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ACCELERATED WEATHERING TESTS OF MINERAL-SURFACED ASPHALT SHINGLES

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ABSTRACT

A method for testing mineral-surfaced asphalt-prepared roofing by accelerated weathering is described, and the results of tests by this method on 39 samples of standard-weight strip shingles, from eight manufacturers, are reported. All of the types of failure encountered in long outdoor exposures of these roofings have been produced in exposures of 7 months or less, the samples furnished by each manufacturer showing a characteristic behavior, largely independent of the granular surfacing materials used.

Except that the samples containing fine mineral filler in the asphalt coatings appear to be the most resistant to weathering, analyses of the samples under test (table 1), including fiber analyses of the felts and petrographic examination of the mineral fillers and fine surfacing materials, show no differences in composition sufficiently great to warrant the prediction of decided differences in their behavior to weathering.

The results of water absorption tests on unweathered samples and on samples exposed 1, 5, and 7 months to accelerated weathering are given. Accelerated blister, slide, and abrasion tests developed by the industry are briefly described, and the results of these tests on the samples in this investigation are reported.

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I. INTRODUCTION

Mineral-surfaced asphalt shingles are a comparatively recent development of the roofing industry, having come into general use within the past 25 years. When properly laid they have proved to be durable and, from the standpoint of cost, are particularly adapted to low-cost housing projects. Because they can be produced in practically any color or combination of colors and in a wide variety of patterns, they are satisfactory decorative roofing materials.

Federal specifications have been adopted for these shingles, in which are included requirements for the weight of the various constituents and for the total weight per unit area of the finished product.

The quality of the raw materials used and the process of manufacture are probably the greatest factors in determining the resistance to weathering of roofing of this type. With an industry that is developing as rapidly as this one, with raw materials and manufacturing processes constantly changing, and with a finished product that will last from 10 to 20 years, or longer, outdoor weathering tests are of no great value. By the time conclusive results are obtained by this method, the material under test is not representative of that then on the market.

This paper describes the results of an investigation made with funds furnished by the Works Progress Administration, for the benefit of the Federal agencies engaged in housing activities and associated with the Central Housing Committee. The purpose of the investigation was to study the effect of accelerated weathering tests on representative shingles now on the market. Analyses were made of all the samples in the test; also, they were subjected to accelerated blister, slide, and abrasion tests that have been developed by the industry. Test pieces similar to those used for the accelerated weathering test, also samples of whole shingles laid as on a roof, have been exposed outdoors for future reference.

As by-products of this investigation, the factors which govern the durability of these materials and the value of the accelerated weathering test for factory control in their manufacture are clearly shown.

II. DESCRIPTION OF MATERIAL AND METHODS OF MANUFACTURE

Mineral-surfaced asphalt shingles are manufactured on an organic felt base, made by pulping fibrous materials and converting the prepared pulp into a dry continuous sheet on a paper-making machine. Low-grade paper stock is used in the manufacture of these felts, the content of cotton rags seldom exceeding 70 percent and being in many cases less than 50 percent.[1]

The shingles are usually made by a continuous process. The felt enters the machine as a dry sheet, passing first into a saturator where it is thoroughly impregnated with a relatively soft asphalt, then around an air-cooled looping system, through the coating rolls, and, while the coatings are still hot, by the granule "feeders" and through press rolls to embed the granules firmly, and finally, through cooling rolls to the shingle cutter and packing machine.[2]

[1] See table 2.

[2] A detailed and illustrated description of the manufacture of asphalt-prepared roofing, and of many types of asphalt shingles, is given in Asphalts and Allied Substances, third edition, by Herbert Abraham, published by D. Van Nostrand Co., New York, N. Y.

Because of limited equipment for making accelerated weathering tests, only so-called standard-weight strip shingles, weighing approximately 90 pounds per 108 square feet of shingle surface, were included in the tests. The samples were restricted to those coated with the natural and artificial mineral surfacing granules in most common use and were taken from the regular stocks of eight of the larger manufacturers of these materials. Table 1 gives the numbers of the shingles and shows them grouped by manufacturers. Under "Color" in this table are the names of the granular surfacing materials furnished by the manufacturers, and under "Granule treatment", their statements as to what treatment, if any, was given the granules before they were embedded in the asphalt coatings. Also, under "Mineral matter", the column headed "Reported" gives the percentages of fine mineral filler each manufacturer states he has added to the coating asphalt.

III. TEST METHODS

1. ANALYTICAL METHODS

In general, the data presented in table 1, showing the composition of the shingles, were obtained by the methods outlined in Federal Specification SS-R-521, Roofing and Shingles; Mineral-Surfaced, Asphalt-Prepared,[3] except that the front and back coatings were examined separately. Petrographic methods were used to determine the nature of the granules and of the fine mineral fillers, all of the mineral matter passing a no. 70 U. S. Standard Sieve being arbitrarily classified as filler and expressed as the percentage of the total weight of the front and back coatings. No correction was made for the mineral surfacing material on the back coatings, or for the mineral matter passing a no. 70 sieve included in the granular surfacing materials. This explains the lack of agreement between the amount of filler found and that reported by the manufacturer.

In the petrographic examination of the mineral matter, that retained on a no. 70 sieve was assumed to be surfacing material, and that passing a no. 200 sieve the fine mineral filler. In each case only the constituent present in greatest quantity is reported.

The fiber analyses of the desaturated felts (table 2) were made by the method given in Federal Specification UU-P-31, Paper, General Specifications.[4] This method is also covered by ASTM Method D 272-34, Standard Methods of Analysis of Roofing Felt for Fiber Composition.[5]

2. HEAT TESTS

The percentage of volatile matter and the behavior at 80° C (table 3) were determined by the methods described in Federal Specification SS-R-521. The accelerated blister and slide tests were made, except for slight modifications, according to methods developed by H. W. Greider of the Philip Carey Co. These tests are briefly described as follows:

(a) ACCELERATED BLISTER TEST

Test pieces, 2½ by 6 inches, are immersed in a water bath at 125° F, for 1 hour; then removed and placed immediately, granule surface upward, in a rotating-shelf oven at 220° F for 1 hour. They are then

[3] Copies of Federal specifications mentioned in this paper may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., price 5 cents each, stamps not accepted.
[4] See footnote 3.
[5] Book of Standards, Am. Soc. Testing Materials, pt. II, p. 1162 (1936).

examined while still hot and before the blisters have had time to subside. In these tests samples showing not more than two blisters not exceeding 1/16 inch in diameter at base were rated "Good"; those with more than two and not more than eight blisters, none exceeding 1/8 inch in diameter at base, were rated "Fair"; and those with more than eight blisters, or with blisters greater than 1/8 inch in diameter at base, were rated "Poor." This test does not exactly duplicate the Greider test in that the latter employs a specially designed oven equipped with electric strip heaters radially arranged in the roof.

(b) ACCELERATED "SLIDE" TEST

Test pieces 2½ by 6 inches are suspended vertically in an oven at 220° F for 1 hour. The slippage of the coating and granular surfacing material is measured from the lower back edge of the test piece.

3. ABRASION TESTS

Wet and dry abrasion tests[6] to determine how well the granular surfacing materials are embedded in the asphalt coatings were made on all the samples, using the "Carey abrasion test apparatus" and the "Minnesota Mining rub test machine." Both of these instruments and the method of the tests are described elsewhere,[7] so that only a general statement of the principles involved in each test is necessary here. The Carey apparatus permits the roofing sample itself to provide the abrasive action by causing two pieces of roofing to abrade each other. The Minnesota Mining machine uses a standardized steel wire brush to abrade the roofing.

4. ACCELERATED WEATHERING TEST

It has been shown in a previous paper that asphalts behave similarly when exposed to accelerated and outdoor weathering tests.[8] In these, as in the previous tests, the purpose was to subject the samples to exaggerated conditions simulating outdoor exposure, in this case to continuous light and heat from a carbon-arc lamp, with intermittent water spray. The apparatus used is essentially the same as that described in previous papers [9] and needs only a brief description here.

The test pieces, cut 3 inches wide and as long as the short dimension of the shingle, i. e., 10 or 12½ inches, were placed in vertical slots around the inside of a metal cylinder encircling the arc lamp. The cylinders were 30 inches in diameter so that the exposed surface of each test piece was approximately 15 inches from the source of light. Each cylinder was equipped with a revolving mechanism geared to give one complete revolution in 20 minutes. The water spray was furnished by a perforated pipe in a fixed, vertical position about 2 inches from the test pieces, and connected with the city water supply through a reducing valve to insure constant pressure. The maximum temperature at the surface of the panels varied from 82° F on a cold day to 102° F on a hot day and was usually sufficient to dry the sur-

[6] The authors are indebted to Dr. H. W. Greider, of the Philip Carey Co., and Mr. L. A. Hatch, of the Minnesota Mining and Manufacturing Co., for making these tests.
[7] H. W. Greider and G. A. Fasold, *A comparision of abrasion test methods for embedding of granular mineral surfacing on asphalt roofing*, Proc. Am. Soc. Testing Materials, pt. I, p. 453 (1936).
[8] O. G. Strieter, BS J. Research **5**, 247 (1930) RP197.
[9] Percy H. Walker and E. F. Hickson, BS J. Research **1**, 1 (1928) RP1; O. G. Strieter, BS J. Research **5**, 247 (1930) RP197.

faces of the panels, except for a small area at the bottom, before they returned to the water spray.

Three exposure units were in practically continuous operation for 7 months, a month in this case meaning 30 days of 24 hours each. All the lamps were adjusted to practically the same conditions at the start of the test, but to insure uniformity of treatment for all samples, a schedule was followed whereby panels were moved from one cylinder to another, and their ends reversed, at regular intervals.

Examinations were made weekly during the first month of the test, and thereafter once each month. One complete set of samples was removed after being exposed 1 month, another after 5 months, and the final set after 7 months. These three sets, with an original unweathered set, were used for the water absorption tests next described.

5. WATER ABSORPTION TESTS

These tests were made by immersing the samples described above, previously dried to constant weight, in water at room temperature for 24 hours; then removing them from the water, drying the surface moisture with a towel, and weighing.

IV. DISCUSSION OF RESULTS

1. ANALYTICAL RESULTS

The data presented in table 1 show that these materials are, in general, remarkably uniform in composition. Except that the samples furnished by manufacturer *H* (samples 35 to 39, inclusive) contain no fine mineral filler in the coating asphalt, and therefore have a correspondingly greater weight of bitumen per unit area, there are no differences in composition great enough to warrant the prediction of decided differences in the behavior of these materials to weathering.

All but 12 of the samples individually met the requirements of Federal Specification SS–R–521 in every respect. Samples 1, 18, 20, 22, and 26 fail to meet the requirement for weight of the desaturated felt (minimum 10.8 pounds per 108 square feet), samples 7, 13, 14, 16, 17, and 31 fail as regards percentage saturation of the felt (minimum 175%), and sample 26 as regards total weight of organic fibers and bitumen per 108 square feet (minimum 45 pounds). Since different sections of the sheet from which these shingles are cut may differ in composition, the average analyses of the materials supplied by each manufacturer are probably more representative of the material furnished by that manufacturer. On this basis only the material furnished by manufacturer *D* would fail to meet all the requirements of the specification, the average saturation of the felt (167%), being lower than the minimum specified (175%).

Federal Specification SS–R–521 contains no requirement for pliability of shingles. The pliability test used was the one required for mineral-surfaced roll roofing under the above specification and all but four samples, from a single manufacturer, passed the test.

The results of the fiber analysis of the felts, table 2, show practically the same constituents in all of the felts, with as much variation in composition between samples from the same manufacturer as between those from different manufacturers. In this table all of the constituents that were identified are listed. The percentages shown, however, are in many cases little better than approximations, it being customary in analyses of this kind to report as a trace any constituent present in small amount. Where a constituent is present in considerable quantity the amount reported can be considered accurate within plus or minus 10 percent.

O. G. Strieter [10] found no significant difference in the resistance to outdoor weathering of asphalt-prepared roofing, which may be attributed to the kind of fiber or combination of fibers employed.

TABLE 2.—*Fiber analysis of felts*

Sample	Ground wood	Chemical wood	Jute	Hair	Wood	Rag	Silk	Rayon	Kapok
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	16.9	8.3	11.8	0.8	2.3	53.5	1.6	4.5	0.3
2	10.9	9.4	13.9	.4	2.6	51.2	2.4	7.5	1.8
3	18.6	18.1	7.2	.4	2.5	45.6	3.0	3.4	0.2
4	12.4	5.9	15.8	.7	2.9	50.9	4.8	6.7	0
Average	14.7	10.4	12.2	.6	2.6	50.3	2.9	5.5	.6
5	17.8	8.2	10.2	.3	4.7	50.7	3.0	1.6	3.5
6	24.0	13.1	13.0	0	0.8	43.3	2.7	1.0	2.1
7	16.2	9.0	11.0	1.4	3.9	57.0	0.9	------	------
8	14.6	9.7	10.1	1.6	4.0	59.2	.6	------	------
Average	18.1	10.0	11.1	0.8	3.3	52.5	1.8	------	------
9	2.0	7.5	5.5	0.6	1.5	77.5	0.4	4.3	------
10	1.5	17.0	6.6	1.8	0.5	65.6	3.8	3.1	------
11	2.8	8.4	13.2	0.6	1.2	68.5	2.0	2.6	------
12	4.4	13.7	8.3	.6	1.2	68.5	1.5	1.6	------
Average	2.7	11.6	8.4	0.9	1.1	70.0	1.9	2.9	------
13	6.2	9.2	10.2	1.5	7.1	59.3	3.3	2.5	0.6
14	15.8	12.7	8.6	1.7	2.7	54.3	2.0	2.2	------
15	14.2	15.5	11.7	1.4	2.4	48.4	4.3	2.2	------
16	17.1	14.0	16.9	1.4	2.4	40.8	5.8	1.6	------
17	8.8	12.9	17.1	1.0	2.5	54.5	2.5	0.7	.2
Average	12.4	12.9	12.9	1.4	3.4	51.5	3.6	1.8	------
18	18.8	13.3	4.6	------	0.5	50.2	3.9	6.6	------
19	22.7	16.2	15.1	0.7	.7	40.4	1.6	7.8	------
20	20.4	16.3	12.8	------	------	33.4	0.5	6.7	------
21	15.8	14.1	4.9	1.2	1.1	54.3	3.6	4.7	------
22	18.5	19.3	4.1	0.6	0.3	48.8	0.5	7.3	------
23	19.8	14.9	3.1	.6	.2	49.3	1.3	5.4	------
24	20.7	18.1	7.0	1.2	.2	42.9	0.7	8.9	------
Average	19.5	16.0	7.4	0.6	0.4	45.6	1.7	6.9	------
25	11.2	14.0	14.9	0.1	1.5	55.4	0.7	1.9	------
26	8.5	22.3	13.9	.6	1.6	46.2	1.6	4.6	------
27	15.2	12.8	16.0	.5	0.1	52.9	0.2	2.0	------
28	13.4	13.9	18.9	.4	1.1	47.3	.7	4.0	------
29	10.2	10.7	11.8	.4	1.7	61.9	1.5	2.3	------
30	5.4	8.1	10.9	.7	0.1	72.1	0.5	2.5	------
Average	10.6	13.6	14.4	0.4	1.0	56.0	0.9	2.9	------
31	17.3	5.3	6.9	0.3	3.6	65.8	0.4	0.5	------
32	12.5	4.4	6.4	.2	3.2	57.1	4.2	6.2	0.7
33	15.1	8.6	10.8	------	3.8	58.2	2.0	1.5	------
34	10.6	5.5	4.2	.6	3.2	69.8	4.0	1.3	.4
Average	13.9	5.9	7.1	0.3	3.4	62.7	2.6	2.4	------
35	5.2	18.3	8.8	------	1.5	54.5	1.9	9.6	------
36	7.5	15.3	13.3	------	1.3	53.2	3.3	6.0	------
37	7.9	20.4	6.2	0.5	------	53.2	2.5	9.4	------
38	9.1	13.4	10.6	.2	7.7	54.9	3.4	------	------
39	3.2	9.6	18.5	1.1	4.4	54.6	4.1	4.5	------
Average	6.6	15.4	11.5	0.4	3.0	54.1	3.0	5.9	------

[10] O. G. Strieter, J. Research NBS **16**, 511 (1936) RP888.

TABLE 1.—*Analytical results*

Sample	Color	Type of granules	Granule treatment: Oiled	Granule treatment: No oil	Granule treatment: Resin-treated	Weight	Felt: Weight	Felt: Thickness	Felt: Saturation	Felt: Ash	Bituminous matter: Top	Bituminous matter: Bottom	Bituminous matter: Saturant	Mineral matter: Top	Mineral matter: Bottom	Mineral matter: Retained on no. 70 sieve	Passing no. 70 sieve: Reported	Passing no. 70 sieve: Determined	Type of filler passing no. 200 sieve	Ash	Pliability at 25° C
MANUFACTURER *A*. SIZE OF SAMPLES 10 BY 36 INCHES																					
						lb/108 ft²	lb/108 ft²	in.	%	%	lb/108 ft²	lb/108 ft²	lb/108 ft²	lb/108 ft²	lb/108 ft²	lb/108 ft²	%	%		lb/108 ft²	
1	Natural green	Slate		×		89.2	10.4	0.049	192	9.8	18.9	0.9	20.0	36.8	0.7	28.9	35.0	32.9	Silicate rock [a]	40.9	Passed.
2	Silicated green	Black slate coated with green cement.	×			90.8	11.5	.056	198	10.4	12.2	1.2	22.7	40.0	.7	31.1	35.0	41.5	do	43.6	Do.
3	Natural blue-black	Slate	×			91.0	11.8	.053	191	9.4	14.0	1.0	22.5	39.6	.4	34.3	35.0	28.7	do	41.4	Do.
4	Natural red	do		×		90.8	11.5	.054	185	10.5	16.1	1.0	21.0	38.6	.7	27.3	35.0	38.5	do	38.7	Do.
Average						90.4	11.3	0.053	191	10.0	15.3	1.0	21.5	38.7	0.6	30.4		35.4		41.1	
MANUFACTURER *B*. SIZE OF SAMPLES 12½ BY 36 INCHES																					
5	Natural red	Slate	×			89.0	11.1	0.057	205	9.1	17.6	1.1	22.8	34.7	0.5	29.6	30.4	26.0	Quartz	37.1	Passed.
6	Ceramic bright green	Quartz with fluxed green coating.			×	90.7	10.9	.058	203	9.4	18.4	.8	22.6	36.3	.4	30.6	30.4	26.5	do	39.2	Do.
7	Natural blue-black	Slate	×			90.0	12.7	.060	171	12.5	17.6	1.1	21.9	36.7	.3	31.0	30.4	25.7	do	39.6	Do.
8	Kentucky green stone	Low order slate	×			89.3	11.0	.052	178	8.6	18.6	1.1	19.7	36.9	.5	33.4	30.4	21.9	do	39.6	Do.
Average						89.7	11.4	0.057	189	9.9	18.0	1.0	21.7	36.1	0.4	31.1		25.0		38.9	
MANUFACTURER *C*. SIZE OF SAMPLES 10 BY 36 INCHES																					
9	Ceramic bright green	Quartz with fluxed green coating.	×			86.7	11.8	0.058	195	8.3	14.9	2.7	24.0	33.2	1.5	28.9	25.0	26.7	Dolomitic limestone	34.0	Passed.
10	Natural green	Slate			×	86.7	11.6	.056	194	8.6	15.6	2.2	22.5	34.3	0.9	29.6	25.0	25.5	do	34.0	Do.
11	Natural red	do	×			91.6	11.3	.052	188	9.1	15.9	2.1	21.3	38.9	1.2	34.2	25.0	26.5	do	38.3	Do.
12	Natural blue-black	do	×			92.8	11.6	.053	181	9.5	16.4	1.7	20.9	41.1	.7	34.2	25.0	30.4	do	39.7	Do.
Average						89.4	11.6	0.055	189	8.9	15.7	2.2	22.2	36.9	1.1	31.7		27.3		36.5	
MANUFACTURER *D*. SIZE OF SAMPLES 10 BY 36 INCHES																					
13	Blue-black	Slate			×	89.4	11.2	0.051	160	8.3	19.3	4.0	17.9	31.9	2.6	22.2	25.3	35.6	Silicate rock,[a] also slate flour.	37.0	Passed.
14	Natural red	do			×	94.6	11.0	.053	163	9.2	20.6	2.8	18.3	36.9	2.0	26.4	25.3	35.7	do	41.1	Do.
15	Ceramic bright red	Burned shale			×	87.6	11.5	.054	177	9.3	18.5	2.3	20.6	33.3	2.0	25.8	25.3	33.2	Black slate flour	38.2	Do.
16[d]	Ceramic bright green	Quartz with fluxed green coating.			×	102.4	10.9	.052	157	9.3	21.3	4.1	17.1	41.1	3.6	29.0	25.3	39.7	Silicate rock [a]	50.2	Do.
17	Natural green	Slate			×	83.8	11.4	.051	169	9.9	22.1	1.7	19.2	33.7	1.7	24.1	25.3	33.2	Black slate flour	49.8	Do.
Average						88.8	11.3	0.052	167	9.2	20.1	2.7	19.0	33.9	2.1	24.6		34.4		41.5	
MANUFACTURER *E*. SIZE OF SAMPLES 12½ BY 36 INCHES																					
18	Ceramic green	Quartz with fluxed green coating.	×			89.6	10.4	0.054	190	11.0	14.2	5.0	19.9	33.7	2.0	29.6	40.0	29.4	Black slate flour	41.8	Passed.
19	do	do		×		94.8	10.9	.051	186	11.4	15.8	5.5	20.9	36.8	2.3	31.2	40.0	30.8	do	43.6	Do.
20	Cement coated brier green.	Gray slate with thin green coating.	×			88.5	9.9	.052	196	10.8	14.9	2.1	19.5	37.1	0.5	32.6	40.0	31.2	do	39.3	Do.
21	Natural red	Slate	×			92.3	10.8	.053	193	13.0	15.4	5.3	21.1	33.2	2.2	31.6	40.0	27.9	do	39.0	Do.
22	Burnt shale indian red	Burned shale		×		93.4	10.7	.052	188	11.9	16.5	6.2	20.2	33.0	2.7	29.8	40.0	29.2	do	40.0	Do.
23	Natural blue-black	Slate	×			91.5	11.5	.052	199	13.7	16.4	1.8	23.0	36.2	0.7	29.4	40.0	29.3	do	43.2	Do.
24	Natural green	do	×			91.5	10.9	.052	185	11.6	19.6	2.1	20.2	35.9	.8	29.1	40.0	30.5	do	38.1	Do.
Average						91.7	10.7	0.052	191	11.9	16.1	4.0	20.7	35.1	1.6	30.5		29.8		40.7	
MANUFACTURER *F*. SIZE OF SAMPLES 12½ BY 40 INCHES																					
25	Natural red	Slate	×			87.5	11.7	0.052	182	8.0	15.1	0.9	21.3	37.2	1.2	29.9	35.0	36.3	Ground quartz	40.7	Passed.
26	Bright red silicate	Gray slate coated with unglazed red cement.	×			87.2	10.7	.051	188	7.8	12.6	.7	20.1	41.9	0.3	37.5	35.0	34.0	Silicate rock [b]	45.2	Do.
27	Dura green silicate	Gray slate coated with unglazed green cement.	×			88.4	11.6	.053	196	10.4	11.0	.4	22.8	40.5	.6	34.0	35.0	42.2	Slate flour, etc	44.1	Do.
28	Natural black	Slate	×			87.7	11.5	.053	195	7.9	12.6	.4	22.5	39.3	.9	34.5	35.0	34.7	Slate flour	42.0	Do.
29	Natural green	do	×			90.9	11.0	.058	201	10.7	15.7	.9	22.1	38.6	.8	32.1	35.0	34.9	do	42.7	Do.
30	Dura green ceramic	Quartz with fluxed green coating.	×			86.4	11.6	.064	175	12.2	12.8	.9	20.3	37.4	1.0	31.0	35.0	39.3	Silicate rock [b]	40.0	Do.
Average						88.0	11.3	0.055	189	9.5	13.3	0.7	21.5	39.1	0.8	33.2		36.9		42.4	
MANUFACTURER *G*. SIZE OF SAMPLES 10 BY 36 INCHES																					
31	Natural blue-black	Slate	×			88.0	12.5	0.057	169	8.8	16.8	1.7	21.2	33.8	0.8	25.5	35.0	34.9	Dark slate flour [c]	37.0	Passed.
32	Tile red	Burned shale	×			91.4	12.6	.060	195	10.7	16.9	1.8	24.6	34.5	.9	27.6	35.0	32.7	do	40.4	Do.
33	Charmain green	Quartz with fluxed green coating.	×			87.6	11.5	.055	183	8.7	16.8	2.3	21.0	34.0	1.0	27.3	35.0	31.4	do	37.5	Do.
34	Natural red	Slate	×			88.1	11.3	.054	193	9.5	14.5	2.9	22.0	33.9	1.3	29.2	35.0	31.0	do	38.1	Do.
Average						88.8	11.9	0.056	185	9.4	16.2	2.2	22.2	34.0	1.0	27.4		32.5		38.2	
MANUFACTURER *H*. SIZE OF SAMPLES 10 BY 36 INCHES																					
35	Natural blue-black	Slate	×			89.5	12.4	0.061	201	8.1	26.1	1.2	25.0	22.4	1.6	21.8	None	9.6	Dark slate flour	26.3	Failed.
36	Natural red	do	×			88.0	12.4	.060	207	10.0	24.1	1.5	25.7	24.3	1.9	24.6	do	8.4	Pale slate flour	28.4	Passed.
37	Jade green	Quartz with fluxed green coating.	×			97.0	11.0	.055	192	8.8	29.2	0.5	21.2	33.2	1.3	32.8	do	7.7	Carbonate, slate flour, etc.	37.7	Failed.
38	Natural green	Slate	×			91.3	11.1	.055	205	9.3	33.3	.9	22.7	21.5	1.0	21.2	do	5.9	Pale slate flour	24.5	Do.
39	Tile red	Burned shale	×			87.5	12.5	.059	202	10.3	25.8	1.0	25.3	22.0	1.2	21.1	do	9.3	Brick dust, pale slate flour, etc.	26.6	Do.
Average						90.7	11.9	0.058	201	9.3	27.7	1.0	24.0	24.7	1.4	24.3		8.2		28.7	

[a] Ground rock in which basic minerals predominate.
[b] Ground rock in which acid minerals predominate.
[c] Small amount of ground asbestos present.
[d] Not included in the average.

2. HEAT TESTS

All the samples met the requirements of Federal Specification SS–R–521 for volatile matter and heat test at 80° C (table 3). The results of the accelerated blister and slide tests reported in this table are discussed in connection with the results of the accelerated weathering test.

TABLE 3.—*Heat tests*

Sample	Volatile at 80° C[a]	Accelerated blister	Accelerated slippage
	Percent		*Inch*
1	0.12	Fair	1/16
2	.18	do	1/16
3	.17	Good	3/16
4	.14	Fair	1/8
Average	0.15		
5	0.12	Good	1/16
6	.09	do	1/8
7	.06	do	1/16
8	.06	do	1/8
Average	0.08		
9	0.06	Poor	1/4
10	.12	Good	1/8
11	.15	Fair	5/16
12	.08	Good	7/16
Average	0.10		
13	0.11	Good	1/8
14	.11	do	1/8
15	.12	do	1/16
16	.05	do	1/8
17	.18	do	1/4
Average	0.11		
18	0.06	Good	1/8
19	.05	do	1/8
20	0.08	Fair	1/8
21	.07	Good	1/16
22	.05	do	1/8
23	.08	Fair	3/16
24	.05	Good	1/8
Average	0.06		
25	0.24	Good	1/16
26	.18	do	1/16
27	.18	Poor	1/16
28	.18	Fair	1/16
29	.17	do	1/8
30	.18	Good	0
Average	0.19		
31	0.12	Poor	1/16
32	.09	Fair	1/16
33	.06	Good	1/16
34	.12	Fair	1/16
Average	0.10		
35	0.12	Fair	1/8
36	.12	do	1/8
37	.06	do	3/16
38	.12	do	3/16
39	.12	do	1/16
Average	0.11		

[a] Behavior at 80° C—all samples satisfactory.

3. ABRASION TESTS

There is very little agreement of results, either between the wet and dry tests of the same method, or between the two abrasion test methods, when the loss of granules on all the samples from each manufacturer is averaged. However, there is a definite relationship between the various methods if the samples are grouped according to the kind of granules with which they are surfaced. That is, by the Philip Carey method, when the granule loss for all of the samples surfaced with the same kind of granules is averaged, they are placed in the following ascending order by both wet and dry tests; black slate, artificial red, green slate, red slate, and ceramic green. By the Minnesota Mining and Manufacturing Co. method, in both wet and dry tests, the order is: black slate, artificial red, ceramic green, green slate, and red slate.

These results indicate that initial adhesion of granules, as determined by abrasion methods, is mainly a function of the type of granule rather than of the asphalt coating or of the method of manufacture.

The loss of granules in the accelerated weathering test for the 5 and 7 months' exposures show very close agreement, that is, samples are rated in the same order by the 5 and 7 months' tests. The results of the accelerated weathering tests, however, are not in agreement with those of the abrasion tests. Apparently, the abrasion tests are of value in determining how well granules are embedded at the time of manufacture, but can not be used to predict how well they will adhere on exposure. More conclusive information on this subject could be obtained by making abrasion tests on samples that had been exposed to the accelerated weathering test for different periods of time.

TABLE 4.—*Loss of granules*

Sample	P. C. abrasion test		M. M. Co. abrasion test		Accelerated weathering loss in—	
	Dry	Wet	Dry	Wet	5 months	7 months
	lb/108 ft²	lb/108 ft²	lb/108 ft²	lb/108 ft²	lb/108 ft²	lb/108 ft²
1	3.08	5.14	0.74	3.32	6.50	9.59
2	2.63	6.05	.37	4.80	7.53	11.64
3	2.74	4.00	1.11	1.11	4.00	5.13
4	3.20	5.37	0.74	2.22	2.28	2.97
Average	2.91	5.14	0.74	2.86	5.08	7.33
5	2.51	3.65	1.48	3.32	2.09	3.14
6	3.43	4.45	2.58	2.95	0.76	1.62
7	1.83	2.85	0.74	1.11	1.52	3.43
8	1.48	1.48	0.74	1.11	1.04	2.38
Average	2.31	3.11	1.38	2.12	1.35	2.64
9	3.20	5.94	1.48	1.11	1.37	0.57
10	2.85	3.72	1.11	0.74	1.94	3.42
11	1.94	3.43	1.11	1.11	0.80	4.22
12	0.46	0.57	0.37	0.37	0.57	1.25
Average	2.11	3.41	1.02	0.83	1.17	2.36
13	4.23	4.23	1.11	1.11	4.67	9.24
14	3.08	5.71	1.48	1.85	4.22	6.16
15	3.08	3.88	1.48	2.22	1.03	1.48
16	4.34	4.80	1.11	1.11	0.91	2.62
17	4.45	6.96	5.54	5.91	6.84	9.36
Average	3.84	5.12	2.14	2.44	3.53	5.77
18	6.87	6.16	2.22	2.95	2.75	6.38
19	6.39	5.14	2.22	2.22	3.13	7.04
20	4.45	7.54	5.17	2.58	3.32	4.18
21	4.57	5.60	4.06	5.91	4.85	7.24
22	2.17	2.74	0.74	0.74	0.95	1.81
23	2.63	3.88	1.48	1.48	4.75	8.00
24	2.74	4.11	0.74	1.48	4.28	5.70
Average	4.26	5.02	2.38	2.48	3.43	5.76
25	2.51	4.11	0.74	1.11	2.38	4.38
26	4.34	6.17	1.11	3.32	1.33	2.66
27	4.80	7.88	1.48	4.43	0.95	2.00
28	1.14	1.83	0.37	0.74	1.23	2.09
29	3.31	4.57	1.11	1.48	4.08	5.33
30	3.88	4.45	1.11	0.74	0.85	2.28
Average	3.33	4.83	0.99	1.97	1.80	3.12
31	3.08	4.11	1.11	1.48	4.90	7.99
32	2.28	2.85	1.11	2.22	0.23	1.14
33	5.14	5.48	1.85	1.48	4.68	9.36
34	4.56	6.40	2.58	2.95	6.27	8.22
Average	3.76	4.71	1.66	2.03	4.02	6.68
35	2.63	4.91	1.11	1.48	5.82	9.47
36	4.00	5.71	2.22	3.32	4.56	6.62
37	4.11	7.08	0.74	2.95	3.08	6.73
38	2.40	4.22	1.11	1.85	5.48	7.76
39	2.17	2.51	0.37	0.74	1.37	2.85
Average	3.06	4.89	1.11	2.07	4.06	6.69

4. ACCELERATED WEATHERING TESTS

Figures 1 to 10, inclusive, are actual-size photographs of sections of the test pieces exposed 7 months to the accelerated test. The numbers on the photographs refer to the numbers of the samples listed in table 1. Examination of these photographs will show practically every type of failure found in asphalt prepared roofing that has been weathered outdoors, that is, fading, blistering, cracking of the surface coating, pitting, and loss of granules. No attempt has been made to rate generally the samples from the various manufacturers in the order of resistance to weathering or to establish a definite time ratio between accelerated and outdoor weathering.

In general, it can be said that the roofings of each manufacturer develop certain types of failure and retain commendable features peculiar to that particular brand. While there are certain similarities of behavior in the samples surfaced with the same granules but from different manufacturers, the most striking similarities are found when all of the samples from each manufacturer are considered without regard to the type of mineral surfacing used.

No detailed description of the behavior of each sample has been attempted. However, the types of failure found are here considered separately with reference to particular samples in which each is illustrated.

(a) COLOR CHANGES

The samples surfaced with oil- or resin-coated granules were the first to show color changes. In some cases this change appeared to be a slight fading, for example, the blue-black granules changed to a grayish-black with an accompanying change of texture which improved the appearance of the sample. In other cases, notably the ceramic red granules, the first change was an apparent color intensification. These changes are similar to those that take place in outdoor exposures and are caused by the destruction of the oil or resin coatings on the granules.

As the test proceeded, decided color changes similar to fading were noticed on all the samples, and were most evident on those surfaced with natural slate granules. Except for the blue-black granules, some of which became almost white, these color changes were described by several experienced observers as typical fading in severe outdoor exposures, and were so reported at the end of the test.

The fact that the continued wetting and drying of the surface of the samples would deposit salts that might be suspended or dissolved in the water, and the presence of a yellowish deposit, which partially obscures the color of the granules, render it impossible to make any definite statement as to the relation of color changes in the accelerated test and those obtained by outdoor exposures.

(b) BLISTERING

Blistering is probably the most frequent cause of complaint in roofing of this type and has been the subject of considerable study by the industry. In addition to giving the roofing an unsightly appearance, blisters physically weaken the asphalt coating; also, by exposing the coating to the effect of light and heat, they decrease its resistance to weathering.

The cause of blistering has been variously ascribed to moisture in the felt or coating asphalt, gases occluded in the coating or saturant, the type of asphalt, moisture in the granules, the kind of granules, faulty manufacturing practices, wetting of the material before application, etc. However, the presence of moisture in the sheet is probably the basic cause of most blisters.

In these tests some samples showed surface blisters after 24 hours of exposure, and at the end of 1 month practically all showed blisters. In general, these blisters increased in size for approximately 5 months, after which a noticeable subsidence was observed.

Figures 11, 12, and 13 show cross sections of typical kinds of blisters, each set of four samples showing the original unweathered material, and the same material after 1, 5, and 7 months in the accelerated weathering test. These sections show wide extremes, from scarcely detectable small blisters to large interconnecting ones.

Samples 30 and 34, figures 8 and 9, respectively, illustrate typical small individual blisters, and samples 9 to 12, inclusive, figure 3, large interconnecting ones.

In the accelerated blister tests, the blisters formed were of a different type than those in the accelerated weathering test, and they were always isolated and higher in relation to the diameter at the base, no doubt as the result of the higher temperature in the blister tests. In the weathering tests the blisters were relatively low and covered a larger area, in many cases several smaller blisters running together to form a series of connecting blisters. There is apparently no direct relationship in the formation of blisters by the two tests.

(c) PITTING

Pitting is closely related to blistering, being a further development in which the thin layer of asphalt surrounding the void has broken, either through the loss of a granule which penetrates the layer, or by the weathering of the thin layer of asphalt coating exposed by the formation of a blister. Pits or holes ranging from pin-point size to more than ¼ inch in diameter may be observed in figures 1 to 10. Samples showing small pits are illustrated by samples 1 and 2, figure 1, and sample 6, figure 2; large pits are shown by sample 35, figure 9, and samples 37, 38, and 39, figure 10. Samples from manufacturers *C* and *F* showed virtually no pits, while those from the other manufacturers had more and larger pits arranged as follows in increasing order of severity: *B, A, E, G, D, H.*

(d) LOSS OF GRANULES

The loss of granules by weight, on weathering, is greater for the natural slate granules than for the artificial granules (table 4). When this loss is averaged for all the samples surfaced with the same kind of granules, they are placed in the following ascending order: Ceramic red, ceramic green, natural red, black, and green slates.

From the standpoint of appearance, the position of the natural and artificial granules is reversed. The loss is less apparent for the natural slate granules because of their flat shape and scalelike overlapping. The artificial granules in most cases are practically equidimensional

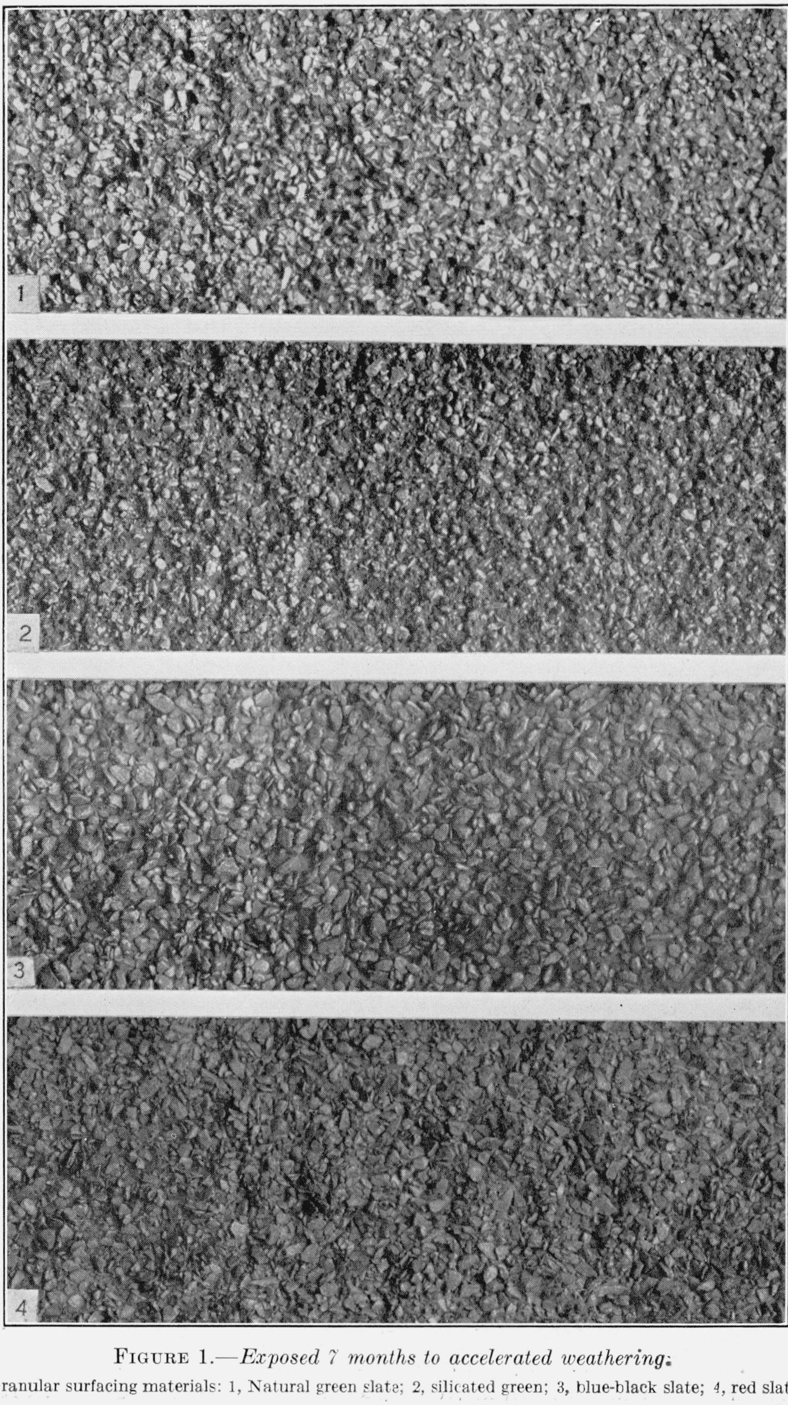

FIGURE 1.—*Exposed 7 months to accelerated weathering.*

Granular surfacing materials: 1, Natural green slate; 2, silicated green; 3, blue-black slate; 4, red slate.

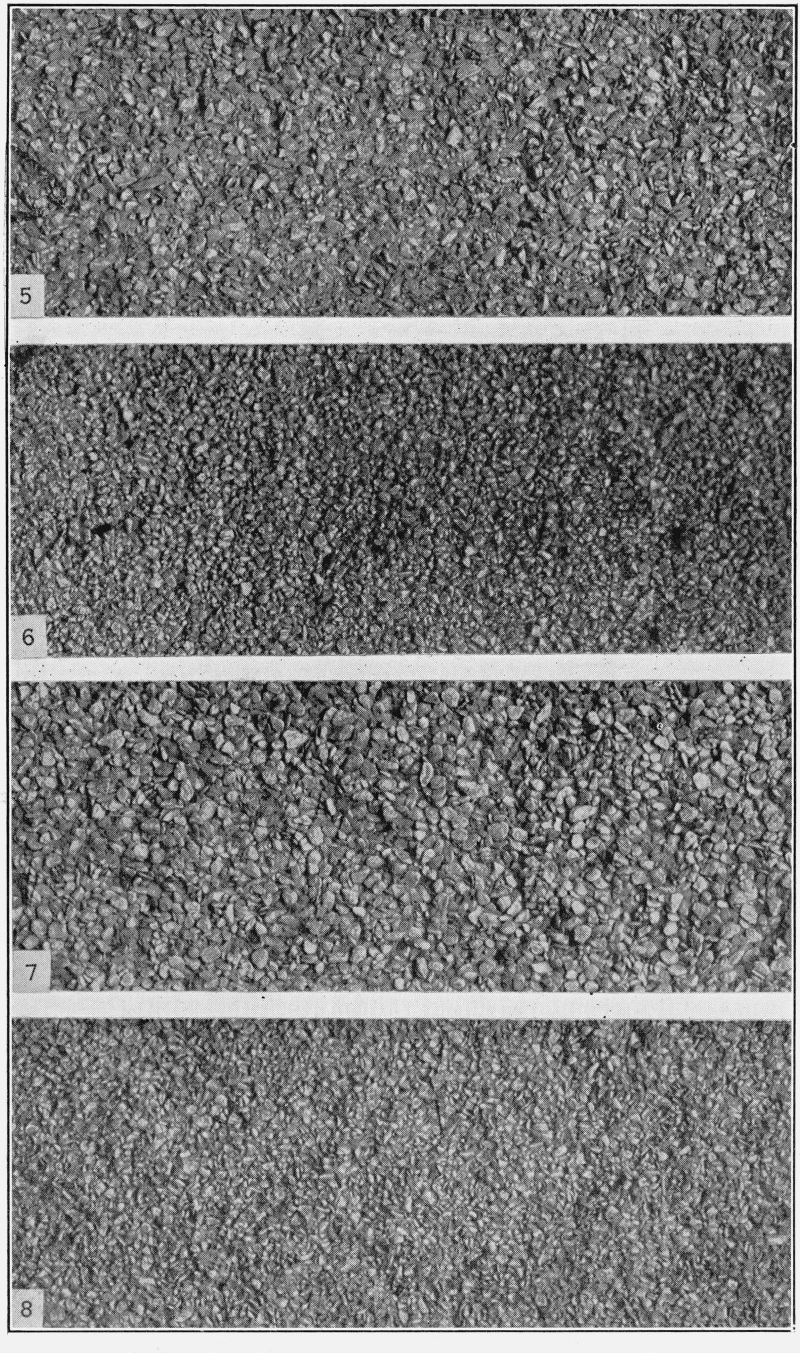

FIGURE 2.—*Exposed 7 months to accelerated weathering.*

Granular surfacing materials: 5, red slate; 6, ceramic green; 7, blue-black slate; 8, Kentucky greenstone.

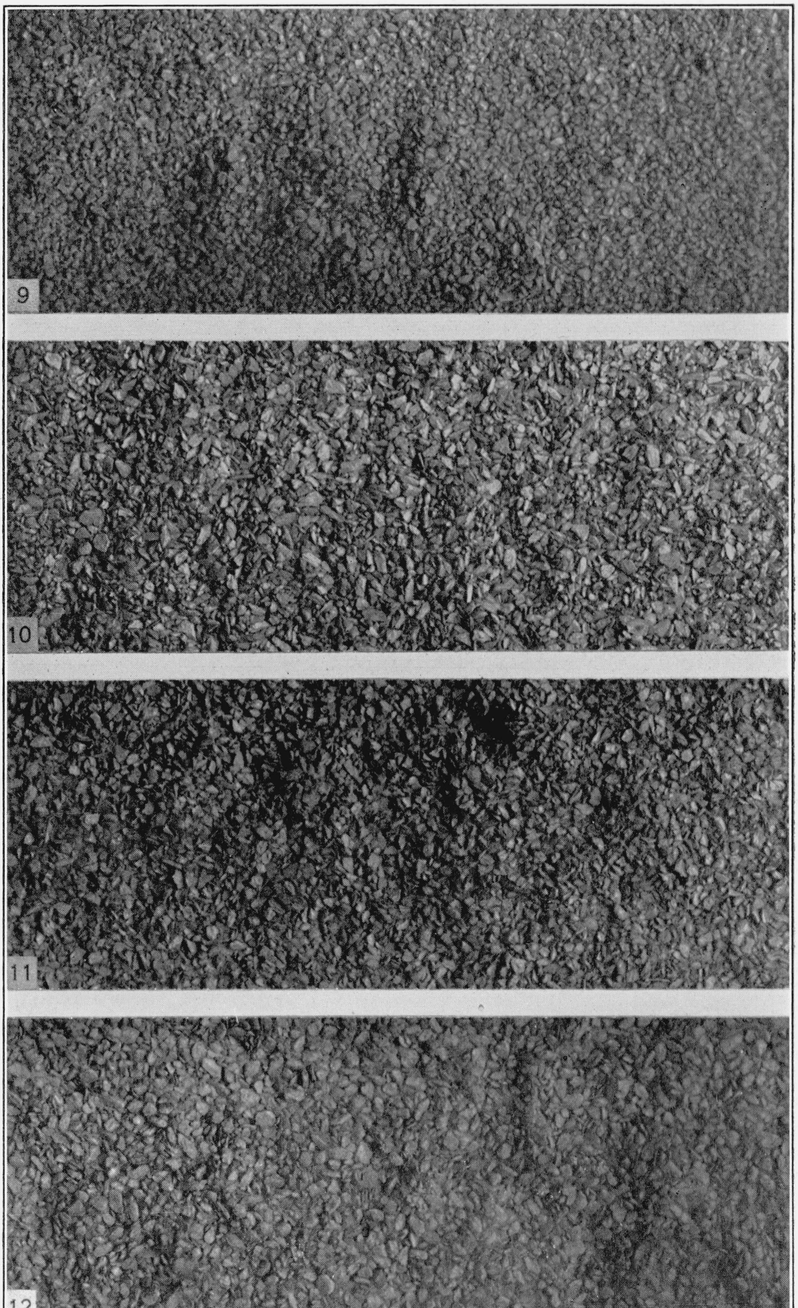

FIGURE 3.—*Exposed 7 months to accelerated weathering.*

Granular surfacing materials: 9, ceramic green; 10, green slate; 11, red slate; 12, blue-black slate.

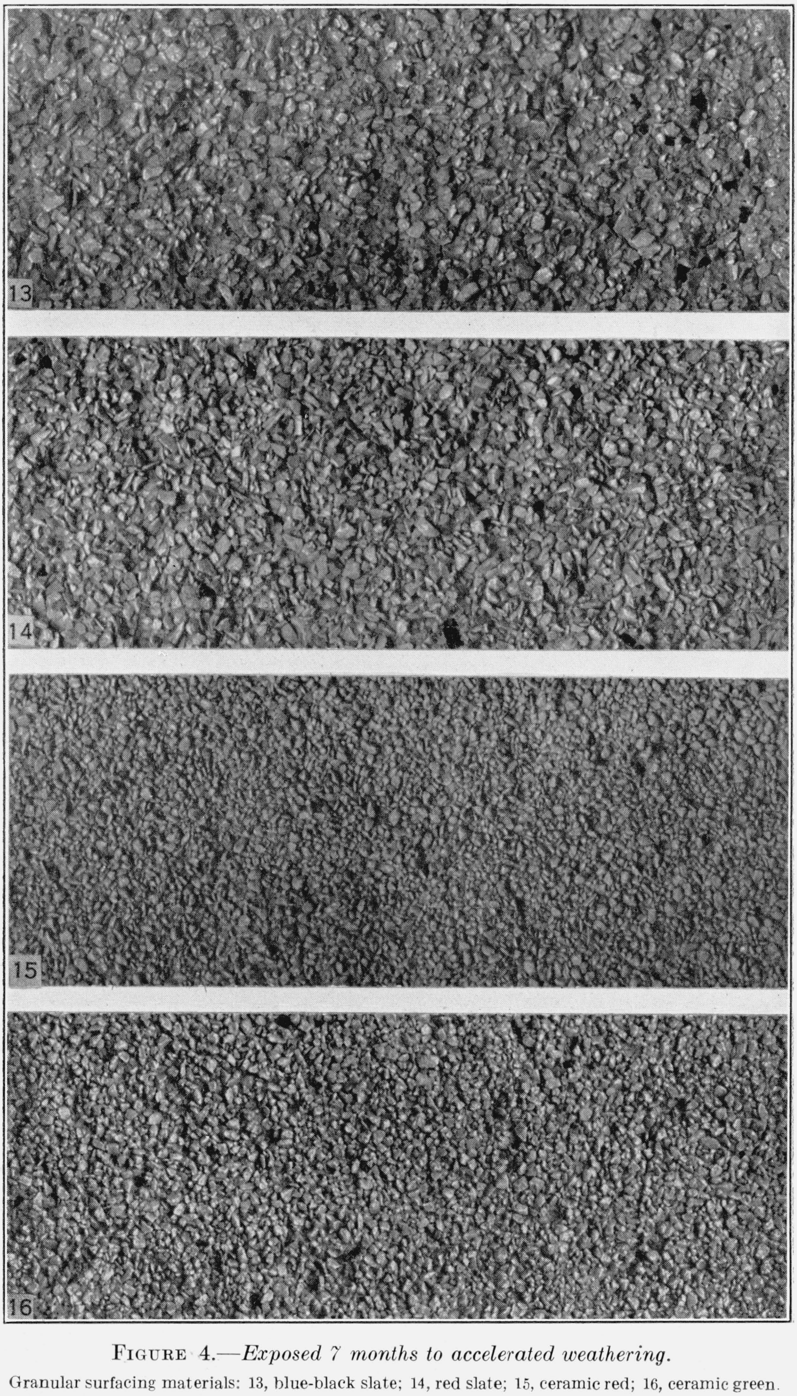

FIGURE 4.—*Exposed 7 months to accelerated weathering.*

Granular surfacing materials: 13, blue-black slate; 14, red slate; 15, ceramic red; 16, ceramic green.

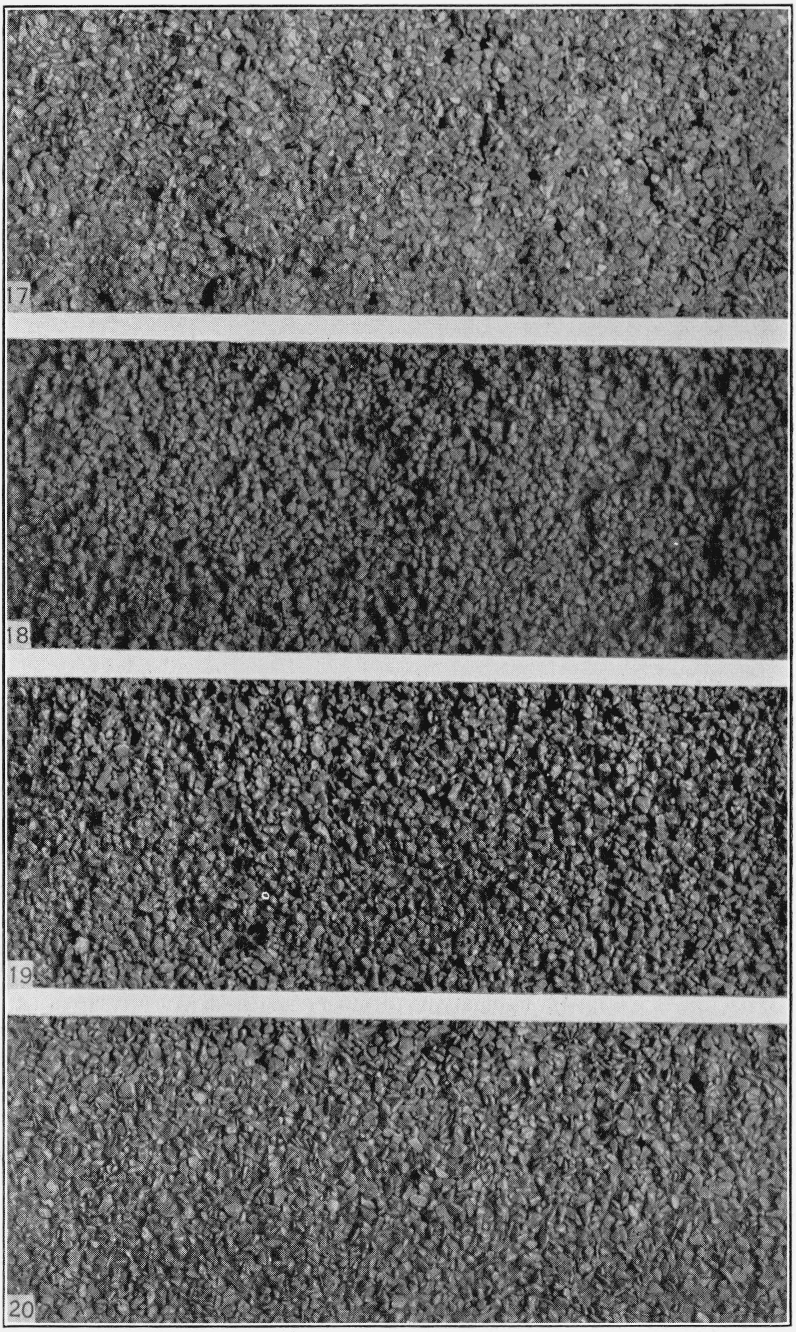

FIGURE 5.—*Exposed 7 months to accelerated weathering.*

Granular surfacing materials: 17, natural green slate; 18, ceramic red; 19, ceramic green; 20, cement-coated brier green.

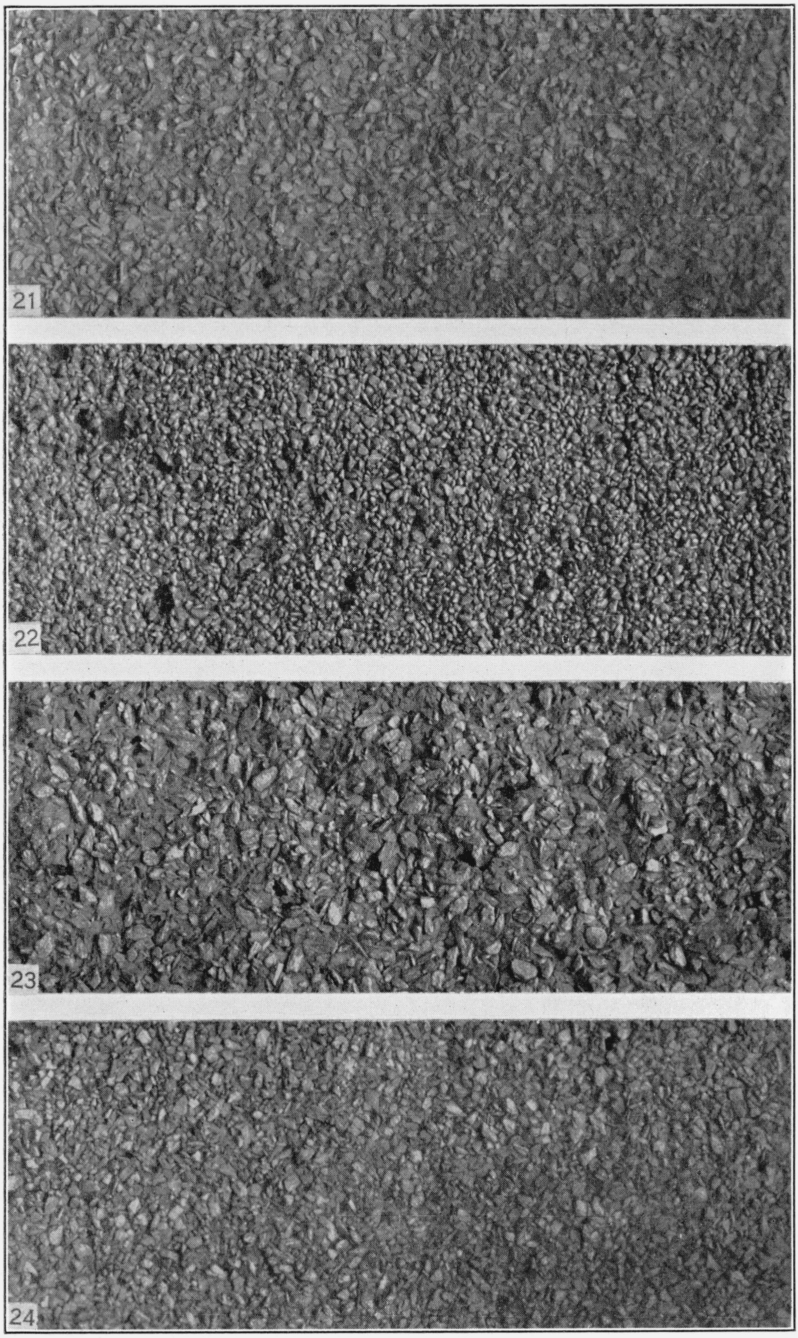

FIGURE 6.—*Exposed 7 months to accelerated weathering.*

Granular surfacing materials: 21, red slate; 22, burnt shale, indian red; 23, blue-black slate; 24, natural green slate.

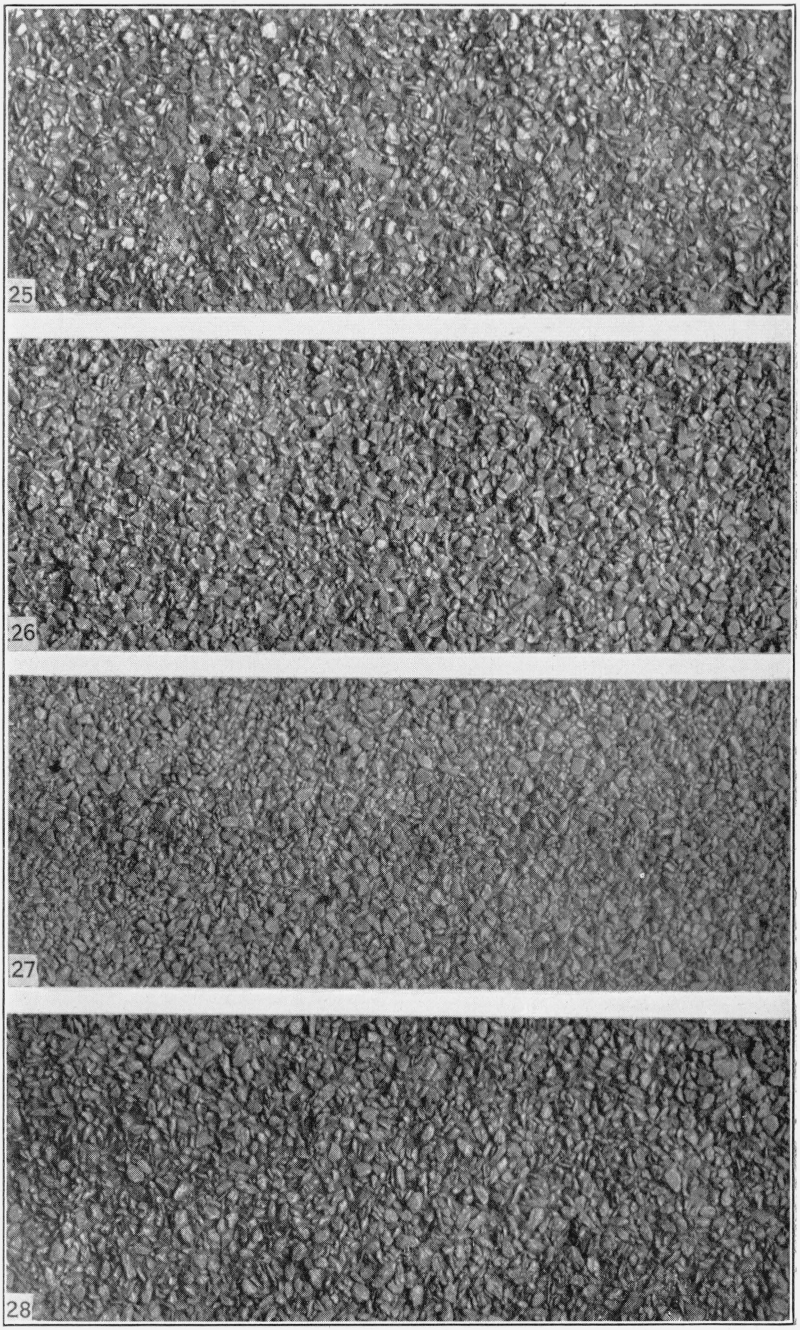

FIGURE 7.—*Exposed 7 months to accelerated weathering.*

Granular surfacing materials: 25, red slate; 26, silicated red; 27, silicated green; 28, black slate.

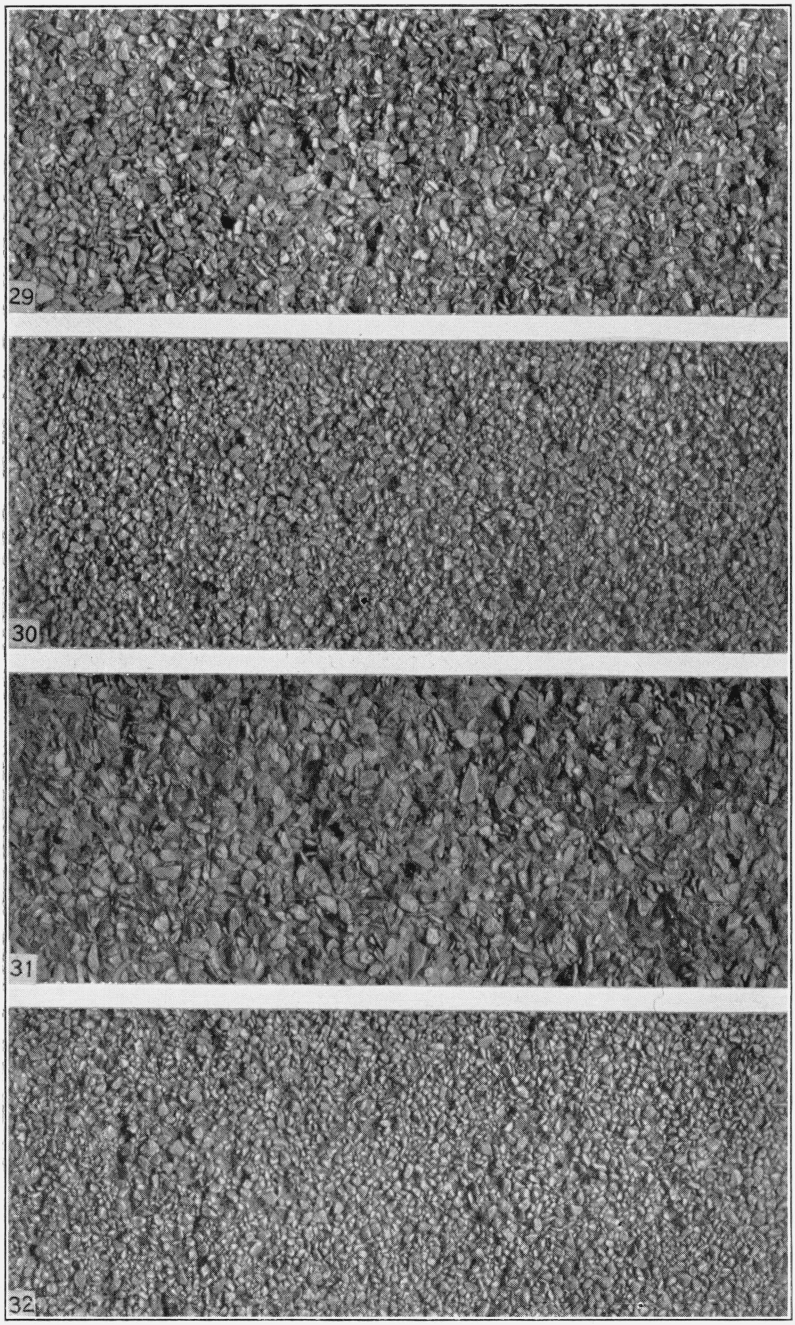

FIGURE 8.—*Exposed 7 months to accelerated weathering.*

Granular surfacing materials: 29, natural green slate; 30, ceramic green; 31, blue-black slate; 32, tile red.

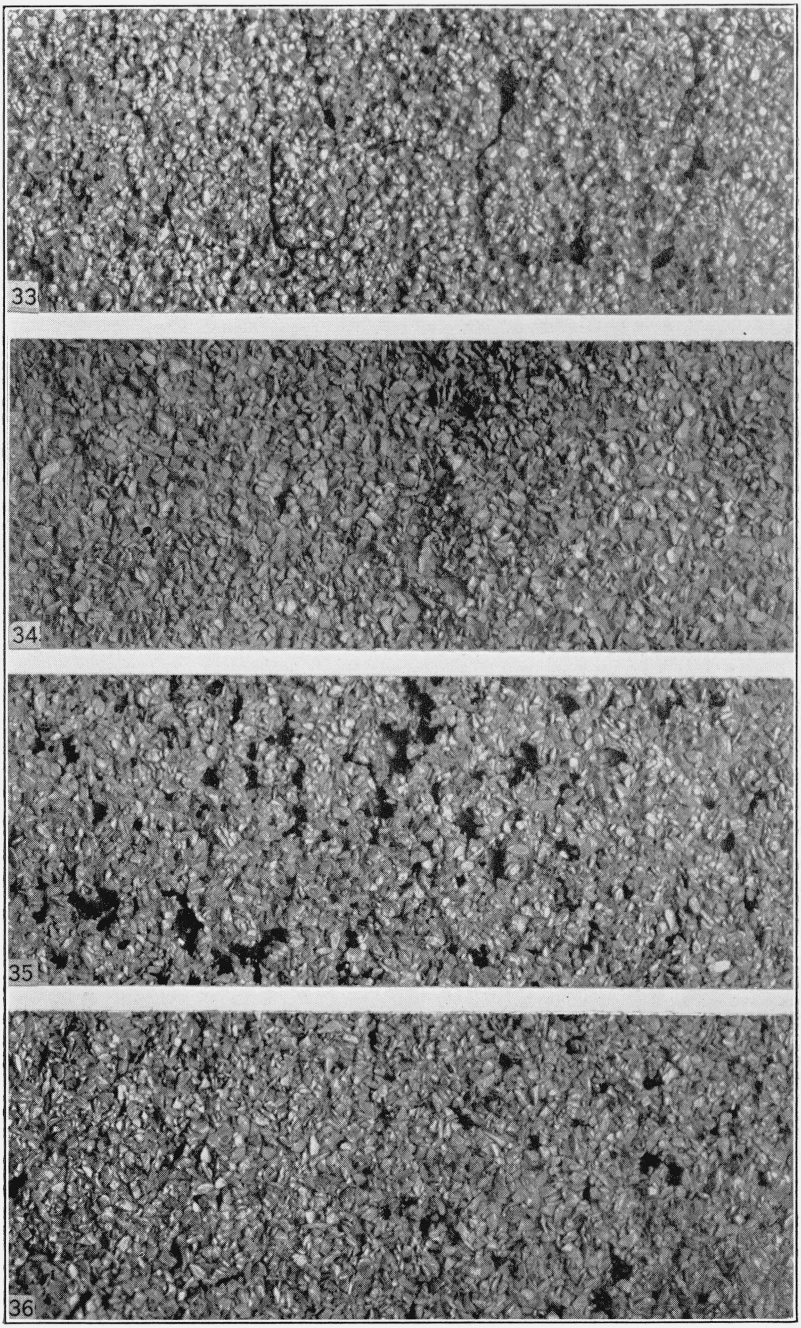

FIGURE 9.—*Exposed 7 months to accelerated weathering.*

Granular surfacing materials: 33, ceramic green; 34, red slate; 35, blue-black slate; 36, red slate.

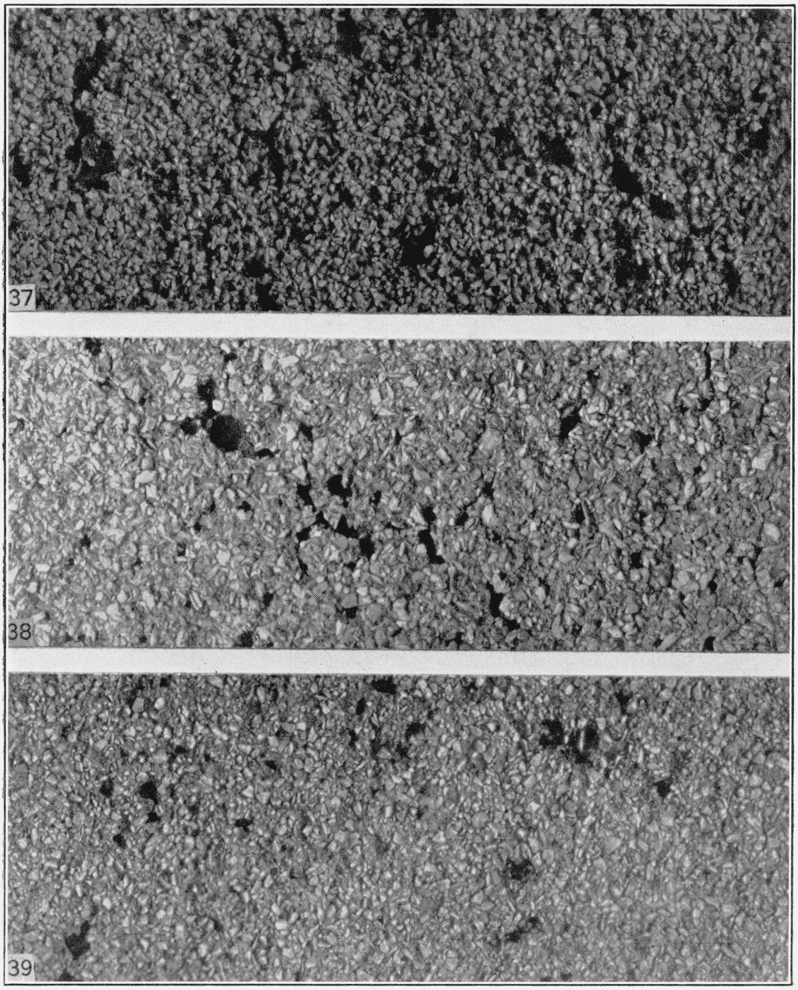

FIGURE 10.—*Exposed 7 months to accelerated weathering.*

Granular surfacing materials: 37, ceramic green; 38, natural green slate; 39, tile red.

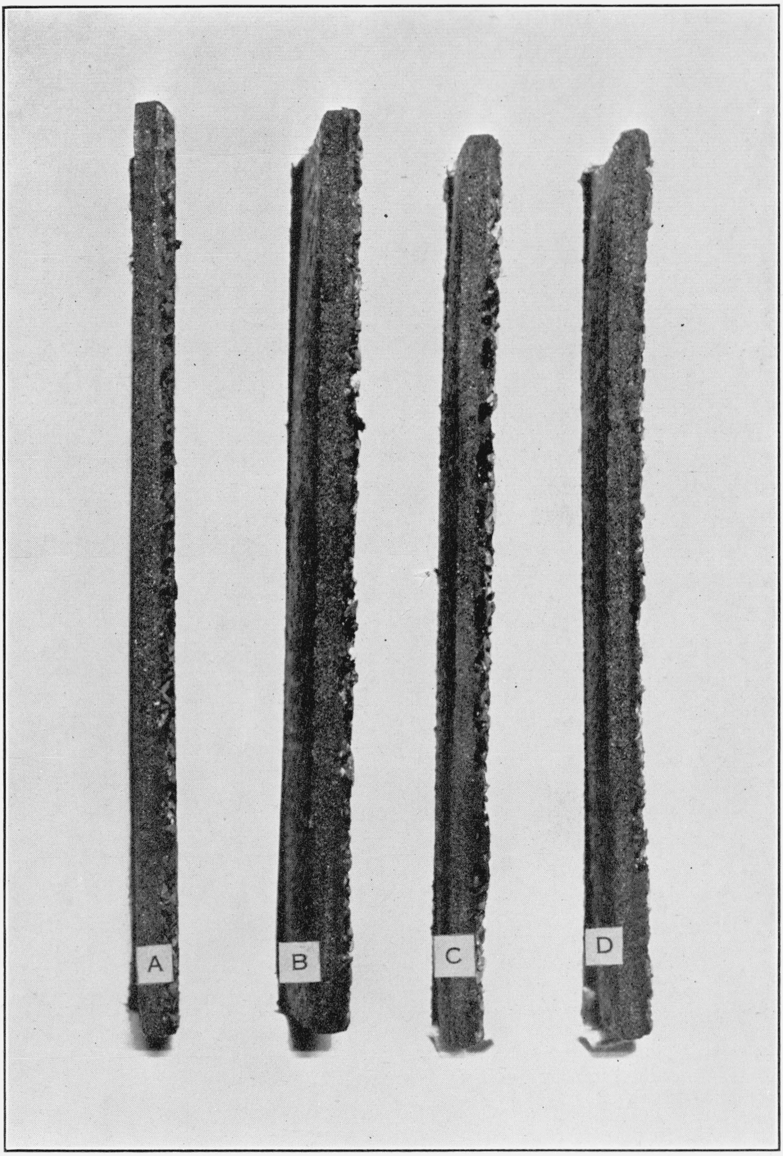

FIGURE 11.—*Cross sections of asphalt shingle test pieces* $\times 1\frac{1}{2}$ *(slight blistering).*

A. Original unweathered material.
B. Exposed 1 month to accelerated weathering.
C. Exposed 5 months to accelerated weathering.
D. Exposed 7 months to accelerated weathering.

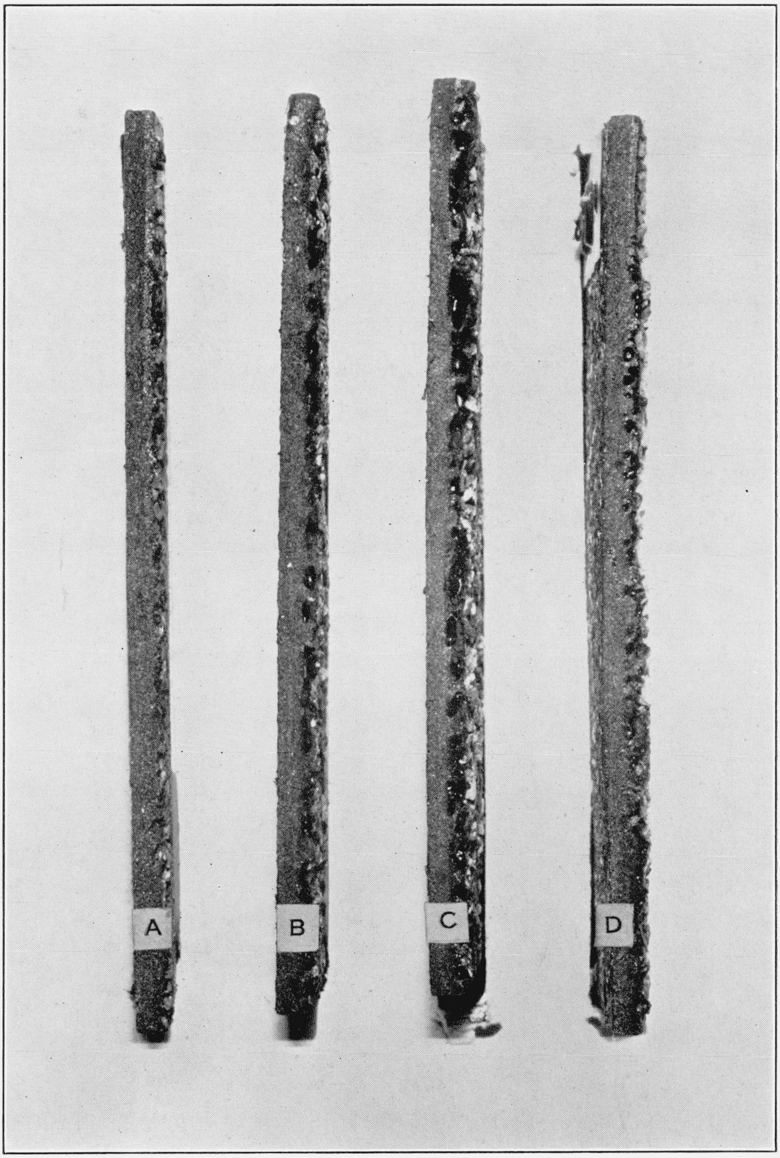

Figure 12.—*Cross sections of asphalt shingle test pieces* $\times 1\frac{1}{2}$ *(medium blistering).*

A. Original unweathered material.
B. Exposed 1 month to accelerated weathering.
C. Exposed 5 months to accelerated weathering.
D. Exposed 7 months to accelerated weatherihg.

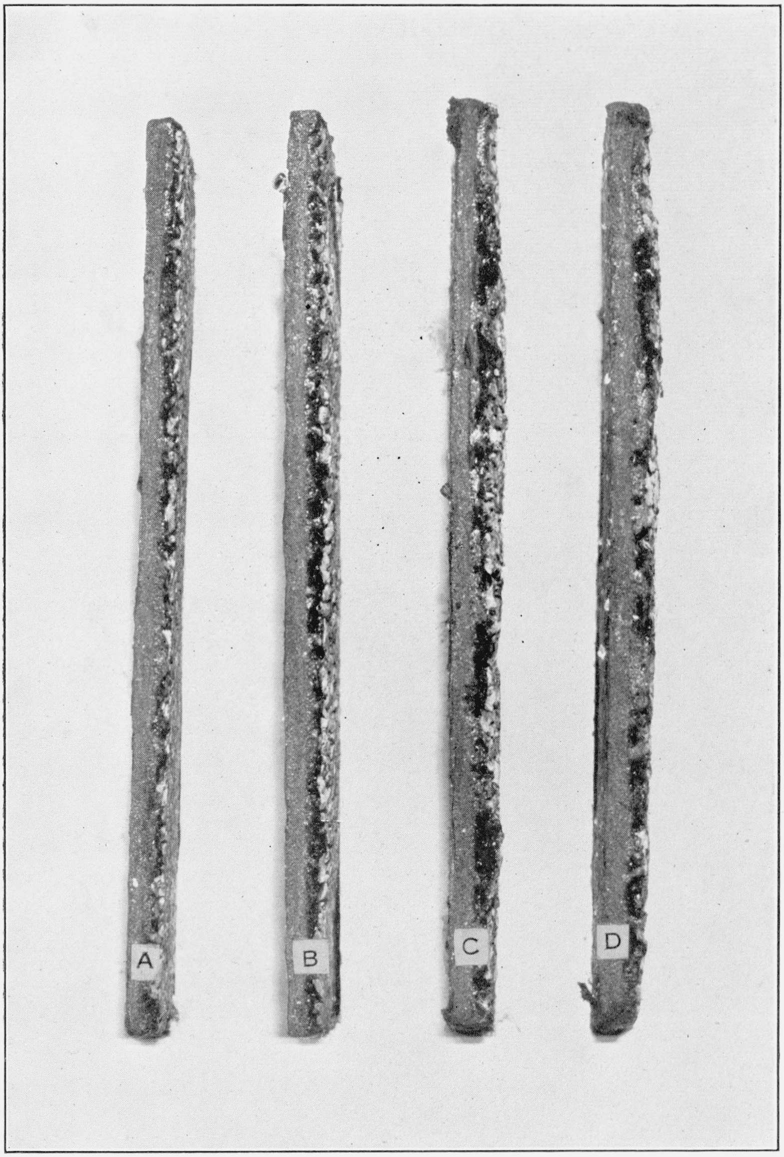

FIGURE 13.—*Cross sections of asphalt shingle test pieces* $\times 1\frac{1}{2}$ *(severe blistering).*

A. Original unweathered material.
B. Exposed 1 month to accelerated weathering.
C. Exposed 5 months to accelerated weathering.
D. Exposed 7 months to accelerated weathering.

and consequently do not overlap. With a few exceptions all samples showed good adhesion of granules. Those which appear noticeably poor in this respect are: Sample 13, figure 4; samples 18 and 19, figure 5; sample 33, figure 9; and sample 37, figure 10.

No general comparison could be made between the various kinds of granule treatments since most of the samples were surfaced with oil-treated granules. Samples 18 and 19 offer the only direct comparison between oiled and unoiled granules, other factors being the same. In this case no appreciable difference was noted.

(e) CRACKING

This defect, which is probably one of the most serious, occurred in relatively few samples. In the most severe cases, the surface coating has large cracks extending as much as 2 inches in length and down to the felt. Cracks of this type are illustrated in samples 36, 17, 13, 38, and 33 in the order of severity. Samples 16 and 22 illustrate slight cracking. The remaining samples show little or no cracking.

(f) WARPING

After about 1 month in the accelerated weathering test, some samples showed a decided tendency to warp or curl. When laid on a flat surface with the granular surfacing upwards, at the end of the test, the most extreme cases showed the center of the panel raised ½ inch, the maximum distortion permitted by the slots used to hold the samples. Samples 31 to 39, inclusive, from manufacturers *G* and *H*, were distorted most. Samples 25 to 30, from manufacturer *F*, showed slight distortion. All other samples remained practically flat.

(g) BEHAVIOR OF BACK COATING

The back coatings of all the samples from manufacturer *G* showed bleeding in spots. The back coatings of those from manufacturer *E* bled uniformly and blistered severely; and those of all other samples were practically unaffected or showed very slight bleeding.

(h) SLIPPAGE

The front asphalt coatings of all samples from manufacturer *C* show a slippage of approximately ¼ inch at the end of the test. This group of samples exhibited the greatest average slide in the accelerated slide test (table 3), which showed a possible relationship between the two tests. Samples from other manufacturers showed no slippage of the coating.

(i) WATER ABSORPTION

Water absorption (table 5) naturally increases with the extent of weathering, and is apparently influenced more by the materials used and the process of manufacture than by the type of granule, since, in general, where low average water absorption is shown for the samples from a particular manufacturer, all of the samples, regardless of the surfacing material, are low.

TABLE 5.—*Water absorption*

Sample	Original	Exposure for— 1 month	Exposure for— 5 months	Exposure for— 7 months
	lb/108 ft²	lb/108 ft²	lb/108 ft²	lb/108 ft²
1	1.94	2.05	2.74	3.42
2	2.28	2.74	3.08	3.88
3	2.05	1.82	2.05	2.85
4	1.94	2.05	2.28	3.54
Average	2.05	2.16	2.54	3.42
5	1.52	1.62	2.57	2 47
6	1.71	1.71	2.57	2.47
7	1.81	3.05	2.28	2.47
8	0.86	1.43	2.76	2.47
Average	1.47	1.95	2.54	2.47
9	1.37	1.60	2.17	2.97
10	1.14	1.14	3.72	4.68
11	1.25	1.60	2.51	3.54
12	0.80	1.25	3.31	3.20
Average	1.14	1.40	2.93	3.60
13	1.48	0.91	1.94	4.45
14	1.94	2.28	3.31	5.82
15	2.17	2.28	2.85	4.33
16	2.05	2.40	2.85	4.22
17	1.83	2.28	3.31	4.22
Average	1.89	2.03	2.85	4.61
18	1.43	1.62	2.19	3.33
19	1.52	2.10	2.00	3.33
20	1.14	1.71	2.00	2.76
21	1.14	1.33	2.19	2.76
22	1.14	1.62	2.85	3.42
23	0.86	1.62	2.19	2.10
24	1.52	1.62	2.00	2.95
Average	1.25	1.66	2.20	2.95
25	2.19	2.76	2.57	2.76
26	2.19	2.19	3.05	2.76
27	2.29	2.48	2.76	3.24
28	1.71	1.90	2.38	2.19
29	1.81	2.29	2.95	3.42
30	1.43	1.62	2.19	2.38
Average	1.94	2.21	2.65	2.79
31	1.48	1.94	2.62	6.85
32	1.71	2.28	2.74	3.88
33	1.37	1.71	2.17	5.25
34	1.60	1.71	2.85	6.05
Average	1.54	1.91	2.59	5.51
35	1.37	1.71	2.05	2.85
36	1.60	1.82	2.51	3.20
37	1.71	2.28	3.08	4.57
38	1.37	2.05	2.85	4.45
39	2.40	2.74	4.45	7.42
Average	1.69	2.12	2.99	4.50

V. SUMMARY

1. Of 39 samples of mineral-surfaced asphalt strip shingles from 8 manufacturers, 12 failed to meet the composition requirements of Federal Specification SS–R–521. Averaging the analyses of shingles from each manufacturer, those from only one manufacturer failed to meet the requirements. Except that the shingles submitted by one manufacturer contained no fine mineral filler in the asphalt coatings, and that those from another were low in percentage saturation of the felt, the samples were remarkably uniform in composition, and showed no differences sufficiently great to warrant the prediction of decided differences in their behavior to weathering.

2. All of the types of failure encountered in long outdoor exposures of these roofings under the most severe conditions can be produced in a relatively short time by accelerated weathering. The samples from each manufacturer exhibit a characteristic behavior which is largely independent of the type of granular surfacing materials used, which indicates that the types of asphalt used and the manufacturing process largely influence the behavior to weathering, if large variations in the proportions by weight of the several constituents in the finished roofing are excluded.

3. In these tests the samples which contained fine mineral filler in the asphalt coatings (not required in the Federal specification) withstood weathering best. In general, noncompliance with the re-

quirements of the Federal specification was not evidenced in the results of these tests.

4. Mechanical abrasion tests are of value to determine adhesion of granules at the time of manufacture and should be of value for factory control. Apparently these tests can not be used to predict how well granules will adhere on exposure to the weather.

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