U. S. DEPARTMENT OF COMMERCE NATIONAL BUREAU OF STANDARDS

RESEARCH PAPER RP1073

Part of Journal of Research of the National Bureau of Standards, Volume 20, February 1938

WEATHERING TESTS ON FILLED COATING ASPHALTS[1]

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ABSTRACT

The durabilities of filled and unfilled coating asphalts were determined both in outdoor and in accelerated exposures. The results show that, in general, the durability of coating asphalt to weathering can be improved by the addition of mineral fillers, and that there is a difference in the effectiveness of various sizes and types of fillers. The data demonstrate the similarity between outdoor and accelerated weathering.

CONTENTS

I. INTRODUCTION

Asphalt shingles and roll-roofings are made by impregnating felt with a relatively soft asphalt and then surfacing with a harder asphalt known as a coating asphalt. Early in the manufacture of these roofings, unfilled coatings were considered superior to those containing mineral filler, but, because of the favorable results obtained in accelerated weathering tests on filled coatings, it has become general practice in recent years to mix finely ground slate, limestone, and similar mineral fillers with the asphalt coatings. Filled coatings, in general, are less affected by sunlight and less subject to plastic flow. However, as no data were available to show the serviceability of filled coatings the present investigation was undertaken to determine the effect of various kinds and grades of commercial fillers on the weather-resisting properties of coating asphalt. Various asphalt-filler mixtures were prepared and tested. Specific gravities, compacting weights, sieve analyses of the mineral fillers, and softening points and penetrations on the asphalt-filler mixtures were determined.

[1] A paper reporting the results up to 1½ years of outdoor exposure was published in the Proc. Am. Soc. Testing Materials 36, pt. II, 486 (1936).

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The weather-resisting properties of the asphalt-filler mixtures were determined by exposing them outdoors in various localities, and to accelerated weathering. Comparisons were made of the durabilities of the various coatings, and also between the effects of accelerated and outdoor exposures.

II. PREPARATION, COMPOSITIONS, AND MODE OF EXPOSURE OF PANELS

Two asphalts of different softening points were used for preparing the asphalt-filler mixtures. Both were made from the same crude

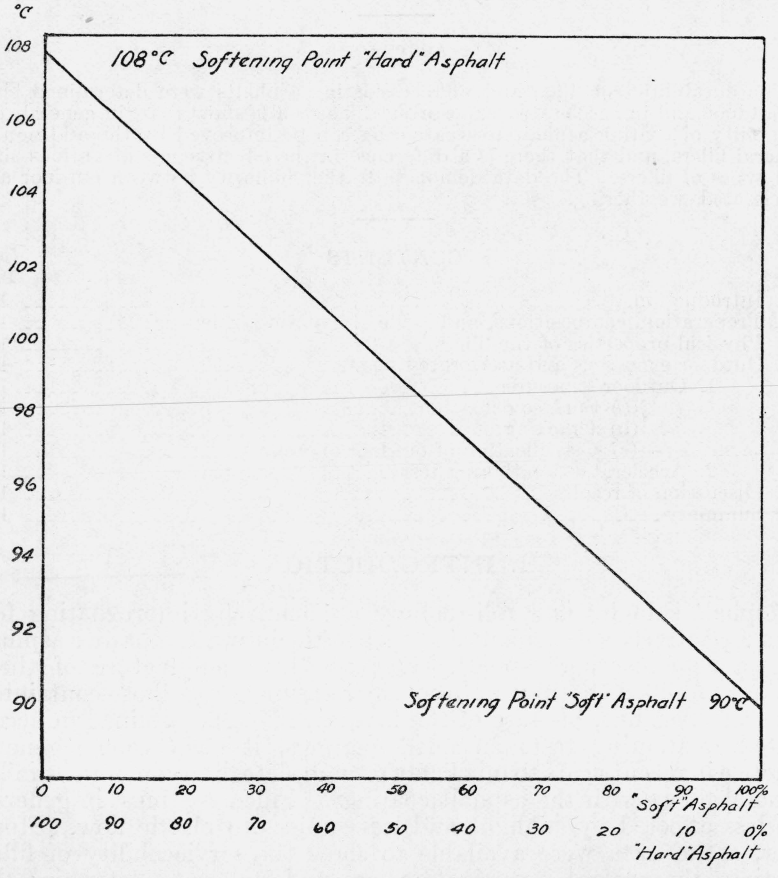

FIGURE 1.—*Ratio of hard and soft asphalts to obtain an asphalt of definite softening point.*

petroleum in a single operation, and their preparation differed only in the duration of the blowing.

The "soft" and "hard" asphalts were so blended that when combined with 15, 25, and 35 percent by weight of various mineral fillers, the softening points of the resulting mixtures were all approximately the same as that of the original "hard" asphalt, namely, 108° C. The proper blend of the two asphalts was determined graphically by

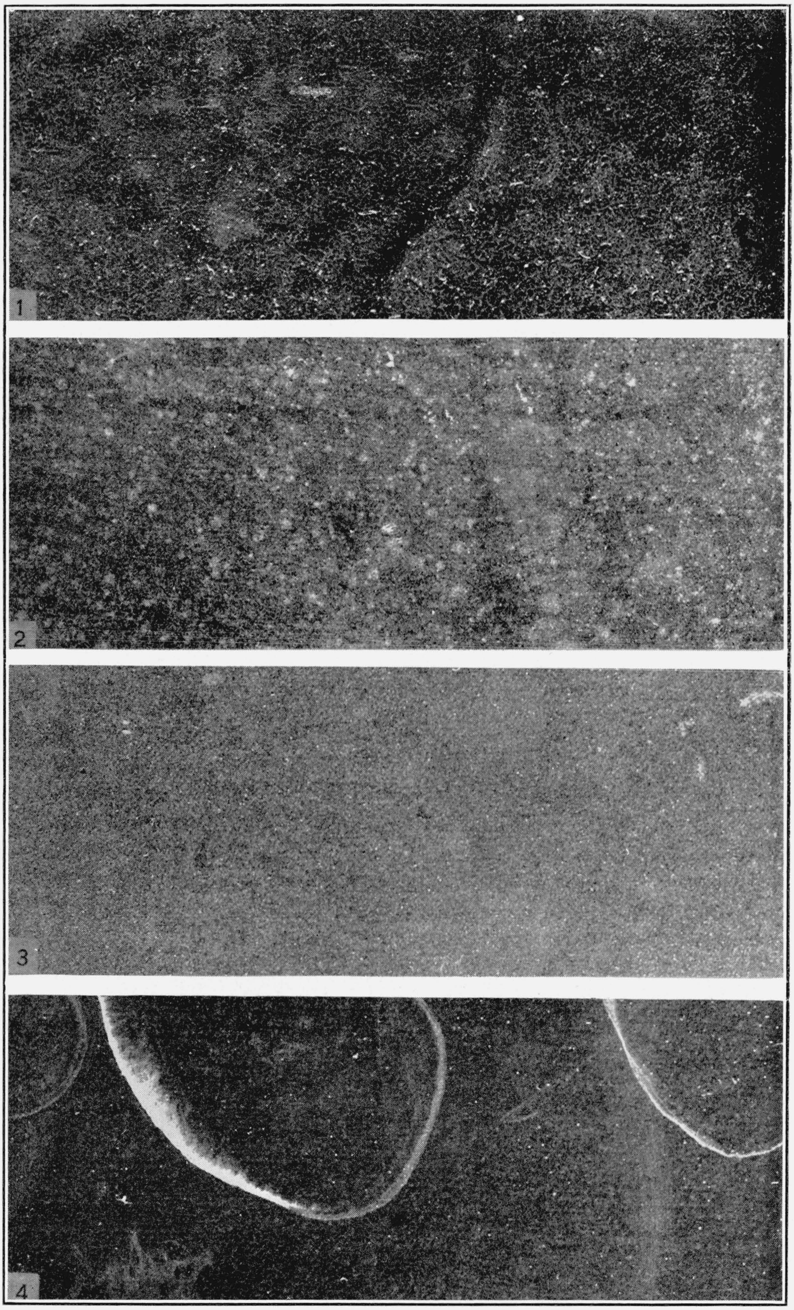

FIGURE 2.—*Specimens of group I (table 4).*

Comparison of specimens 30 (table 1) in their outdoor- and accelerated-weathering exposures. The specimens contain 35 percent of talc (filler 12). Exposures: 1, accelerated weathering; 2, Los Angeles; 3, Washington; and 4, Manville.

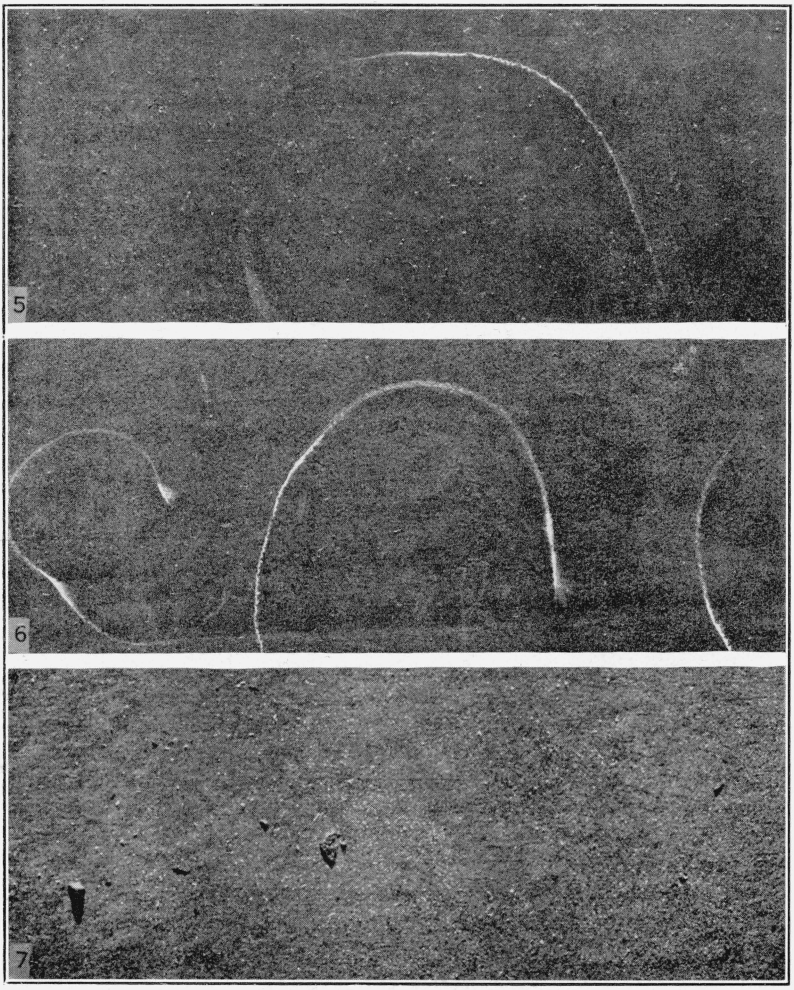

FIGURE 3.—*Specimens of group I.*

Comparison of specimens 30 (table 1) in their outdoor- and accelerated-weathering exposures. The specimens contain 35 percent of talc (filler 12). Exposures: 5, Chicago; 6, Buffalo; and 7, New Orleans.

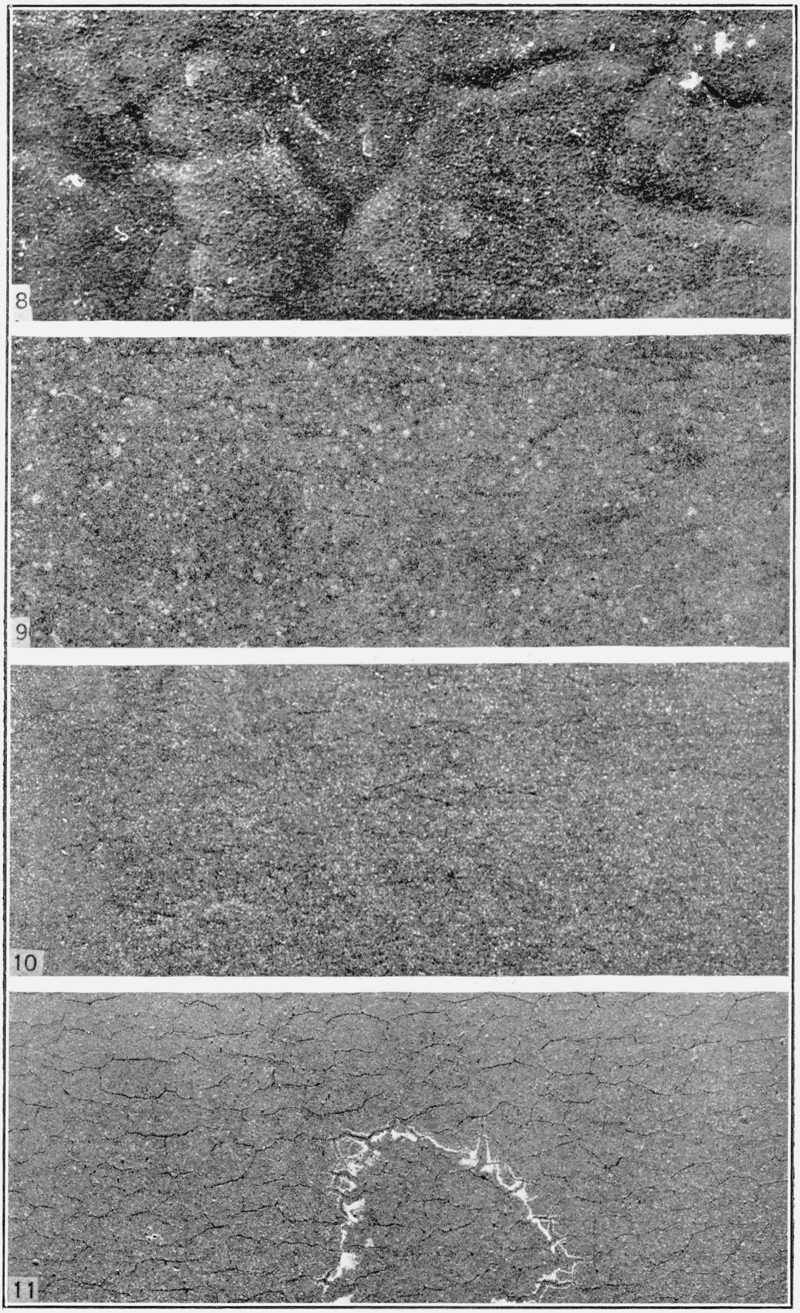

FIGURE 4.—*Durable specimens of group II (table 4).*

Comparison of specimens 19 (table 1) in the outdoor- and accelerated-weathering exposures. The specimens contain 35 percent of greenstone (filler 7). Exposures: 8, accelerated weathering; 9, Los Angeles; 10, Washington; and 11, Manville.

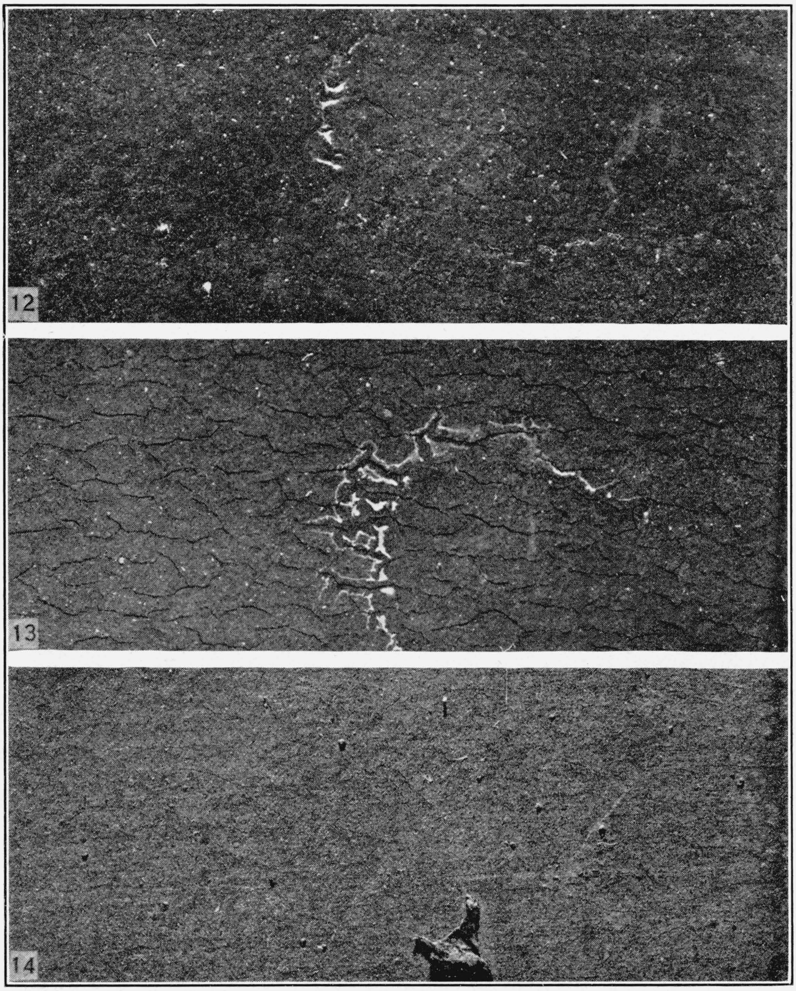

FIGURE 5.—*Durable specimens of group II.*

Comparison of specimens 19 (table 1) in the outdoor- and accelerated-weathering exposures. The specimens contain 35 percent of greenstone (filler 7). Exposures: 12, Chicago; 13, Buffalo; and 14, New Orleans.

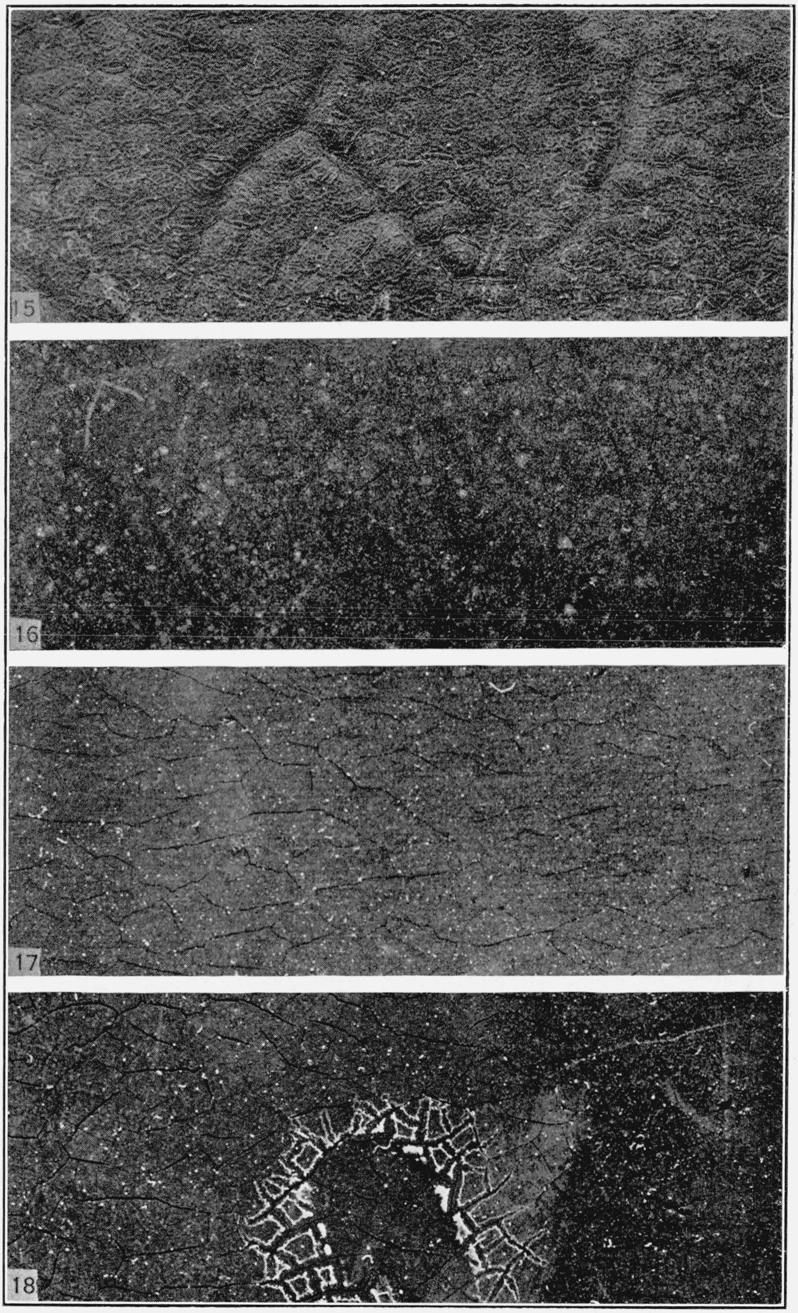

FIGURE 6.—*Less durable specimens of group II (table 4).*

Comparison of specimens 21 (table 1) in the outdoor- and accelerated-weathering exposures. The specimens contain 15 percent of greenstone (filler 7). Exposures: 15, accelerated weathering; 16, Los Angeles; 17, Washington; and 18, Manville.

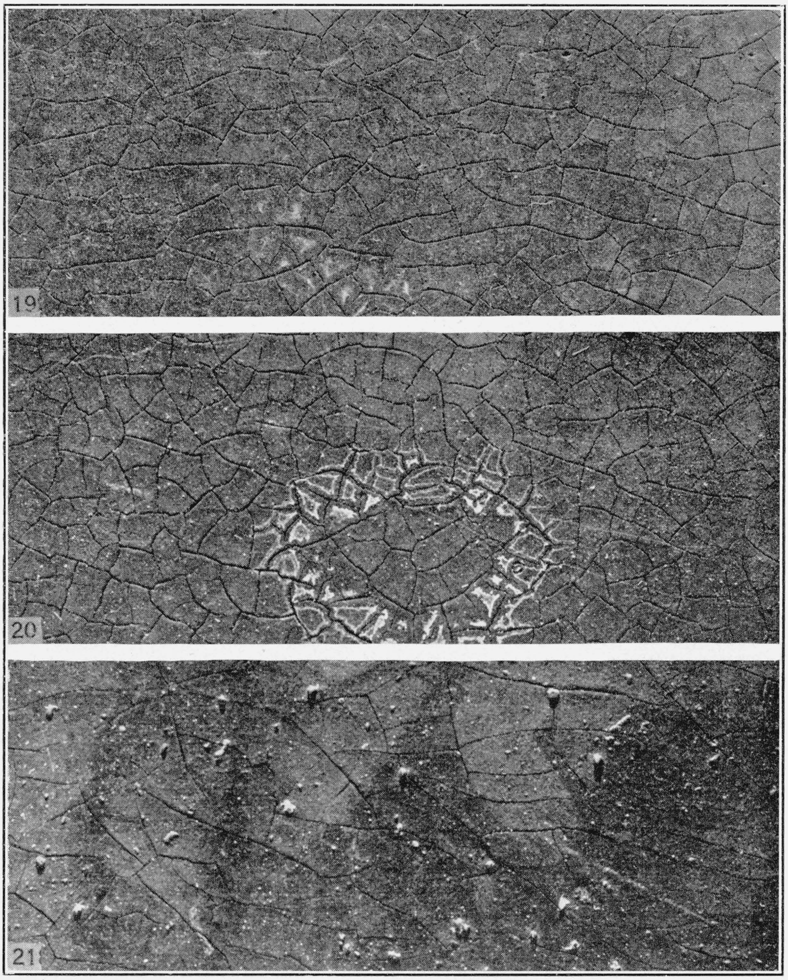

FIGURE 7.—*Less durable specimens of group II.*

Comparison of specimens 21 (table 1) in the outdoor- and accelerated-weathering exposures. The specimens contain 15 percent of greenstone (filler 7). Exposures: 19, Chicago; 20, Buffalo; and 21, New Orleans.

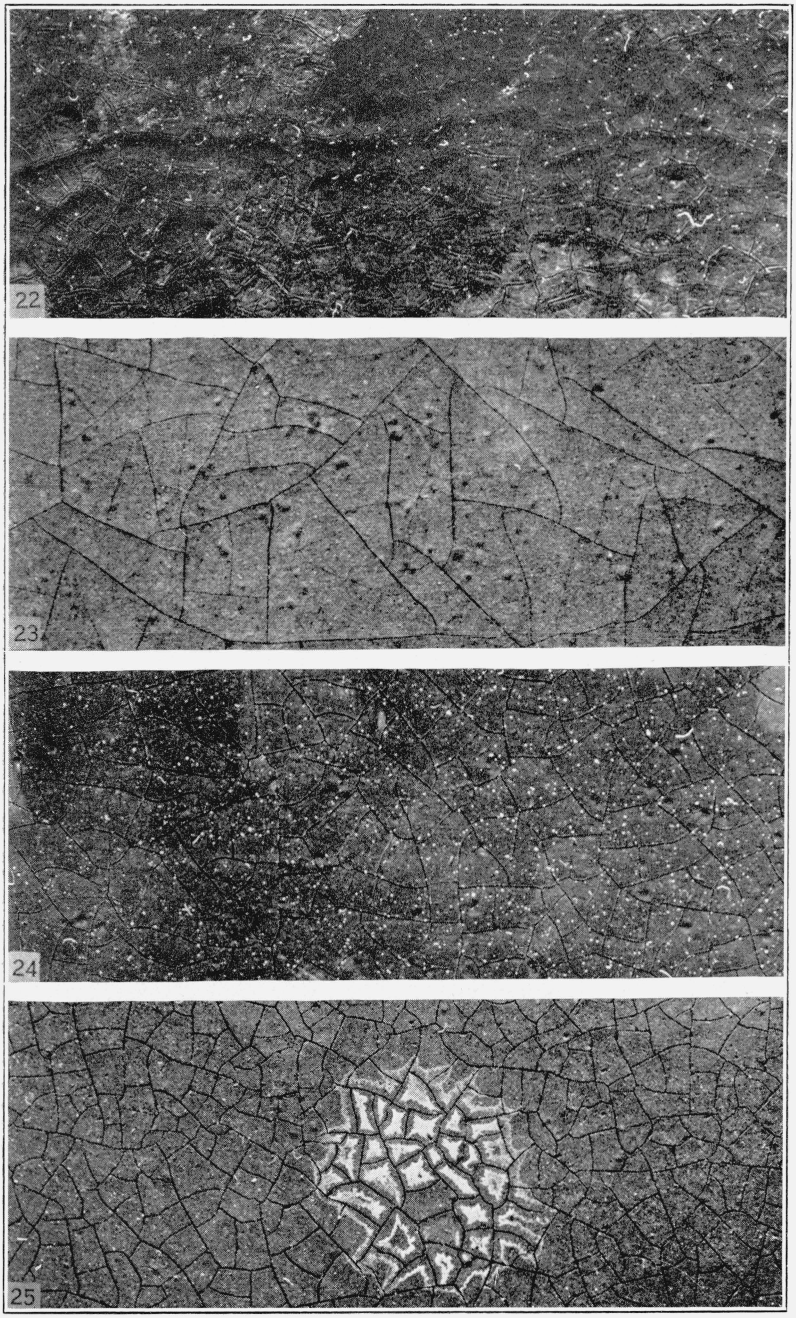

FIGURE 8.—*Specimens of group III (table 4).*

Comparison of specimens 24 (table 1) in the outdoor- and accelerated-weathering exposures. The specimens contain 15 percent of hydrated lime (filler 8). Exposures: 22, accelerated weathering; 23, Los Angeles; 24, Washington; and 25, Manville.

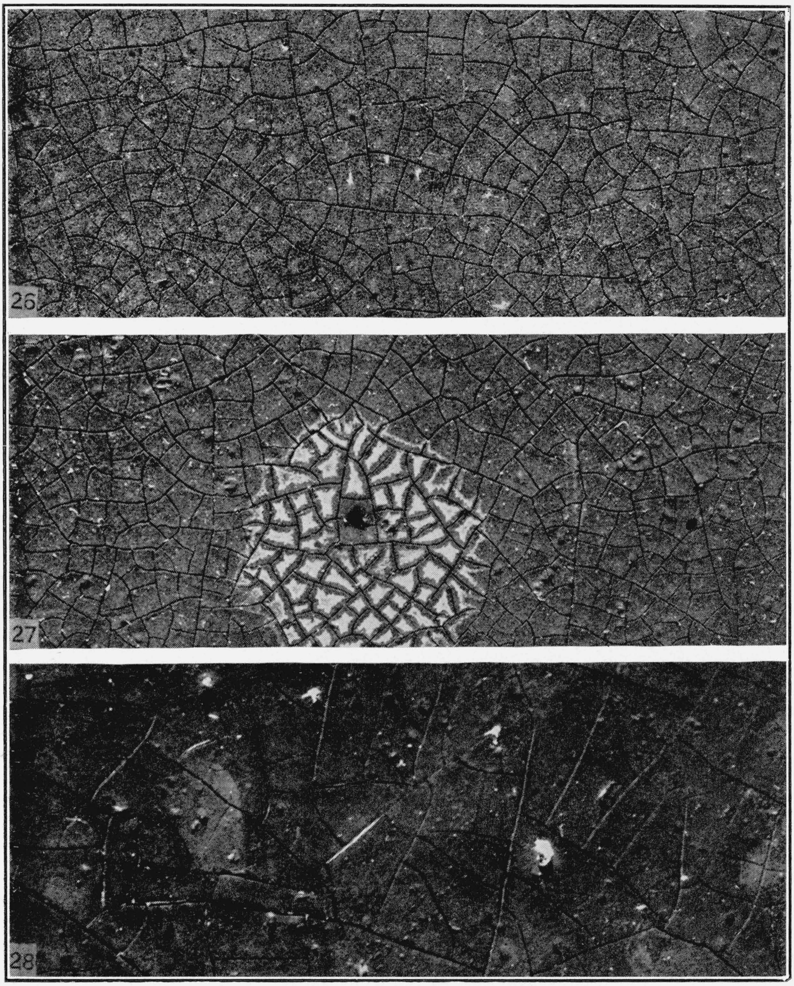

FIGURE 9.—*Specimens of group III.*

Comparison of specimens 24 (table 1) in the outdoor- and accelerated-weathering exposures. The specimens contain 15 percent of hydrated lime (filler 8). Exposures: 26, Chicago; 27, Buffalo; and 28, New Orleans.

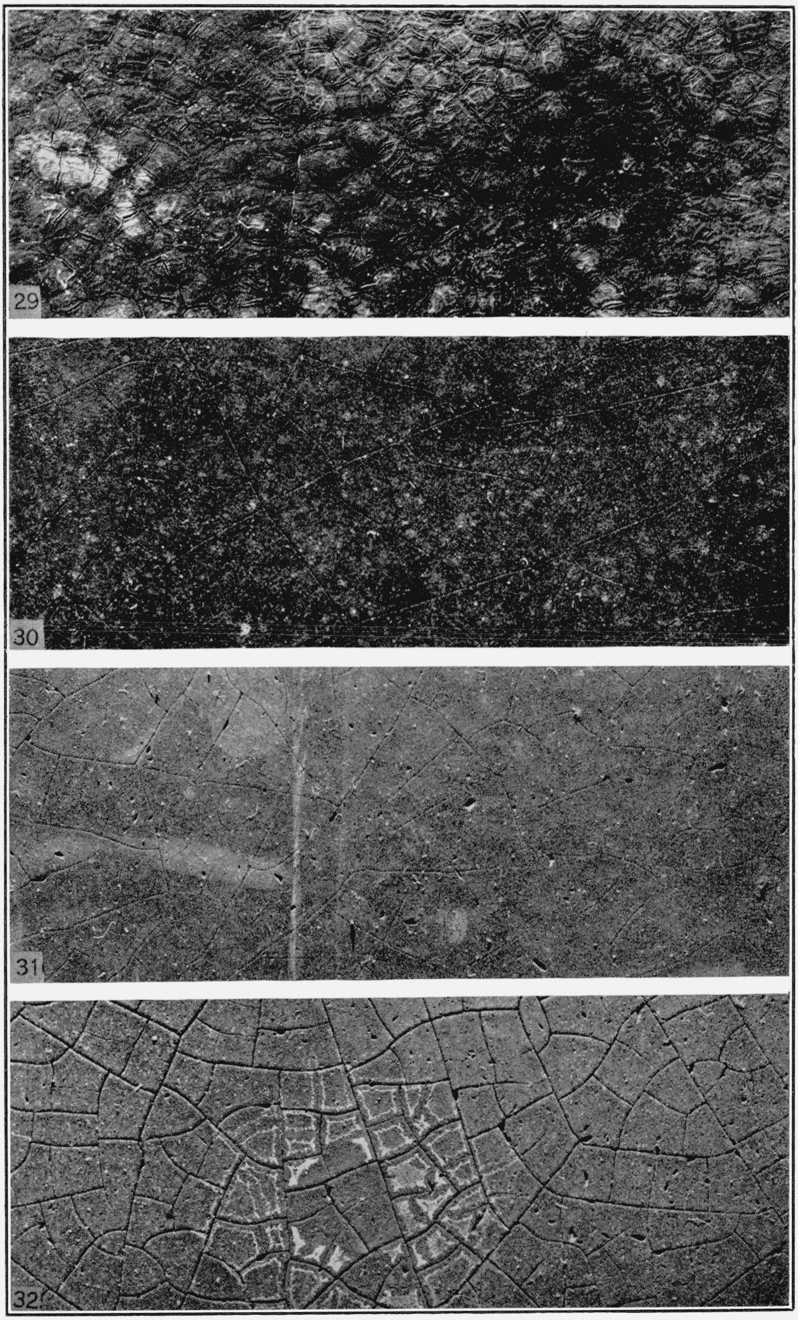

FIGURE 10.—*Unfilled-coating asphalt (specimens 55, table 1) in the outdoor- and accelerated-weathering exposures.*

Exposures: 29, accelerated weathering; 30, Los Angeles; 31, Washington; and 32, Manville.

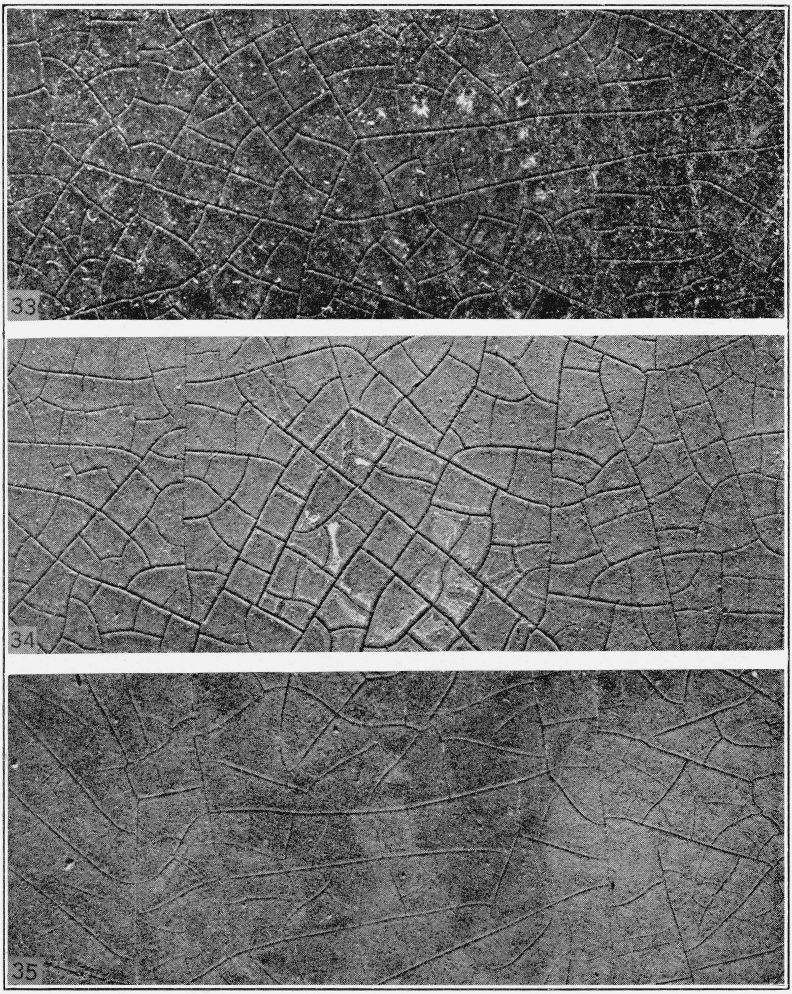

FIGURE 11.—*Unfilled-coating asphalt (specimens 55, table 1) in the outdoor- and accelerated-weathering exposures.*

Exposures: 33, Chicago; 34, Buffalo; and 35, New Orleans.

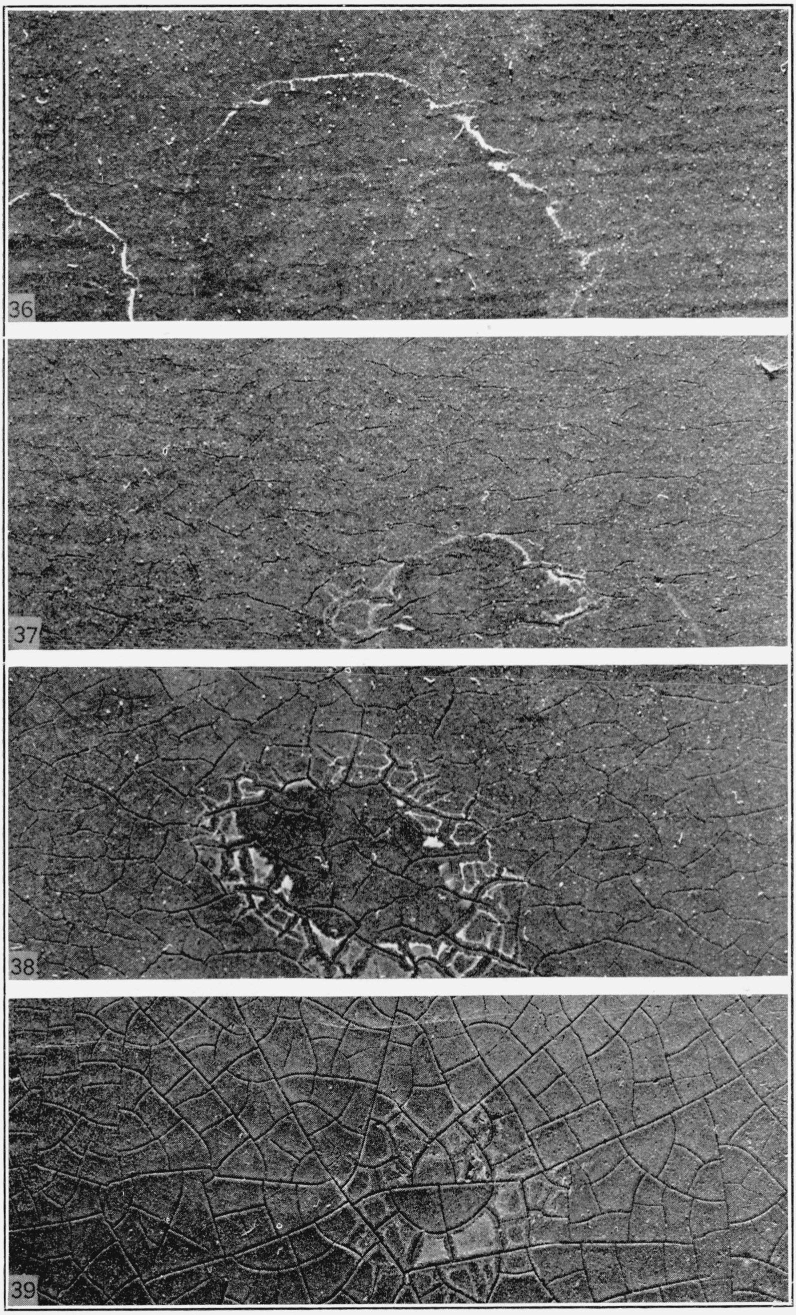

FIGURE 12.—*Comparison of specimens containing 35, 25, and 15 percent of slate, respectively, with the unfilled-coating asphalt.*

All specimens exposed at Buffalo.

Compositions: 36. Specimen 13 (table 1) containing 35 percent of slate, filler 5.
37. Specimen 14 (table 1) containing 25 percent of slate, filler 5.
38. Specimen 15 (table 1) containing 15 percent of slate, filler 5.
39. Specimen 54 (table 1) coating asphalt, without filler.

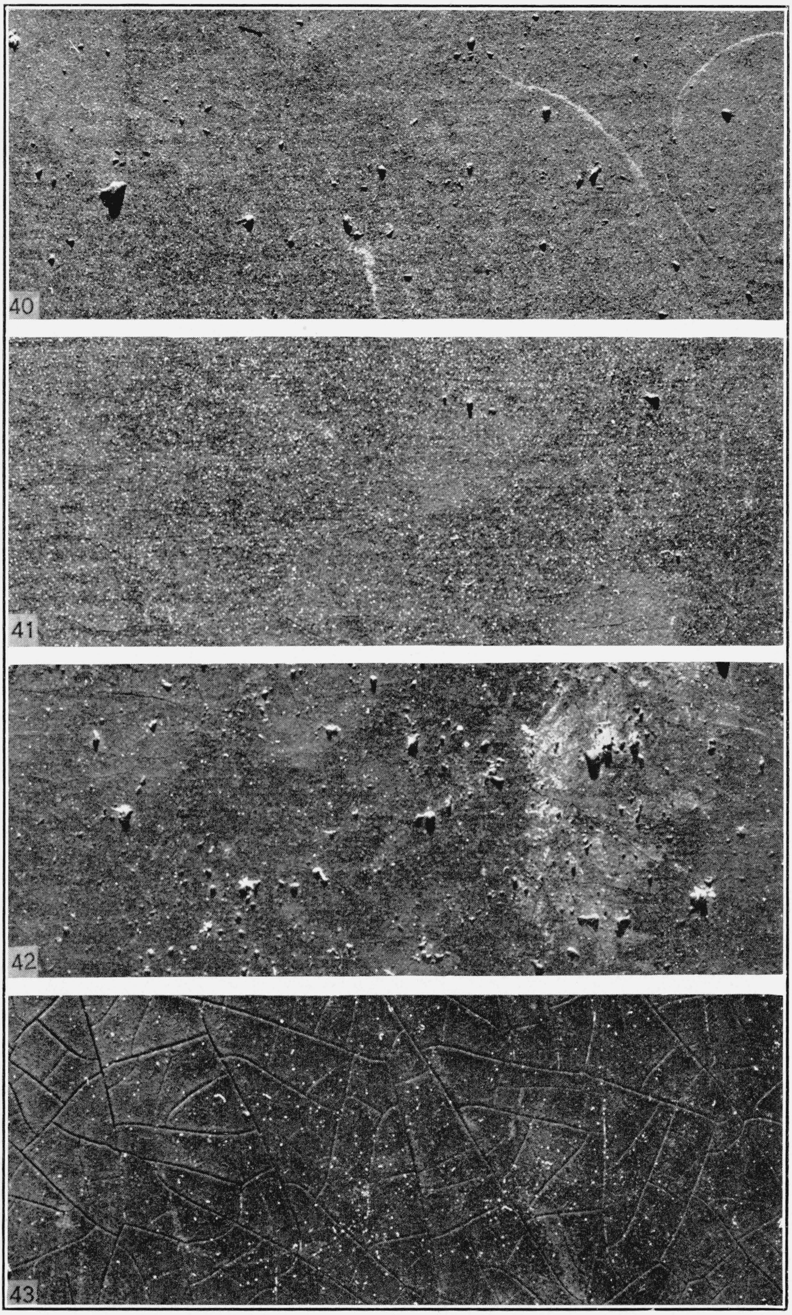

FIGURE 13.—*Comparison of specimens containing 35, 25, and 15 percent of slate, respectively, with the unfilled-coating asphalt.*

All specimens exposed at New Orleans.

Compositions: 40. Specimen 13 (table 1) containing 35 percent of slate, filler 5.
41. Specimen 14 (table 1) containing 25 percent of slate, filler 5.
42. Specimen 15 (table 1) containing 15 percent of slate, filler 5.
43. Specimen 54 (table 1) coating asphalt, without filler.

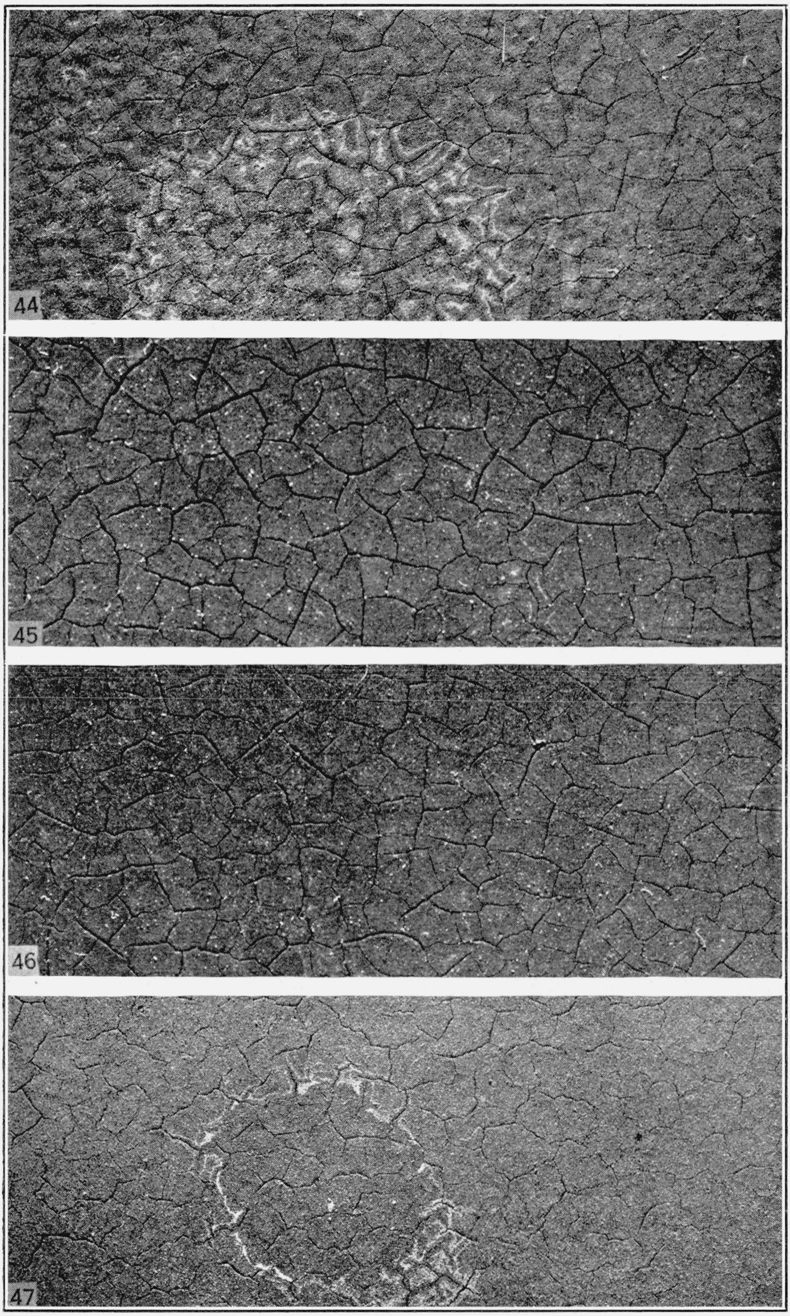

FIGURE 14.—*Comparison of specimens containing various fillers.*

All specimens exposed at Buffalo.

Compositions: 44. Specimen 25 (table 1) containing 35 percent of trap rock, filler 9.
45. Specimen 4 (table 1) containing 35 percent of dolomite, filler 2.
46. Specimen 10 (table 1) containing 35 percent of limestone, filler 4.
47. Specimen 33 (table 1) containing 35 percent of silica, filler 13.

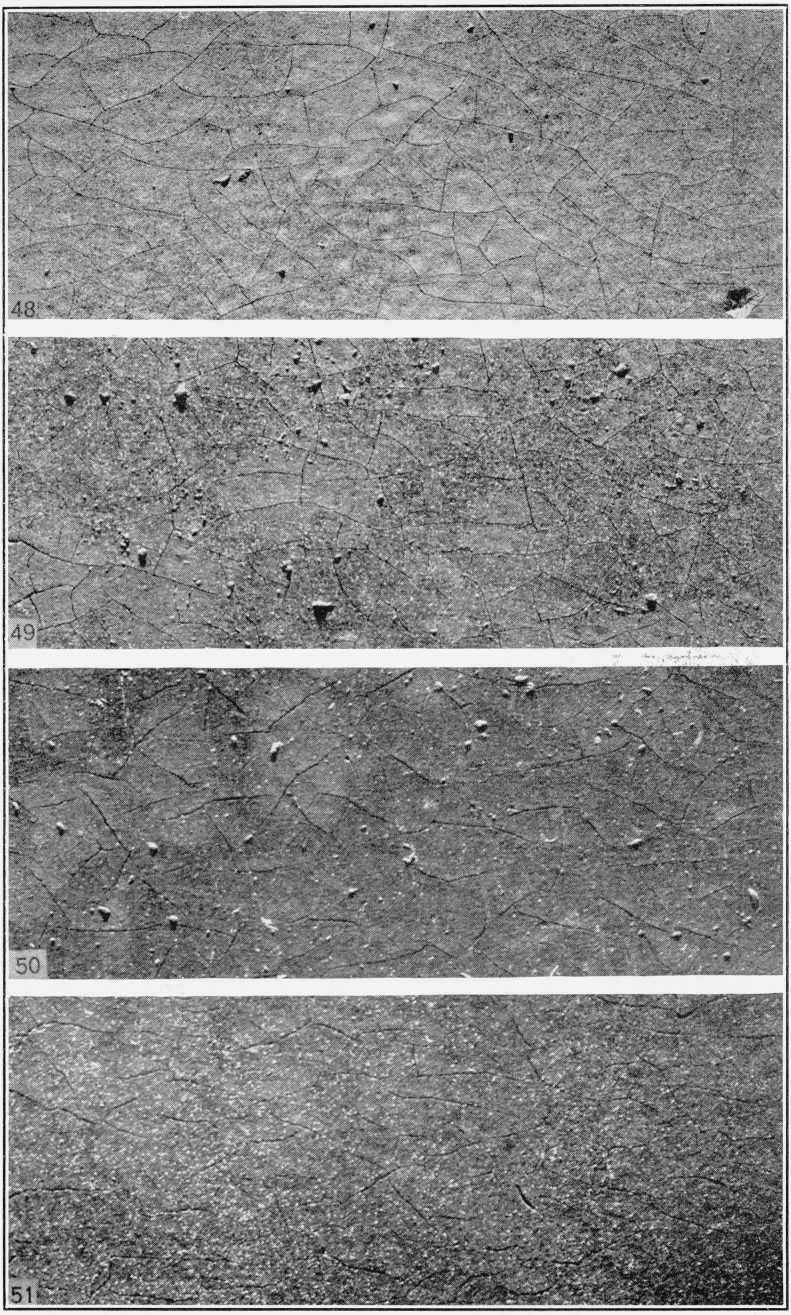

FIGURE 15.—*Comparison of specimens containing various fillers.*

All specimens exposed at New Orleans.

Compositions: 48. Specimen 25 (table 1) containing 35 percent of trap rock, filler 9.
49. Specimen 4 (table 1) containing 35 percent of dolomite, filler 2.
50. Specimen 10 (table 1) containing 35 percent of limestone, filler 4.
51. Specimen 33 (table 1) containing 35 percent of silica, filler 13.

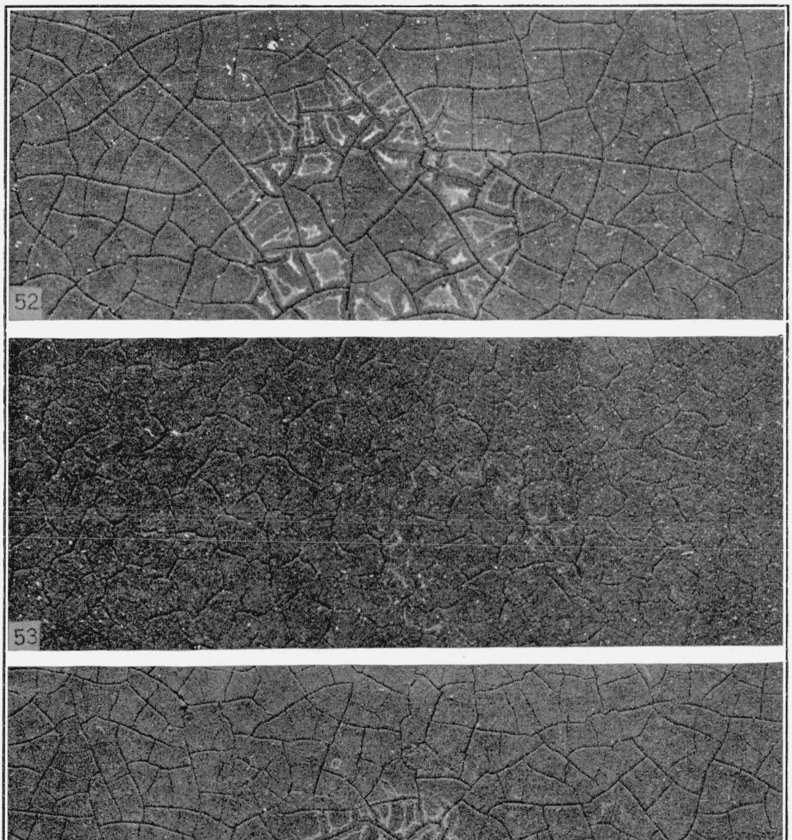

FIGURE 16.—*Comparison of specimens containing limestone filler of various particle sizes.*

All specimens exposed at Buffalo.

Compositions: 52. Specimen 49 (table 1) containing 25 percent of limestone, filler 18, passing No. 200 sieve.
53. Specimen 52 (table 1) containing 25 percent of limestone, filler 19, passing No. 100 but retained on No. 200 sieve.
54. Specimen 11 (table 1) containing 25 percent of limestone, filler 4, 91 percent passing No. 200 sieve.

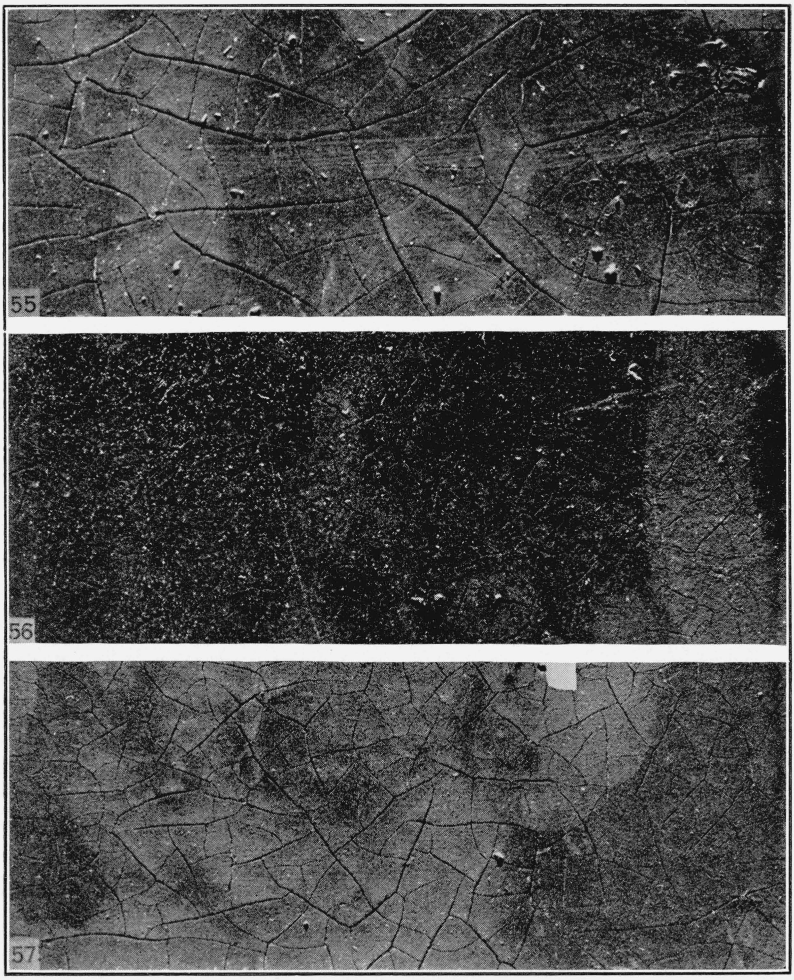

FIGURE 17.—*Comparison of specimens containing limestone filler of various particle sizes.*

All specimens exposed at New Orleans.

Compositions: 55. Specimen 49 (table 1) containing 25 percent of limestone, filler 18, passing No. 200 sieve.
56. Specimen 52 (table 1) containing 25 percent of limestone, filler 19, passing No. 100 but retained on No. 200 sieve.
57. Specimen 11 (table 1) containing 25 percent of limestone, filler 4, 91 percent passing No. 200 sieve.

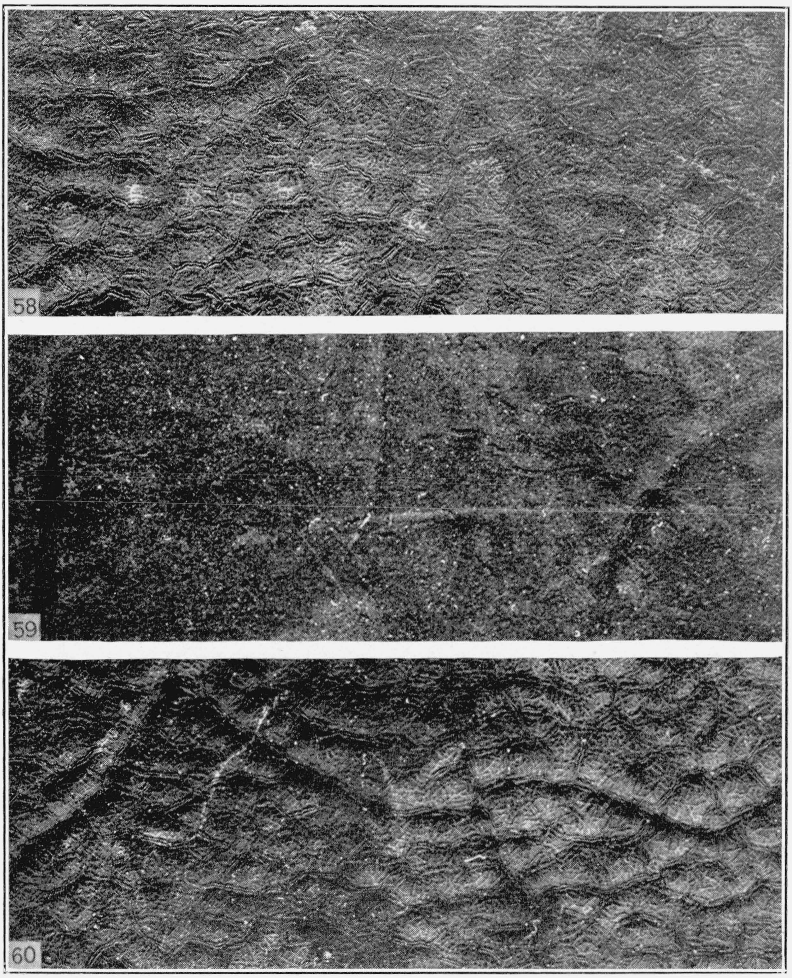

FIGURE 18.—*Comparison of specimens containing limestone filler of various particle sizes.*

All specimens exposed to accelerated weathering.

Compositions: 58. Specimen 49 (table 1) containing 25 percent of limestone, filler 18, passing No. 200 sieve.
59. Specimen 52 (table 1) containing 25 percent of limestone, filler 19, passing No. 100 but retained on No. 200 sieve.
60. Specimen 11 (table 1) containing 25 percent of limestone, filler 4, 91 percent passing No. 200 sieve.

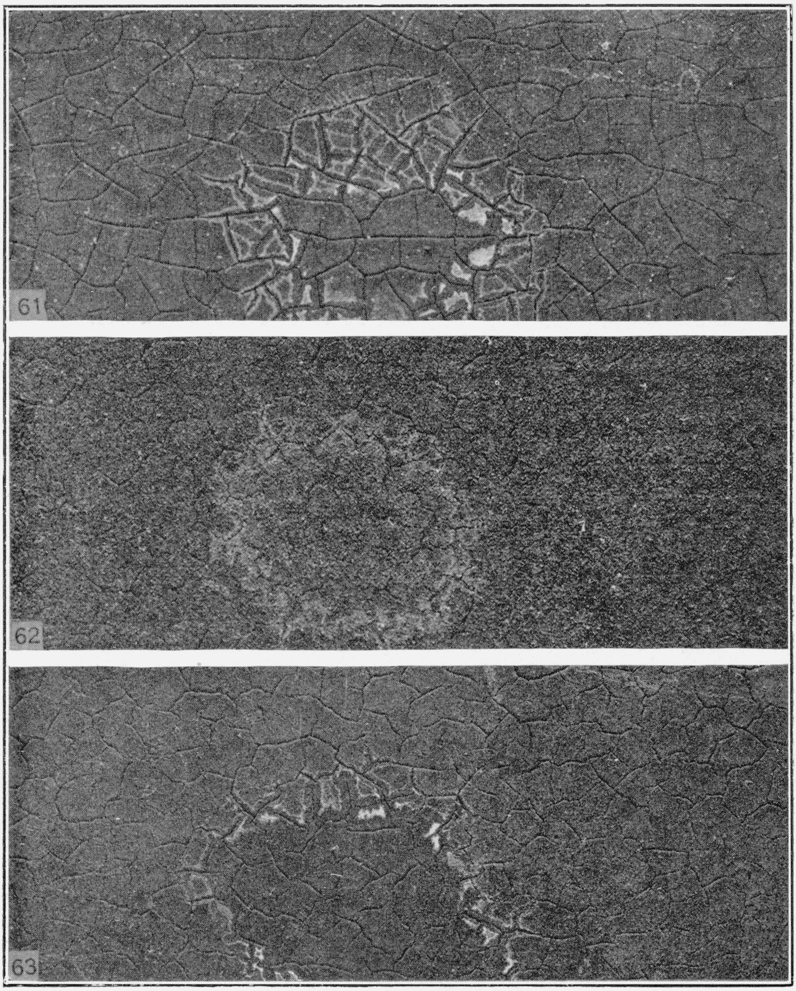

FIGURE 19.—*Comparison of specimens containing silica of various particle sizes as filler.*

All specimens exposed at Buffalo.

Compositions: 61. Specimen 37 (table 1) containing 25 percent of silica, filler 14, passing No. 200 sieve.
62. Specimen 40 (table 1) containing 25 percent of silica, filler 15, passing No. 100 but retained on No. 200 sieve.
63. Specimen 34 (table 1) containing 25 percent of silica, filler 13, 67 percent passing No. 200 sieve.

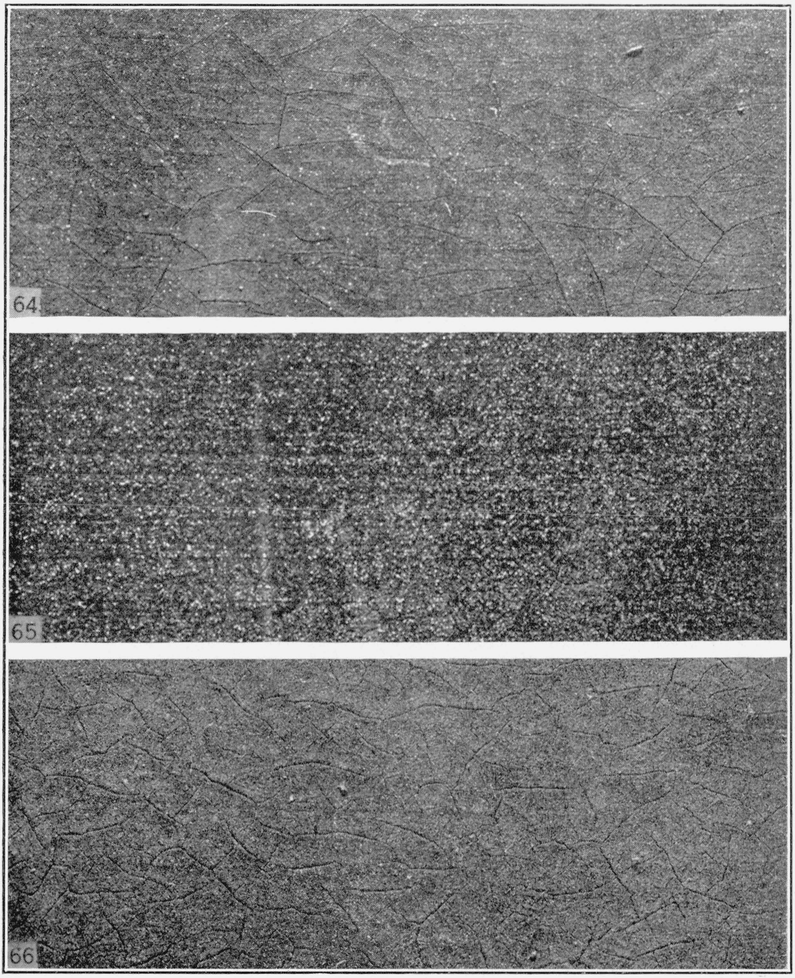

FIGURE 20.—*Comparison of specimens containing silica of various particle sizes as filler.*

All specimens exposed at New Orleans.

Compositions: 64. Specimen 37 (table 1) containing 25 percent of silica, filler 14, passing No. 200 sieve.
65. Specimen 40 (table 1) containing 25 percent of silica, filler 15, passing No. 100 but retained on No. 200 sieve.
66. Specimen 34 (table 1) containing 25 percent of silica, filler 13, 67 percent passing No. 200 sieve.

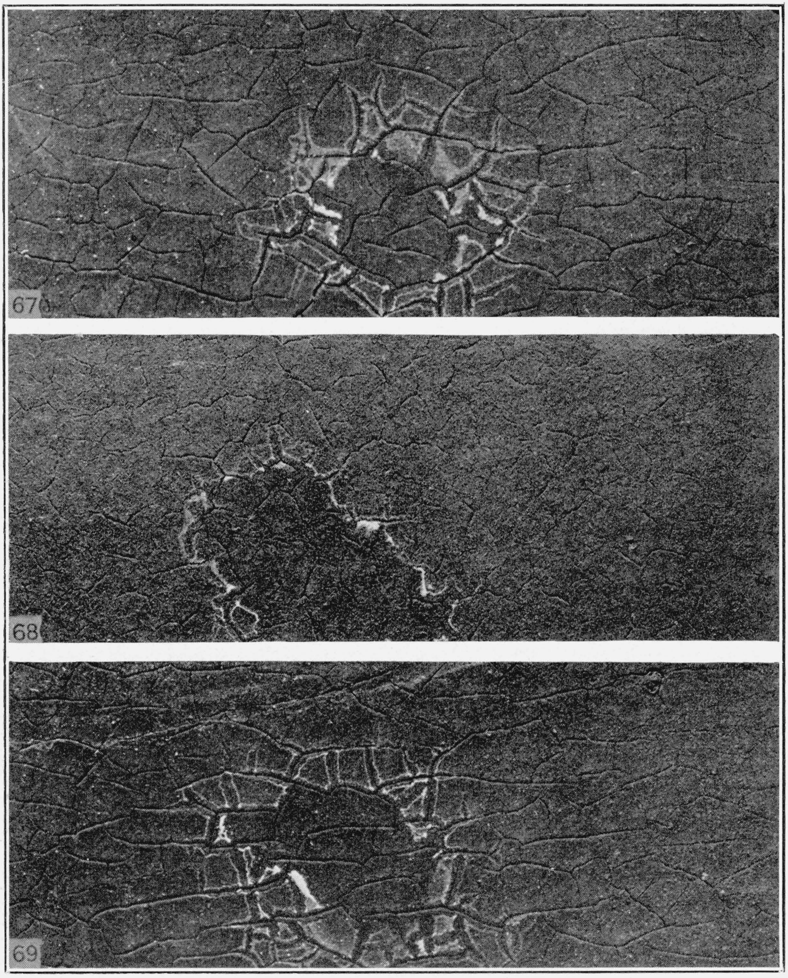

FIGURE 21.—*Comparison of specimens containing slate of various particle sizes as filler.*

All specimens exposed at Buffalo.

Compositions: 67. Specimen 44 (table 1) containing 15 percent of slate, filler 16, passing No. 200 sieve.
68. Specimen 47 (table 1) containing 15 percent of slate, filler 17, passing No. 100 but retained on No. 200 sieve.
69. Specimen 15 (table 1) containing 15 percent of slate, filler 5, 79 percent passing No. 200 sieve.

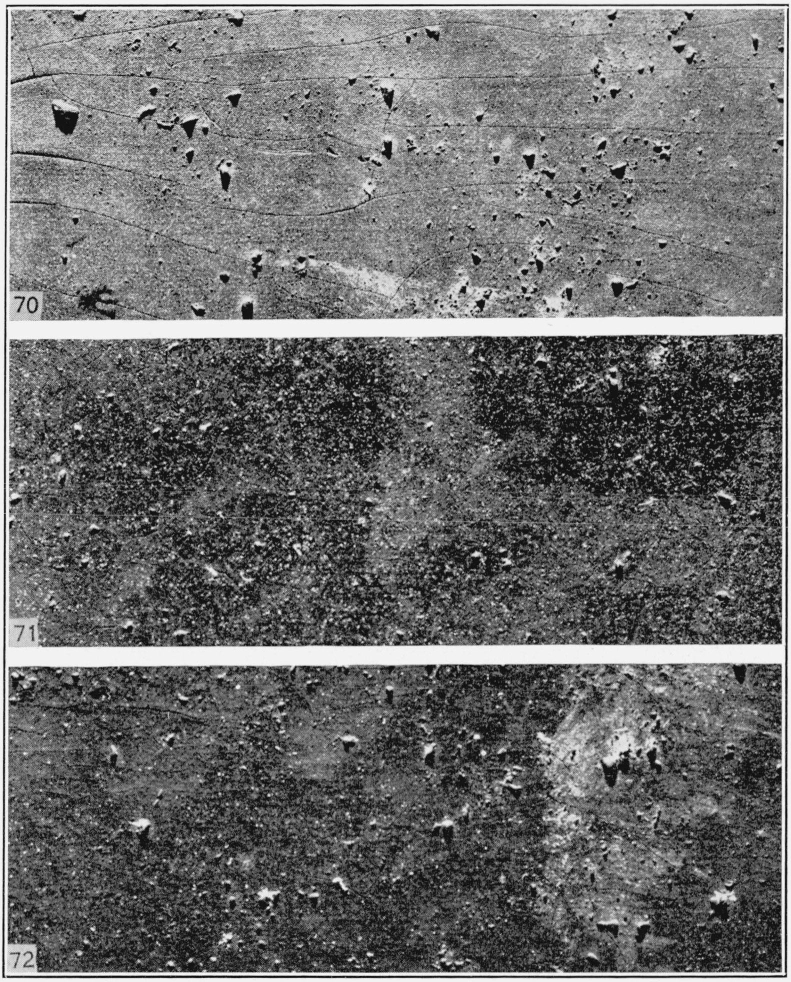

FIGURE 22.—*Comparison of specimens containing slate of various particle sizes as filler.*

All specimens exposed at New Orleans.

Compositions: 70. Specimen 44 (table 1) containing 15 percent of slate, filler 16, passing No. 200 sieve.
71. Specimen 47 (table 1) containing 15 percent of slate, filler 17, passing No. 100 but retained on No. 200 sieve.
72. Specimen 15 (table 1) containing 15 percent of slate, filler 5, 79 percent passing No. 200 sieve.

plotting the softening points[3] in a system of coordinates, using the ordinate as the temperature scale and the abscissa as the percentage scale, as shown in figure 1. With such a system of coordinates, the percentage composition of "hard" and "soft" asphalt for a blend of a desired softening point was readily determined by inspection. The effect of filler on the softening point of the asphalt was determined by trial.

Table 1 shows the compositions and penetrations[4] of the asphalt-filler mixtures.

Table 1.—*Compositions, physical properties, and durabilities of asphalt-filler mixtures*

Specimen number	Asphalt-filler mixture				Kind of filler	Filler No.	Penetrations in 0.01-cm units			Durability	
	Hard asphalt	Soft asphalt	Filler	Hard asphalt in total asphalt			At 32° F, 200 g, 60 sec	At 77° F, 100 g, 5 sec	At 115° F, 50 g, 5 sec	3-yr outdoor exposure, group number[a]	Life in accelerated test
	%	%	%	%							Cycles
1	47	18	35	72			6	9	13	I	62
2	62	13	25	83	Green-slate flour	1	6	9	16	II	45
3	73	12	15	86			7	9	17	II	37
4	47	18	35	72			6	10	18	II	37
5	60	15	25	80	Dolomite	2	6	10	17	II	28
6	73	12	15	86			7	10	17	III	28
7	47	18	35	72			6	9	15	II	40
8	60	15	25	80	do	3	8	11	18	II	37
9	73	12	15	86			7	10	17	III	28
10	47	18	35	72			6	9	16	II	43
11	60	15	25	80	Limestone	4	6	10	17	II	37
12	73	12	15	86			6	9	18	III	33
13	47	18	35	72			6	8	15	I	65
14	60	15	25	80	Peach Bottom slate	5	7	10	16	I	62
15	73	12	15	86			7	8	18	II	43
16	47	18	35	72			8	12	18	II	28
17	68	7	25	90	Silica sand	6	6	11	15	II	28
18	80	5	15	94			8	11	14	III	28
19	47	18	35	72			7	11	14	II	65
20	60	15	25	80	Greenstone	7	7	10	16	II	46
21	73	12	15	86			7	10	17	II	40
22	------	65	35	0			6	8	14	III	28
23	------	75	25	0	Hydrated lime	8	8	11	21	III	28
24	37	48	15	56			7	11	21	III	28
25	36	29	35	55			6	9	15	II	43
26	53	22	25	70	Trap rock	9	7	9	17	II	37
27	72	13	15	85			7	9	16	III	28
28	13	72	15	15	Supercel	10	8	10	22	II	40
29	41	44	15	48	Mica	11	7	10	17	I	65+
30	23	42	35	36			6	10	16	I	65
31	44	31	25	58	Foliated talc	12	7	9	18	I	65
32	66	19	15	78			7	9	18	I	48
33	49	16	35	75			7	8	16	II	35
34	62	13	25	83	Silica dust	13	7	8	16	II	33
35	78	7	15	92			7	9	17	III	28

[a] See p. 166 of text for identification of groups.

[3] The softening points were determined by the ring-and-ball method described by Herbert Abraham in Asphalts and Allied Substances, 3d edition (D. Van Nostrand Co., New York, N. Y.).

[4] The method of test is fully described in *Standard method of test for penetration of bituminous materials*, A. S. T. M. Designation: *D 5–25* Book of Standards, Am. Soc. Testing Materials, pt. II, 971 (1933).

TABLE 1.—*Compositions, physical properties, and durabilities of asphalt-filler mixtures*—Continued

Specimen number	Asphalt-filler mixture				Kind of filler	Filler No.	Penetrations in 0.01-cm units			Durability	
	Hard asphalt	Soft asphalt	Filler	Hard asphalt in total asphalt			At 32° F, 200 g, 60 sec	At 77° F, 100 g, 5 sec	At 115° F, 50 g, 5 sec	3-yr outdoor exposure, group number	Life in accelerated test
	%	%	%	%							*Cycles*
36	40	25	35	62			7	9	18	II	35
37	54	21	25	72	Silica dust	14	6	9	16	II	30
38	72	13	15	85			6	9	16	III	28
39	49	16	35	75			7	9	17	II	35
40	64	11	25	85	do	15	7	10	17	II	35
41	77	8	15	91			7	9	17	II	28
42	33	32	35	51			7	10	17	I	65
43	50	25	25	67	Slate flour	16	7	10	17	I	51
44	68	17	15	80			7	10	17	II	43
45	44	21	35	68			7	10	14	I	65
46	58	17	25	78	do	17	7	10	15	I	65
47	75	10	15	88			7	10	18	II	43
48	43	22	35	66			7	10	18	II	45
49	56	19	25	75	Limestone	18	7	10	18	III	33
50	75	10	15	88			7	10	19	III	28
51	49	16	35	75			7	10	18	II	58
52	64	11	25	85	do	19	8	10	17	II	48
53	81	4	15	95			6	10	19	III	28
54	100			100			7	10	17	III	28
55	75	25		75			9	11	17	III	28
56	50	50		50			8	12	21	III	28
57	25	75		25			9	15	27	III	28

Fifty-seven different combinations of asphalts and asphalt-filler mixtures, including nearly all of the fillers in commercial use, were prepared and surfaced to a thickness of 0.025 in.[5] on aluminum sheet panels (3 by 6 in.). Seven sets of such panels were prepared in duplicate, making 114 panels for each set. Single sets were exposed outdoors at Buffalo, N. Y., Manville, N. J., Chicago, Ill., Los Angeles, Calif., New Orleans, La., and Washington, D. C. The panels in the outdoor exposures were placed on racks at an angle of 45 degrees facing south. The seventh set of panels was subjected to an accelerated-weathering test which consisted in exposing the panels alternately to light from an inclosed carbon arc, water spray, and to sudden temperature changes.[6]

III. PHYSICAL PROPERTIES OF THE FILLERS

The physical properties of the fillers are listed in table 2. As shown in the table, fillers 14 to 19 were prepared from fillers 4, 5, and 13.

[5] The method of preparing the panels is fully described in a paper by O. G. Strieter, *Accelerated tests of asphalts*, BS J. Research **5**, 247 (1930) RP197; also in the *Proposed method for accelerated-weathering tests on bituminous materials*, Proc. Am. Soc. Testing Materials **33**, pt. I, 381 (1933).

[6] The accelerated weathering test is fully described in the *Proposed method for accelerated-weathering tests on bituminous materials*, Proc. Am. Soc. Testing Materials **33**, pt. I, 381 (1933).

TABLE 2.—*Physical properties of the fillers*

Filler number	Kind of filler	Particle size of filler: Passing No. 200 sieve	Particle size of filler: Passing No. 100, retained on No. 200 sieve	Particle size of filler: Retained on No. 100 sieve	Specific gravity	Compacting weight	Fineness factor, *f*.
		Percent	*Percent*	*Percent*			
1	Slate flour—air-floated No. 000 grade	81	17	1	2.86	1.35	1.1
2	Dolomite	92	7	1	2.85	1.63	0.8
3	do	85	14	1	2.88	1.73	.7
4	Limestone	91	8	1	2.76	1.62	.7
5	Peach Bottom slate—No. 000 grade	79	16	5	2.98	1.40	1.1
6	Silica sand	2	13	85	2.69	1.74	0.6
7	Greenstone	65	24	12	3.08	1.66	.9
8	Hydrated lime	99	2		2.39	.83	1.9
9	Trap rock	97	3		2.94	1.52	0.9
10	Celite (Hy Flo Supercel)	100			2.52	.30	7.4
11	Mica	42	28	30	3.20	.51	5.3
12	Foliated talc	100	(a)		2.97	1.05	1.8
13	Silica dust	67	26	7	2.69	1.68	0.6
14	Silica dust (prepared from filler 13)	100			2.69	1.63	.7
15	do		100		2.69	(b)	
16	Slate flour (prepared from filler 5)	100			2.98	1.30	1.3
17	do		100		2.98	(b)	
18	Limestone (prepared from filler 4)	100			2.76	1.63	0.7
19	do		100		2.76	(b)	

[a] Trace retained on No. 200 sieve.
[b] Insufficient material for test.

The specific gravities of the fillers were determined by means of a picnometer, using kerosene as the liquid. The details of the method have been described elsewhere.[7]

The compacting weight (weight of the filler occupying a volume of 1 ml when compacted) was determined in a 100 ml graduated cylinder. A quantity of filler judged to approximate a volume of 10 ml when compacted was placed in the cylinder and compacted by tapping the bottom of the cylinder against a padded table top. A distinctive, dull sound indicated when the filler was compact. This operation was repeated until a volume of 100 ml of compact filler was obtained. The weight of this filler divided by 100 was taken as the "compacting" weight.

Since the compacting weights of fillers with different specific gravities cannot be directly compared, the compacting weights were used to calculate a "fineness factor," f, according to the following formula.[8]

$$f=\frac{\text{density}-\text{compacting weight}}{\text{compacting weight}}$$

The finer a given filler has been ground, the larger is its fineness factor.

Table 3 shows the increases in the softening points of the asphalt due to the addition of filler. Examination of the data will show that the higher the fineness factor of the filler, the greater the increase in the softening point of the asphalt. It should be borne in mind, how-

[7] *Standard methods of test for specific gravity of pigments*, A. S. T. M. Designation D 153–27, Book of Standards, Am. Soc. Testing Materials, pt. II, 568 (1933).
[8] Franz Pöpel. Der Moderne Asphaltstrassenbau (Strassenbau-Verlag Martin Boerner, Halle, 1929).

TABLE 3.—*Effect of fillers on the softening point of the asphalt*

Kind of filler	Filler number	Filler by weight	Fineness factor *f*	Increase in softening point of asphalt due to addition of filler
		Percent		°C
Supercel	10	15	7.4	14.0
Mica	11	15	5.3	9.5
Hydrated lime	8	15	1.9	8.0
Foliated talc	12	15	1.8	3.5
Slate	16	35	1.3	7.0
Do	5	35	1.1	6.5
Green slate	1	35	1.1	5.5
Greenstone	7	35	0.9	5.0
Dolomite	2	35	.8	5.0
Limestone	4	35	.7	5.0
Silica dust	13	35	.6	4.5
Silica sand	6	35	.6	2.0

ever, that the increases in the softening points of an asphalt due to additions of filler follow a parabolic curve,[9] i. e., the first small additions of filler have only a slight effect, but with subsequent additions of small amounts of filler the softening point of the asphalt increases rapidly. The average void diameter of the fillers as present in the mixture can also be used to characterize the filler in place of the fineness factor, and instead of the increase in softening point the increase in absolute viscosity can be determined.[10]

IV. OUTDOOR EXPOSURES AND ACCELERATED TESTS

1. OUTDOOR EXPOSURES

Asphalts exposed outdoors weather characteristically, depending upon their composition and upon the weather peculiar to the locality of exposure. Thus there is a marked difference in appearance in the six series of panels exposed in the various localities. The outdoor panels, examined after 3 years of exposure, are described under the following headings.

(a) SURFACE OXIDATION

Asphalts exposed to the weather form a film of oxidized material on the surface, which may be readily rubbed off. The amount of such oxidized material formed depends upon the nature of the asphalt, the intensity of the sunlight, and the amount of moisture.

As regards the degree of surface oxidation of the coatings, the localities of exposure are rated in the following ascending order: Los Angeles, *L;* Chicago, *C;* Manville, *M;* Buffalo, *B*; Washington, *W;* and New Orleans, *N*.

(b) CRACKING

Asphalts crack upon continued exposure to the weather. This type of weathering is influenced by the composition of the coating and is also characteristic for each locality.

The *B* coatings cracked to the greatest degree but are followed closely by the *M* and *C* coatings. The *N* and *W* coatings cracked

[9] See footnote 8.
[10] R. N. Traxler, Ind. Eng. Chem. 29, 489–492 (1937).

less and the L coatings the least of all. As a rule, the B, M, and C coatings showed short cracks tending to form four-sided but irregular checks. The W coatings, as a rule, showed long, narrow cracks, whereas in the N coatings the cracks were much wider.

(c) CLASSIFICATION OF OUTDOOR EXPOSURES

The degree of cracking during outdoor exposure was made the basis for classifying the various coating mixtures. For this purpose the coatings in each outdoor exposure were arranged in order from best to poorest according to appearance and were subdivided into three groups, as shown in table 4, according to the following scheme:

TABLE 4.—*Order of durability of asphalt-filler mixtures*

Specimen number	Composition			Durability
	Amount	Kind of filler	Filler No.	
GROUP I				
	Percent			*Cycles*
29	15	Mica	11	65+
30	35	Talc	12	65
31	25	do	12	65
42	35	Slate	16	65
45	35	do	17	65
13	35	do	5	65
1	35	do	1	62
14	25	do	5	62
46	25	do	17	65
43	25	do	16	51
32	15	Talc	12	48
GROUP II				
51	35	Limestone	19	58
19	35	Greenstone	7	65
39	35	Silica	15	35
40	25	do	15	35
2	25	Slate	1	45
47	15	do	17	43
28	15	Supercel	10	40
20	25	Greenstone	7	46
36	35	Silica	14	35
44	15	Slate	16	43
25	35	Trap rock	9	43
16	35	Silica	6	28
17	25	do	6	28
41	15	do	15	28
52	25	Limestone	19	48
5	25	Dolomite	2	28
15	15	Slate	5	43
4	35	Dolomite	2	37
3	15	Slate	1	37
33	35	Silica	13	35
34	25	do	13	33
26	25	Trap rock	9	37
8	25	Dolomite	3	37
37	25	Silica	14	30
7	35	Dolomite	3	40
11	25	Limestone	4	37
48	35	do	18	45
10	35	do	4	43
21	15	Greenstone	7	40

TABLE 4.—*Order of durability of asphalt-filler mixtures*—Con.

Specimen number	Composition			Durability
	Amount	Kind of filler	Filler No.	
GROUP III				
	Percent			*Cycles*
18	15	Silica	6	28
38	15	do	14	28
27	15	Trap rock	9	28
35	15	Silica	13	28
9	15	Dolomite	3	28
53	15	Limestone	19	28
54		Asphalt, softening point 108° C		28
55		Asphalt, softening point 104° C		28
56		Asphalt, softening point 99.5° C		28
57		Asphalt, softening point 94° C		28
49	25	Limestone	18	33
50	15	do	18	28
6	15	Dolomite	2	28
12	15	Limestone	4	33
24	15	Hydrated lime	8	28
23	25	do	8	28
22	35	do	8	28

No. I. Panels showing no cracks visible to the unaided eye, or, at most, showing faint cracks to the unaided eye.

No. II. Panels showing fair-sized cracks to the unaided eye.

No. III. Panels showing wide cracks to the unaided eye.

Such a method of classification can only approximate the true relative positions of the panels. The detailed descriptions of the coatings after 3 years of outdoor exposure in various localities are given in table 5. In this table, however, the same arrangement of the panels as listed in table 4 has been retained.

2. ACCELERATED-WEATHERING TESTS

The life or durability of the coatings in the accelerated-weathering tests is given in cycles (table 4). The results are the average of duplicate panels differing by not more than 3 to 5 cycles. The end point of the accelerated-weathering test was determined by measurement of electrical conductivity. In the "conductivity test,"[11] the panel is placed in a circuit and covered with a template having 10 holes. The asphalt surface is then moistened through these holes with an electrolyte. If cracks through to the aluminum are present in the coating, the electrolyte will conduct electricity. The end point of the test is reached when at least 6 of the 10 holes in the template conduct current.

The results of the "conductivity test" on the outdoor exposure samples are shown in table 5.

[11] Method described in *Proposed method for accelerated-weathering tests on bituminous materials*, Proc. Am. Soc. Testing Materials **33**, pt. I, 384-385 (1933).

n=No cracks on surface of panel visible to eye.
c=Cracks on surface of panel visible to eye.
1=No cracks on surface of panel visible under magnifying glass (12×).
2=No cracks at side of panel visible under magnifying glass (12×).
3=No cracks at side of panel visible to eye.
4=No conductivity in the electrical conductivity test.
+=Although specimen has deteriorated in the manner stated, the deterioration is not marked.
v=Aluminum panel visible to eye through cracks in coating.

TABLE 5.—*Appearance of coatings after three years' exposure outdoors in various localities*

Specimen number	Composition			Exposures						
	Amount	Kind of filler	Filler number	L	W	M	C	B	N	A
				GROUP I						
	%									*Cycles*
29	15	Mica	11	n, 1, 2, 3, 4	n, 1, 2, 3, 4	n, 1, 2, 3, 4	n, 1, 2, 3, 4	n, 1, 2, 3, 4	n, 1, 2, 3, 4	[a] 65+
30	35	Talc	12	n, 1, 2, 3, 4	n, 1, 2, 3, 4	n, 1, 2, 3, 4	n, 1, 2, 3, 4	n, 1, 2, 3, 4	n, 1, 2, 3, 4	65
31	25	do	12	n, 1, 2, 3, 4	n, 1, 2, 3, 4	c+	c, 2, 3	c, 2, 3	n, 1, 2, 3, 4	65
42	35	Slate	16	n, 1, 2, 3, 4	n, 1, 2, 3, 4	c+	c	c, 2, 3	n, 2, 3, 4	65
45	35	do	17	n, 2, 3	n, 1, 2, 3, 4	n	n	c, 3	n, 2, 3	65
13	35	do	5	n, 1, 2, 3, 4	n, 1, 2, 3, 4	c+	c+	c, 3	n, 2, 3	65
1	35	do	1	c+, 2, 3	c, 2, 3	c	c	c+	c, 3	62
14	25	do	5	n, 2, 3, 4	c, 2, 3	c	c+	c+	c, 3	62
46	25	do	17	n, 2, 3	n, 3	c	c	c+	n, 3	65
43	25	do	16	n, 2, 3	c, 2, 3	c	c	c+	c, 3	51
32	15	Talc	12	c, 2, 3	c, 2, 3	c	c	c+	c, 2, 3	48
				GROUP II						
51	35	Limestone	19	c,	c	c	c	c	c	58
19	35	Greenstone	7	c, 3	c, 3	c	c	c	c, 3	65
39	35	Silica	15	c	c+	c	c	c	c	35
40	25	do	15	c	c+	c	c	c	c	35
2	25	Slate	1	c, 3	c, 3	c	c	c	c+	45
47	15	do	17	c, 3	c, 3	c	c	c	c	43
28	15	Supercel	10	c, 2, 3	c, 2, 3	c	c	c	c+	40
20	25	Greenstone	7	c, 3	c, 3	c	c	c	c	46
36	35	Silica	14	c, 3	c, 3	c	c	c	c+	35
44	15	Slate	16	c, 2, 3	c, 3	c	c	c	c+	43

[a] In this particular case the + means that the panel had not reached the end point of test after an exposure of 65 cycles.

n=No cracks on surface of panel visible to eye.
c=Cracks on surface of panel visible to eye.
1=No cracks on surface of panel visible under magnifying glass (12×).
2=No cracks at side of panel visible under magnifying glass (12×).
3=No cracks at side of panel visible to eye.
4=No conductivity in the electrical conductivity test.
+=Although specimen has deteriorated in the manner stated, the deterioration is not marked.
v=Aluminum panel visible to eye through cracks in coating.

TABLE 5.—*Appearance of coatings after three years' exposure outdoors in various localities*—Continued

Specimen number	Composition			Exposures						
	Amount	Kind of filler	Filler number	L	W	M	C	B	N	A
				GROUP II—Continued						
25	35	Trap rock	9	c, 3	c+	c	c	c	c	43
16	35	Silica	6	c	c	c	c	c	c	28
17	25	do	6	c	c	c	c	c	c	28
41	15	do	15	c	c+	c	c	c	c	28
52	25	Limestone	19	c	c	c	c	c	c	48
5	25	Dolomite	2	c, 3	c+	c (wide)	c	c	c	28
15	15	Slate	5	c	c+	c	c	c	c+	43
4	35	Dolomite	2	c, 2, 3	c	c	c	c	c	37
3	15	Slate	1	c	c+	c	c	c	c	37
33	35	Silica	13	c	c+	c	c	c	c	35
34	25	do	13	c	c+	c	c	c	c	33
26	25	Trap rock	9	c (badly)[b]	c+	c	c	c	c	37
8	25	Dolomite	3	c (badly)	c+	c	c	c	c	37
37	25	Silica	14	c	c+	c	c	c	c	30
7	35	Dolomite	3	c, 2, 3	c+	c	c	c	c	40
11	25	Limestone	4	c (badly)	c+	c	c	c	c	37
48	35	do	18	c (badly)	c	c	c	c	c	45
10	35	do	4	c, 2, 3	c	c	c	c	c	43
21	15	Greenstone	7	c	c+	c	c	c	c (large)	40

[b] Indicates that the coating was badly cracked.

GROUP III

18	15	Silica	6	c	c	c	c	c	c	28
38	15	do	14	c	c	c	c	c	c (wide)	28
27	15	Trap rock	9	c (badly)	c	c	c	c	c (wide)	28
35	15	Silica	13	c	c	c	c	c	c	28
9	15	Dolomite	3	c	c	c	c	c	c (wide)	28
53	15	Limestone	19	c	c	c	c	c	c	28
54	----------	Asphalt, softening point 108° C	----------	c (v)	c	c (v)	c	c (wide)	c (wide)	28
55	----------	Asphalt, softening point 104° C	----------	c (v)	c	c	c	c (wide)	c (wide)	28
56	----------	Asphalt, softening point 99.5° C	----------	c (v)	c	c (v)	c	c (wide)	c (wide)	28
57	----------	Asphalt, softening point 94° C	----------	c (v)	c	c	c	c (wide)	c (wide)	28
49	25	Limestone	18	c	c	c	c (wide)	c (wide)	c (wide)	33
50	15	do	18	c (long)	c	c	c (wide)	c (wide)	c (wide)	28
6	15	Dolomite	2	c	c	c	c	c (wide)	c (wide)	28
12	15	Limestone	4	c	c	c	c	c (wide)	c (wide)	33
24	15	Hydrated lime	8	c (badly)	c (v)	c (v)	c	c (v)	c (v)	28
23	25	do	8	c (badly)	c (v)	c (v)	c (v)	c (v)	c	28
22	35	do	8	c (badly)	c (v)	c (wide)	c (v)	c (v)	c (v) lost adhesive properties.	28

V. DISCUSSION OF RESULTS

In general, the coatings failed in the same order in the outdoor as in the accelerated-weathering test. In the outdoor exposures the silica-filled coatings received higher ratings, when classified according to appearance, than in the accelerated tests. The conductivity test showed that the panels exposed to accelerated weathering were porous and absorbed the electrolyte readily, giving an end point of test, although their appearance was still excellent. The relatively poor adhesion of the silica particles to asphalt is the cause of this porosity.

Figures 2 to 22, inclusive, are actual-size photographs of sections of the test pieces exposed outdoors for 3 years. Some of the photographs are of coatings exposed for 65 cycles in the accelerated test.

Groups I, II, and III (table 4) are illustrated in figures 2 to 9, inclusive. Since the specimens within a group are arranged in the order from best to poorest, and since group II is large, photographs are shown which typify the most durable panels (figs. 4 and 5) and the least durable (figs. 6 and 7) in this group. Examination of these photographs will show differences in the durabilities of the coatings resulting from differences of composition and location of exposure.

Figures 10 and 11 show the unfilled coating asphalt, specimens 55 (table 4), in the outdoor and accelerated-weathering exposures. Comparison with figures 2 and 3 shows that a suitable filler greatly improves the durability of the asphalt.

In figures 12 and 13, 35, 25, and 15-percent of slate, respectively, are compared with one another and also with the unfilled coating asphalt. The specimens are shown in their exposures at Buffalo and New Orleans. These exposures were chosen because they differ widely in temperature and humidity. The coatings with the greatest amount of filler are the best, the unfilled coating asphalt is the worst.

The behavior of various fillers to outdoor exposure is shown in figures 14 and 15. These specimens are quite similar in durability, but are not as good as those shown in figures 2 and 3, or the 35-percent of slate shown in figures 12 and 13.

Figures 16 and 17 show specimens containing 25 percent by weight of limestone filler, but in various particle sizes. The one size was a finely cracked material practically all of which passed a No. 100 sieve and 91 percent a No. 200 sieve. The other two sizes consisted of the portions of the material which passed through and were retained on a No. 200 sieve, respectively. Figure 18 shows the same coatings after exposure to accelerated weathering. Figure 19 shows the Buffalo exposures and figure 20 the New Orleans exposures of a similar series of compositions, but using silica instead of limestone as a filler. Figures 21 and 22 show similar coatings with slate, however, only in amounts of 15 percent by weight instead of 25 percent. In each case, irrespective of the kind or amount of filler, the specimens containing fillers passing a No. 100 but retained on a No. 200 sieve have the best appearance. The specimens with filler passing a No. 200 sieve do not show up as well. However, final conclusions regarding the most suitable size of fillers cannot be drawn from those tests. More extensive testing is required to settle this question.

Fillers appear to affect asphalts in two ways, first, a stiffening effect, normal to all fillers and evidenced by a higher softening point, and, second, an effect shown mostly by the coarser fillers, which is actually the production of a rigid structure. This structure-giving property of the coarser fillers is probably the reason for the better appearance of the specimens containing 100- to 200-mesh filler (see figs. 16 to 22). It is also the reason for the good appearance of those coatings containing silica, a structure-giving filler.

VI. SUMMARY

These weathering tests, outdoor and accelerated, show that the addition of fillers increases the durability of coating asphalts in varying degrees, depending upon the character, proportion, and particle size of the fillers.

The best results were obtained with coatings containing talc, mica, and Peach Bottom slate. Less positive results were obtained with coatings containing silica, trap rock, dolomite, and limestone in amounts of 15 percent by weight. Hydrated lime was the only filler tested that did not increase the durability of the coating.

Within the limits tested, and excepting the coatings containing hydrated lime, the higher the percentage of a given filler, the more durable was the coating. The coatings containing 35 percent by weight of hydrated lime lost their adhesive properties and separated from the aluminum panels.

The question of the most suitable particle size and distribution of the fillers was not settled by these tests. The tests do show, however, that fillers passing a No. 100 sieve, but retained on a No. 200 sieve, produce better coatings than fine filler, all of which passes a No. 200 sieve.

The data demonstrate the similarity between outdoor and accelerated exposures.

The author expresses appreciation to H. R. Snoke and to L. R. Kleinschmidt, both of the Bureau staff, for their assistance in many ways in this investigation.

WASHINGTON, November 26, 1937.