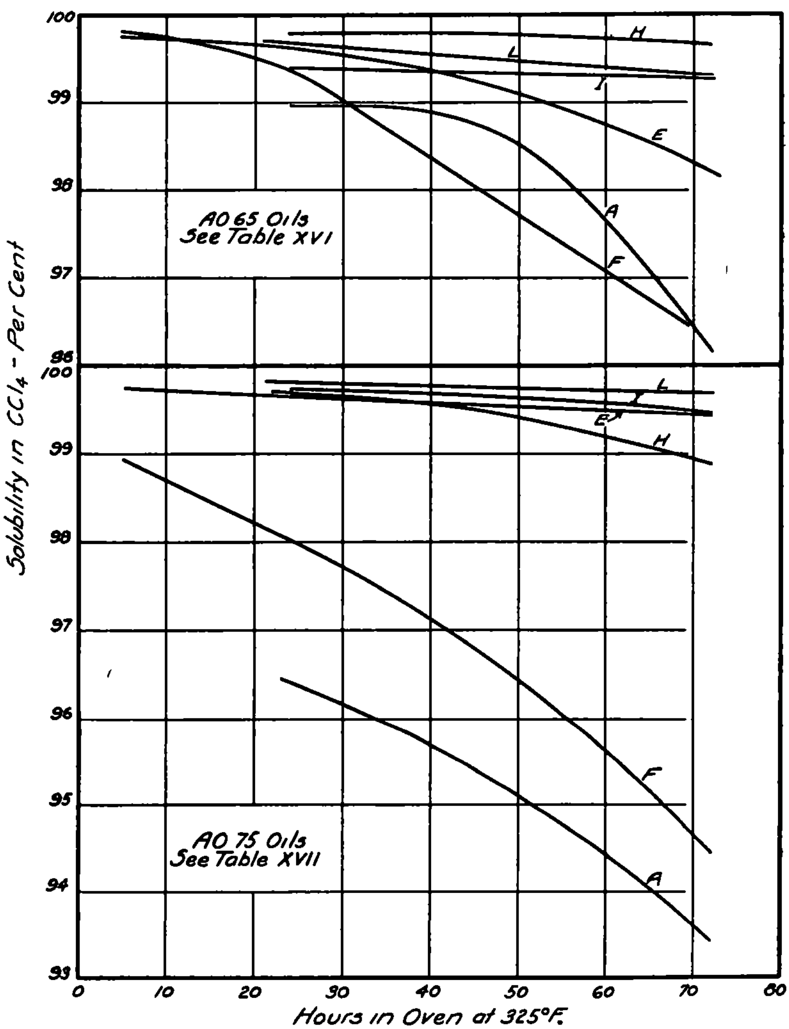

Figure 13. Results of Volatilization Solubility in CCl_4 versus Time

the ductility at 39 2°F. as at this temperature the asphalt was quite brittle and in most cases at a penetration of 150 or less it would not pull out into a fine thread

As shown in Tables XV and XXI, some of the oils harden more rapidly than others in service. Various tests were made in order to determine whether this was caused by the loss of the light volatile constituents or by weathering These tests consisted in determining the characteristics of the distillate or light volatiles present in the different road oils Table No. XIV gives the percentage of distillate obtained by the A S. T M Standard Test for Distillation of Bituminous Materials Suitable for Road Treatment—D 20–30 Additional tests were made on the distillate Table XXII gives the results of these tests While there were

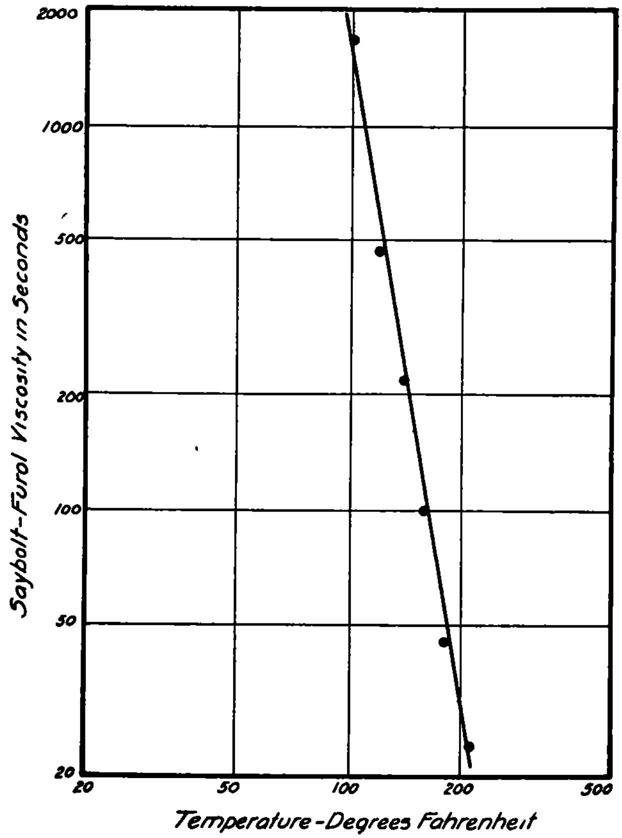

Figure 14. Viscosity Curve for Oil A0–75, 1932. Average of all Oils Tested. Log Y = –6.04324 Log X +15 30503.

some variations in the light volatiles from the different oils, there was not enough difference to account for the great variation found in the weathering of the road oils

Viscosity of road oil is an important factor in its use, the lighter oils being used for penetration work and the heavier road oils and cutbacks for mat construction. There is very little uniformity in the requirements of the various States for the temperatures at which the viscosity tests are made. In this series the first step was to determine the viscosity at various temperatures ranging from 100° to 210°F. These results are given in Table XXIII. When the viscosity in seconds is plotted against temperature in degress Fahrenheit on logarithmic paper the curve approximates a straight line. These curves fall in the class

$$y = ax^b$$

where y = viscosity in seconds
x = temperature in degrees Fahrenheit

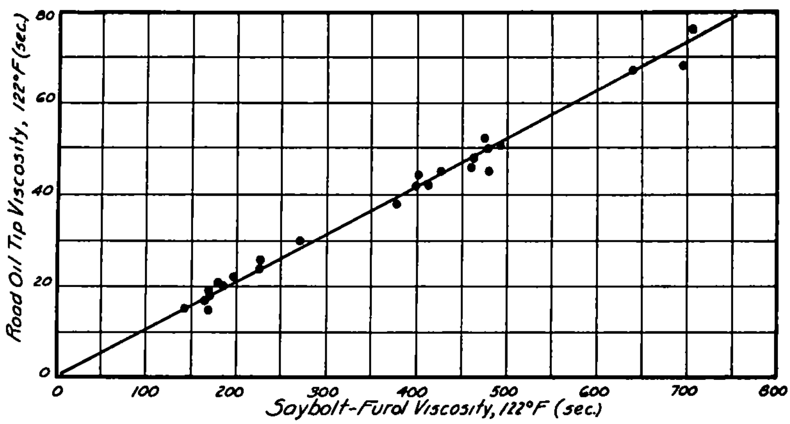

Figure 15. Relation Between Viscosities Using Saybolt-Furol Tip at 122°F. and Road Oil Tip at 122°F.

Type Oil and Lab No	Viscosity 122°F (Sec) Saybolt-Furol Tip	Viscosity 122°F (Sec) Road Oil Tip	Type of Oil and Lab No	Viscosity 122°F (Sec) Saybolt-Furol Tip	Viscosity 122°F (Sec) Road Oil Tip	Type of Oil and Lab No	Viscosity 122°F (Sec) Saybolt-Furol Tip	Viscosity 122°F (Sec) Road Oil Tip
AO-65			AO-75			RC-2		
A	191	21	A	406	44	23775	270	30
E	188	20	E	400	42	23951	229	24
F	172	19	F	463	46			
H	169	15	H	462	48	RC-3		
I	172	18	I	705	76	23824	693	68
L	199	22	L	475	52	24013	640	67
			23794	377	38			
MC-2			MC-2K			MC-3		
22399	411	42	23884	255	26	22400	166	17
23746	427	45	23978	171	18			
23773	482	50	24004	143	15			
23774	478	49						
23947	490	51						

By dividing the data for each curve into two parts, writing an equation for each part and solving the equations simultaneously it is possible to solve for the constants a and b.

Fig 14 gives the average curve for all of the oils tested To get this curve and the corresponding equation the viscosities for all the oils were averaged for the various temperatures The equation for this curve is $\text{Log } y = -6\ 04324 \text{Log } x + 15\ 30503$

Since these curves plot as a straight line on logarithmic paper it is known that there is a definite relationship between temperature and viscosity From this it was assumed that if a constant temperature and various sized orifices were used, there might be a constant relationship between viscosities For this test three orifices were selected the Universal tip, the Furol tip, and a special road oil tip

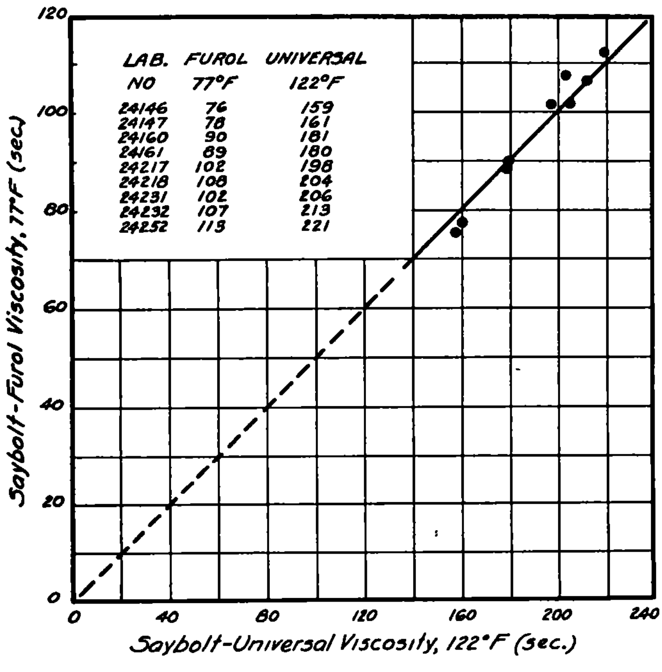

Figure 16 Relation Between Viscosities Using Saybolt-Furol Tip at 77°F. and Saybolt-Universal Tip at 122°F. Material MC-1 Oil

Fig 15 shows that the viscosities at 122°F using the special road oil tip are approximately one tenth of those at the same temperature using the Furol tip Fig 16 shows that the Furol viscosities at 77°F are approximately one half the Universal viscosities at 122°F These results indicate that viscosities on all materials may be specified at one temperature and made conveniently by means of modified tips. The accuracy of this method is well within the limits justified by the use that is made of the data

Table XXIV gives the results of tests made on samples of cutback asphalts submitted by the different refineries These samples were also tested by the Oliensis spot test, by the Oxidation test as described by the Kansas City Testing Laboratory, and under an ultra-violet light for 20 hours at 77°F The ultra-violet light tests were made by painting the bituminous materials on tin panels 3 in by 4 in placed 18 in below the tube under a Cooper Hewett Mercury Vapor Lamp

The Oliensis Spot test was made on most of the road oils and cutback asphalts used in the 1933 construction season In these tests only one oil was shown to be homogeneous, although most of these oils have produced mats that have given excellent service The same can be said of the results of the oxidation and the ultra-violet tests One test will show the road oil to be a good grade while the other test will show it of poor quality These tests and certain requirements in the other tests are for differentiating between various kinds of asphalts and should not be included in the specifications unless it is desirable to exclude certain types of materials

CONCLUSIONS

1 Carbon tetrachloride should be used as a solvent to determine the bitumen content of asphaltic materials The test should be made by Method No 1 of the American Society for Testing Materials Standard Method of Test for Determination of Bitumen, D4 – 27

2 The percentage of asphaltic oil or bitumen soluble in carbon tetrachloride decreases as the time in service or the volatization period increases

3 The ductility at 77°F of the road oil residue reduced to a penetration of from 15 to 25 is a better test of the quality of the asphalt than the ductility test on 100 penetration asphalt at 77°F

4 The ductility of bitumen at 39 2°F is not a criterion of the quality of asphalt, as asphalt of 150 penetration or less will not elongate to a fine thread Such a test will not impart any information that cannot be determined by other tests

5 Some oils harden much faster than others when placed in road surfaces and this hardening is due to causes other than loss of volatile constituents

6 Viscosities should be determined at a constant temperature, preferably at 122°F , and the sizes of the orifices selected for the different grades of oil should be such that the time for making the test will fall between 40 and 400 seconds

7 Specifications covering asphaltic materials should be so written that they will give the type and grade most satisfactory for the purchaser's needs, and tests such as the Oliensis spot test, the Oxidation test, or others which differentiate between asphalts should not be included unless it is desirable to eliminate certain types of asphaltic oils

TABLE XIV

Results Obtained from Tests on 1932 Research Oils

Oil	Spec Grav at 77°F	Flash Point °F	Viscosity Saybolt Furol at 122°F	Solubility		Insoluble		Loss 50 g at 325°F		100 Penetration Asphalt	Ductility		Distillation Per Cent Off		
				CS_2	CCl_4	Water, in 86° API Naphtha	Sediment	5 hours	24 hours		77°F	39 2°F	437° F	600°F	680°F
				%	%	%	%	%	%	%	cm	cm			
A	1 020	285	563	99 69	99 47	14 73	0 30	3 37	11 04	75 90	100+	0 0	0 0	0 0	8 0
B	1 060	280	375	99 68	99 16	18 19	0 70	5 94	10 59	75 59	100+	0 0	0 0	0 5	8 5
C	1 055	340	504	99 56	98 61	16 60	1 10	1 63	6 29	74 16	100+	0 0	0 0	0 0	2 5
D	1 058	290	503	99 59	99 47	14 68	0 30	2 84	6 47	75 48	100+	0 0	0 0	0 0	5 5
E	1 058	290	550	99 62	99 45	13 77	1 10	2 91	9 02	76 42	100+	0 0	0 0	0 0	4 0
F	1 035	271	473	99 70	97 72	17 12	1 10	3 15	9 50	76 08	100+	0 0	0 0	0 0	8 0
H	1 035	285	422	99 39	98 87	17 30	0 70	3 05	7 89	77 52	100+	0 0	0 0	0 0	5 5
I	1 010	252	479	99 42	99 02	18 39	0 70	5 19	10 55	86 64	100+	9 0	0 0	2 0	14 5

TABLE XV

Test Results on Asphalt Recovered from Oiled Aggregate Mixes

Oil	Months in Service	Penetration 77-100-5	Specific Gravity 77°F	% Soluble in CS_2	% Soluble in CCl_4	% Insoluble in 86° API Naphtha	Flash Point °F	Melting Point R & B °F	Ductility Cm at 77°F	Tests on Residue After Distilling off CS_2 and CCl_4 at 680°F	
										Pen 77-100-5	Pen 32-100-5
A	13	109	1 05	99 38	94 40	25 23	435	120	52	360+	78
B	17	31	1 11	99 98	98 68	36 93	420	130	100+	360+	15
B	6	70	1 11	100 00	97 40	34 30	420	125	100+	224	15
B	5	65	1 10	98 19	93 52	30 23	410	120	100+	360+	36
B	4	89	1 09	99 90	98 89	26 21	425	115	100+	360+	37
B	3	110	1 09	99 67	96 42	24 10	435	115	100+	360+	29
C	16	85	1 08	99 81	93 65	31 70	420	120	100+	360+	33
C	17	84	1 07	99 68	98 39	27 81	435	118	100+	360+	38
C	17	56	1 09	99 69	96 73	29 97	460	144	9	360+	65
D	17	30	1 09	99 22	92 47	34 09	425	125	100+	200	17
D	18	13	1 11	99 91	99 61	37 22	475	154	0	360+	24
D	16	105	1 08	99 73	96 86	36 52	420	110	90	360+	33
D	7	59	1 10	99 96	96 51	31 76	430	122	100+	360+	26
H	5	97	1 07	99 95	99 31	26 19	475	120	100+	360+	59
H	5	90	1 07	99 96	96 05	26 17	471	138	22	360+	68
I	6	40	1 07	97 71	97 71	33 25	380	160	7	20	7

TABLE XVI

RESULTS OBTAINED FROM THE VOLATIZATION TESTS ON RESEARCH OIL 1933

Oil AO-65	Time in Oven at 325°F	Per Cent Loss	Penetration on Residue 77-100-5	Per Cent Solubility in CCl_4	Ductility in Cm on Residue at	
					77°F	39 2°F
A	5 Hrs	8 51	*	*	*	*
	24 Hrs	14 90	360+	99 98	*	*
	48 Hrs	18 20	73	98 64	110+	5
	72 Hrs	19 46	30	96 16	12	0
E	5 Hrs	5 60	*	99 76	*	*
	24 Hrs	11 62	360+	99 62	*	*
	48 Hrs	13 32	360+	98 93	*	92
	72 Hrs	16 62	84	98 43	110+	0
F	5 Hrs	4 29	*	99 76	*	*
	24 Hrs	10 52	360+	99 35	*	*
	48 Hrs	14 00	360+	97 82	*	16
	72 Hrs	16 70	96	96 29	18	6
H	5 Hrs	8 93	*	*	*	*
	24 Hrs	14 54	360+	99 80	*	*
	48 Hrs	18 04	162	99 78	98	67
	72 Hrs	19 14	82	99 65	110+	0
I	5 Hrs	9 01	*	*	*	*
	24 Hrs	14 58	360+	99 39	*	*
	48 Hrs	18 16	85	99 32	18	4
	72 Hrs	19 42	49	99 27	5	2
L	5 Hrs	7 85	*	*	*	*
	24 Hrs	11 64	360+	99 69	*	*
	48 Hrs	14 00	188	99 43	110+	5
	72 Hrs	14 76	94	99 28	17	5

* No tests were made

TABLE XVII

Results Obtained from the Volatization Tests on Research Oil 1933

Oil AO-75	Time in Oven at 325°F	Per Cent Loss	Penetration on Residue 77-100-5	Per Cent Solubility in CCl_4	Ductility in Cm on Residue at 77°F	Ductility in Cm on Residue at 39 2°F
A	5 Hrs	7.33	*	*	*	*
	24 Hrs	13 12	135	96 421	*	*
	48 Hrs	16 14	43	95 238	100	0
	72 Hrs	17 58	23	93 455	19	*
E	5 Hrs	6 23	*	99 747	*	*
	24 Hrs	12 69	178	99 639	*	*
	48 Hrs	16 22	37	99 542	29	0
	72 Hrs	21 04	10	99 413	0	0
F	5 Hrs	3 57	*	98 948	*	*
	24 Hrs	8 62	360+	98 020	*	*
	48 Hrs	9 64	195	96 569	110+	23
	72 Hrs	12 28	51	94 478	87	5
H	5 Hrs	7 25	*	*	*	*
	24 Hrs	13 02	150	99 696	*	*
	48 Hrs	16 24	65	99 438	110+	0
	72 Hrs	17 40	32	98 862	110+	0
I	5 Hrs	3 91	*	*	*	*
	24 Hrs	7 28	360+	99 715	*	*
	48 Hrs	8 58	105	99 619	21	5
	72 Hrs	10 64	58	99 429	6	3
L	5 Hrs	4 36	*	*	*	*
	24 Hrs	7 30	360+	99 812	*	*
	48 Hrs	9 28	184	99 744	110+	16
	72 Hrs	9 92	93	99 681	17	5

* No tests were made

TABLE XVIII

Penetration 77-100-5	Specific Gravity at 77°F	Solubility in CS_2 Per Cent	Solubility in CCl_4 Per Cent	Insoluble in 86° API Naphtha Per Cent	Flash C O °F	Melting Point R & B °F	Ductility at 77°F Cm
Test Results on Residue of Desired Penetration before Mixing with Aggregate							
100	1 109	99 77	99 15	26 27	425	105	100+
80	1 109	99 56	99 12	26 12	440	110	100+
60	1 111	99 77	98 93	29 38	450	120	100+
40	1 112	99 78	99 08	29 84	450	120	100+
20	1 119	99 57	98 68	28 10	465	130	100+
12	1 120	99 53	98 40	31 86	465	140	100+
Results of Tests on the Same Road Oil Mixed with Aggregate Extracted, recovered and Reduced to Desired Penetration							
100	1 101	99 94	98 81	27 75	405	100	100+
85	1 106	99 98	98 63	26 09	415	105	100+
71	1 105	99 94	98 82	31 02	420	105	100+
51	1 106	99 81	98 72	31 08	430	120	100+
30	1 110	99 67	98 27	31 13	435	145	100+
15	1 119	99 94	98 12	33 88	450	140	100+

TABLE XIX

RESULTS OF TESTS ON RESIDUE REDUCED AS OUTLINED IN A S T M D 243-28T
RESEARCH 1933 OIL

Oil AO-65	Per Cent Asphalt	Penetration 77-100-5	Ductility in Cm at			
			77°F	60°F	50°F	39 2°F
A	71 74	118	110+	110+	110+	7
	69 18	58	110+			
	68 14	35	110+			
	65 60	22	110+			
	64 64	20	70			
	61 96	13	15			
	55 96	3	0			
E	71 60	97	110+	110+	0	0
	69 14	74	110+			
	66 78	37	110+			
	63 78	12	110+			
	60 40	6	0			
F	69 30	111	110+	110+	27	0
	68 36	80	110+			
	66 30	54	110+			
	64 62	33	110+			
	63 88	22	71			
	60 59	10	4			
	60 32	8	0			
H	69 90	89	110+	110+	0	0
	68 92	75	110+			
	68 12	57	110+			
	66 80	35	110+			
	64 88	25	110+			
	62 64	11	110+			
	60 92	5	0			
	50 30	2	0			
I	68 76	99	110+	53	13	7 5
	67 66	65	100			
	66 68	49	63			
	66 58	47	59			
	63 96	25	12			
	61 58	13	4			
	58 82	12	0			
L	73 38	104	110+	95	15	10
	71 14	75	100			
	69 96	56	96			
	67 30	38	48			
	66 20	25	9			
	64 98	20	9			
	64 22	18	5			

TABLE XX

RESEARCH 1933 OIL—RESULTS OF TESTS ON RESIDUE REDUCED AS OUTLINED IN A S T M D 243-28T

Oil AO-75	Per Cent Asphalt	Penetration 77-100-5	Ductility in Cm at			
			77°F	60°F	50°F	39 2F
A	76 76	93	110+	110+	93	0
	75 46	68	110+			
	72 92	41	110+			
	68 76	19	110+			
	68 64	13	38			
	67 48	12	38			
	67 24	12	16			
	61 02	2	0			
E	78 02	99	110+	110+	51	0
	76 45	62	110+			
	74 04	20	110+			
	71 44	14	110+			
	69 12	10	0			
F	76 02	94	110+	110+	48	0
	75 26	68	110+			
	72 86	45	110+			
	71 60	32	110+			
	70 14	12	110+			
	69 50	11	80			
	66 82	8	0			
H	78 12	86	110+	110+	0	0
	77 28	65	110+			
	74 32	36	110+			
	72 24	19	110+			
	69 98	10	110+			
	68 24	5	0			
	66 54	3	0			
I	77 50	82	110+	20	6	5
	76 98	70	110+			
	75 96	52	46			
	74 14	40	21			
	73 22	30	10			
	72 16	25	10			
	69 92	21	7			
	66 72	13	3			
	65 12	10	0			
L	76 99	114	110+	110+	10	8
	76 42	100	110+			
	75 70	75	110+			
	75 32	60	96			
	73 96	39	29			
	72 50	33	16			
	70 16	24	9			
	66 92	15	7			
	64 21	9	0			

TABLE XXI

COMPARISON OF OILS BEFORE AND AFTER INCORPORATING IN ROAD SURFACING

Results of Orignal Oil before Mixing with Aggregate

Oil	Flash Point °F	Spec Grav at 60°F	Per Cent Soluble in CCl_4	Sec Viscosity Saybolt Furol 122°F	Per Cent Insoluble in 86°API Naphtha	Per Cent Loss 5 Hrs 325°F	Per Cent Sediment	Melting Point	Per Cent Asphalt	Penetration 77–100–5	Ductility 77°F
A	240	1 037†	99 40	189	14 13	7 53	0 64		71 41		100+
A	265	1 052†	99 71	431	19 55	5 71	0 55		76 00		100+
B	305	1 062†	99 81	324	21 81	3 45			75 31		100+
B	305	1 062†	99 81	324	21 81	3 45			75 31		100+
E	285	1 062†	99 76	481	15 55	3 64	0 62		78 28		100+
E	290	1 060†	99 69	439	16 30	2 80	0 40		76 40		100+
G	285	1 050†	99 57	299	30 27	5 70			74 70		100+
G	285	1 051†	99 63	281	26 41	5 61	0 55		72 35		100+
H*	240	1 062	99 69	401	19 44	5 55	0 40		78 64		100+
E*	205		99 66	244							100+
G	170		99 88	571							100+
24363	270	1 040	99 81	480	14 19	6 06	0 50		78 50		100+

Results Obtained from Road Oil Extracted from Samples Taken from Road Surface and Reduced to Penetrations

Oil	Months in Service	Spec Grav at 60°F	Per Cent Soluble in CCl_4	Per Cent Ash	Per Cent Insoluble in 86°API Naphtha	Per Cent Loss 5 Hrs 325°F	Pene on Loss 77–100–5	Melting Point °F	Penetration 77–100–5	Ductility 77°F
A	10	1 05	95 11	0 32	30 24	0 31	50	170	84	3
A	25	1 07	99 16	0 06	28 45	0 75	56	120	125‡	89
B	34	1 07	93 84	1 99	32 04	0 15	15	125	50	110+
B	34	1 10	96 34	1 50	28 80	0 84	183	100	300‡	80
E	22	1 07	98 90	0 14	26 13	0 72	91	105	275‡	80
E	22	1 08	99 09	0 07	29 55	0 24	26	135	44	110+
G	34	1 11	97 18	0 24	33 71	0 13	18	135	97	10
G	35	1 07	99 23	0 04	28 72	0 79	38	112	95‡	20
H	10	1 10	98 74	0 13	34 07	1 38	76	105	163‡	110+
E‡	12	1 06	99 08	0 07	31 45	0 42	55	185	75‡	0
G	12	1 08	98 48	0 14	33 56	0 22	76	115	118	110+
G‡	13	1 07	99 09	0 06	26 79	0 90	85	110	139‡	110+

* Medium Curing Cutbacks

† Specific Gravity at 77°F.

‡ It was not necessary to reduce these samples by method D 243–28T as the residues after distilling off the CCL_4 & CS_2 at 680°F yielded asphalts of the penetrations as shown.

TABLE XXII

1932 Research Oils

Test Data on Solvents Distilled from AO-75 1932 Oils

Oil	Specific Gravity at 77°F	Viscosity Saybolt Universal at 122°F	Flash Point C O °F	Pour Point °F
A	0 900	40 Sec	140	45
B	0 910	40 Sec	175	15
C	0 953	48 Sec	175	35
D	0 930	42 Sec	200	45
E	0 985	43 Sec	145	45
F	0 885	41 Sec	170	45
H	0 933	42 Sec	150	40
I	0 903	38 Sec	150	60

Distillation Per Cent Off by Volume

Oil	I B P	10	20	30	40	50	60	70	80	90	95	Max Temp	Per Cent Re-covery	Per Cent Res-idue
A	226°F	477	520	549	570	592	621	646	689	738	761	779	98 5	1 0
B	330	465	510	535	570	600	625	655	685	725		780	98 5	1 0
C	297	525	568	597	621	642	662	678	698	734	759	779	98 5	1 0
D	270	468	518	538	556	603	644	657	687	723	752	788	97 5	1 5
E	270	507	538	569	590	615	639	644	693	741	779		97 5	2 0
F	289	487	527	547	565	586	608	635	667	725	748		98 5	1 0
H	298	493	520	547	572	597	626	657	694	743	770	775	96 0	3 0
I	262	462	498	532	552	572	592	612	644	684	718	780	98 5	1 0

TABLE XXIII

1932 Research Oils

AO-75 1932 Oils

Oil	Viscosity Saybolt Furol at Indicated Temperatures					
	100°F	122°F	140°F	160°F	180°F	210°F
A	1782	563	219	129	57	25
B	1365	375	154	67	36	20
C	1691	504	207	95	47	23
D	1965	503	222	94	43	23
E	1920	550	218	92	47	25
F	1675	475	224	124	55	24
H	1511	422	182	84	42	22
I	1405	479	223	100	57	27
Ave	1664	484	206	98	48	24

TABLE XXIV

RESULTS OF TESTS ON CUTBACK ASPHALTS

Type of Tests	Type of Material								
	21652 RC 2	21719 RC 2	22961 RC 3	23067 MC 3	23484 MC 2K	23647 RC 3	23656 RC3	22680 RC3	23809 RC3
Specific Gravity—60°F	0 966	0 965	0 963	1 025	0 970	0 960	0 990	0 958	0 955
Viscosity Saybolt Furol 77°F		219							
Viscosity Saybolt Furol 122°F	257		697			655	610	733	667
Viscosity Saybolt Furol 140°F				331	145				
Flash C O °F	95	120	125	195	165	140	120	130	110
Distillation Per Cent Off by Volume 437°F	13 0	9 3	9 0	0 0	0 0	15 0	6 0	11 0	11 0
Distillation Per Cent Off by Volume 600°F	20 0	20 5	19 5	9 8	19 5	23 5	15 0	18 5	17 5
Distillation Per Cent Off by Volume 680°F	22 5	23 5	22 0	15 3	25 5	25 5	17 0	20 5	19 5
Tests on Distillation Residue									
Penetration 77–100–5	91	97	77	220	124	71	99	79	88
Ductility—Cm 77°F	100+	100+	60+	100+	110+	110+	110+	110+	110+
Solubility Per Cent in CS_2	99 81	99 83	99 81					99 87	
Solubility Per Cent in CCl_4				99 77	99 26	99 86	99 64		99 67
% Loss—50–5–325	0 19	0 40	0 29	0 58	0 74	0 29	0 24	0 58	0 26
Residue after Volatilization Penetration, 77–100–5	70	63	57	97	74	44	72	45	64
Residue after Volatilization Ductility, Cm 77°F	110+	67	46	100+	41	73	110+	91	110+
Dst Res Reduced by ASTM D243-28T Penetration, 77–100–5	28	22	12	22	12	25	28		
Dst Res Reduced by ASTM D243-28T Ductility, Cm 77°F	5 5	3	0 0	102	0 0	14	6		
Oxidation Test	Good	Poor	Good	Poor	Fair	Good	Poor	Fair	Good
Ultra Violet Light for 20 Hours at 77°F	Dull	Good	Good	Good	Good	Good	Bad	Good	Good
Oliensis, Heterogeneity	Non-homogeneous			Non-homogeneous	Non-homogeneous		Non-homogeneous	Homogeneous	