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NATIONAL RESEARCH COUNCIL
CANADA
DIVISION OF BUILDING RESEARCH

THE EFFECT OF MOISTURE ON ASPHALT SHINGLES

by

M. Ayukawa and P.J. Sereda

Prepared for Central Mortgage and Housing
Corporation in co-operation with Forest
Products Laboratories, Department of
Northern Affairs and National Resources

Report No. 84
of the
Division of Building Research

Ottawa
May 1956

PREFACE

The study of the dimensional instability of asphalt shingles, the preliminary results of which are now reported, was undertaken as part of a project involving a critical examination of the practices recommended at present in the use of asphalt shingles over wood roof boards. This project, carried out in the first instance for Centreal Mortgage and Housing Corporation, is a co-operative one with the Forest Products Laboratory undertaking the studies on wood performance. Observations are being made, in co-operation with C.M.H.C. of the performance of the roofs of substantial numbers of relatively new houses, and an experimental roof has been constructed on a research house being operated at the Montreal Road Laboratories by this Division.

Further reports may be expected as these studies progress, on various aspects of the project.

Ottawa,
April 1956.

N.B. Hutcheon,
Assistant Director.

THE EFFECT OF MOISTURE ON ASPHALT SHINGLES

by

M. Ayukawa and P.J. Sereda

Buckling of asphalt shingles on the roofs of houses has been observed in a number of instances for some time. Comprehensive surveys indicating the extent of the problem, however, have not been reported in the literature. There is no information available that relates the occurrence of buckling to the method used for fixing the shingles, the design feature of the roof, moisture condition and board width of the roofing lumber, the age of the particular roof, or the season of the year in which it is most prevalent.

It has been generally believed that the movement of the roof boards due to moisture content changes was responsible for the buckling of shingles.

The dimensional changes which take place in wood with changes in moisture content are well known. An experiment was carried out to determine the extent of movement required to produce "cupping" in shingles when they are fixed with the row of nails spaced 5 inches apart. It was found that a $\frac{1}{4}$ -inch rise of shingle at mid-position produces a noticeable "cup". This corresponds to a relative change of $\frac{3}{64}$ -inch in the distance between the centre lines of shingle nails, or 0.9 per cent.

Studies were then undertaken to determine whether asphalt shingles were dimensionally stable when subjected to moisture. Results of the preliminary work suggested that the asphalt shingles examined were not dimensionally stable during changes in moisture conditions and that a length change of over 1 per cent accompanied the absorption of up to 4.0 gm. of water in specimens 2 by 6 inches in size.

This evidence prompted an experiment in which asphalt shingles were nailed to 18-gauge galvanized sheet metal fixed to wooden supports for nail-holding purposes. This assembly which was 3 feet wide with four rows of shingles was placed in a humid chamber. After approximately 10 days noticeable buckling was observed.

As a result of the above observations an extensive series of test was undertaken to determine the properties of asphalt shingles insofar as dimensional instability was concerned. For this purpose one bundle of three-tab square

butt strip shingles of nominally 210-pound weight, of each manufacturer's product available in Ottawa, a total of seven, was purchased on the open market. One of the seven, No. 4, was a thick-butt type and the exposed area was used for the tests.

Two shingles were picked at random from each bundle, and four 2- by 6- inch test specimens were cut from each shingle representing the portion of the shingle normally between two horizontal rows of nails. Of these samples, two were used for a vacuum saturation and heat cycle, and two for a water immersion and heat cycle.

Vacuum Saturation and Heat Test

This test was carried out by vacuum saturation during the week from Monday to Friday and leaving the samples in an oven at 160°F. over the weekend, cooling them in a desiccator to weigh on Monday, and then vacuum saturating again. The specimens were weighed and measured at the beginning of each working day.

A sample run showing the dimensional changes of each product is shown in Fig. 1 in which the change in length is plotted against time. For the purpose of comparison 0-length has been taken to be the length after vacuum saturating for four days. Almost identical results were obtained with the two shingles from each bundle. Table I gives the corresponding change in length of the samples and Table II the change in weight with time. The reference point for the latter table is the weight as received. It is seen that there is a difference in the behaviour of the products subjected to these test conditions. Product No. 1 absorbed the most water, from 5.6 to 5.9 gm. in 4 days and showed 1.1 per cent change in length, while product No. 3 absorbed from 1.5 to 2.7 gm. of water with a corresponding increase in length of 0.4 to 0.7 per cent.

It is seen that on drying, the samples shrank to less than their original size. With each successive cycle of wetting and drying, the samples showed less increase in length with wetting and less shrinkage with drying. It was also found that it took a longer period for equilibrium to be established with regard to their length. At the conclusion of the run, therefore, the vacuum saturation was continued for two weeks at the end of which time all the shingles had reached a constant length which was from .02 to .07 inch less than the length observed after vacuum saturating for 4 days at the start of the experiment. Thus irreversible shrinkage took place with each complete cycle from dry to wet to dry. This shrinkage may have been related to the rate and period of drying and wetting but this was not investigated.

Water Immersion and Heat Cycles

It was thought that vacuum saturation might be too extreme a wetting condition to be applied to the shingles. A number of cycles were run by immersing the shingles in a pan of water for 8 to 10 days and then drying them for 3 to 4 days in an oven at 160°F. It was found that the water immersion and heat cycles followed the same pattern as the vacuum saturation as shown in Fig. 2 where representative runs are plotted, but that the absorption of water and therefore the change in length took place at approximately half the rate. However, the total amount of water absorbed and the increase in length was almost identical.

Comparison of the Rate of Absorption and Loss of Moisture by the Two Sides of the Shingle

When shingles are in place on a roof, not only the mineral-granuled side, but also the reverse side is exposed to water, in the form of wind-driven rain and melting snow and in some instances for prolonged periods of time. Therefore, it was considered of interest to determine from which side of the shingle more absorption of water takes place and whether the underside is more susceptible.

Four 2- by 6-inch test specimens of products No. 4 and No. 7 were taken. These shingles were coated with a wax mixture in such a way that half of the samples had only the mineral-granuled side unprotected and the other half had the reverse side unprotected. These samples were then placed in water and the total amount of water absorbed was determined daily. After 24 days the samples were placed in the conditioned room and the daily weighings were continued.

Representative results are shown in Fig. 3. It is seen that more water was absorbed through the reverse side, and that the rate of loss of moisture was greater through this side.

It may be concluded, therefore, that the reverse side is more susceptible to moisture pick-up.

Pliability

It is logical to assume that asphalt shingles should retain a degree of pliability in service if they are to give good performance, but a decrease of pliability with age has been noted. It was of interest, therefore, to determine what caused this change in pliability, whether it was heat, moisture, or both, and also to compare the performance of the different manufacturer's products.

Approximately 25 1- by 8-inch test specimens were cut vertically from each shingle. Half of these were placed in an oven at 160°F. to be used to test the effect of heat alone, and the other half were vacuum saturated during the week days and then placed in the oven over the weekends. The first set of specimens was tested for pliability on Fridays and Mondays while the second set only on Mondays, that is, after the heating period. The test was carried out by allowing the specimens to cool to room temperature and then bending them through 90° over the rounded edge of a block at a uniform rate in approximately 2 seconds.

The block was 3 inches square by 2 inches thick, with rounded corners of $\frac{1}{2}$ -, $\frac{3}{4}$ - and 1-inch radius.

At first the specimens were bent over the $\frac{1}{2}$ -inch radius corner. Where failure was observed, another end of the specimen, or a new specimen, was used to test for failure on the other corners. Failure was considered to be any surface rupture exceeding 1/8-inch in length.

The observations are given in Table III where the A columns are the results obtained for heat alone, and the B columns for heat and vacuum saturation, with the reference point being the number of days of heating. There was a wide range in pliability of the shingles from the different manufacturers. In the first test, No. 4 which was the exposed area of a thick-butt shingle, failed on the 1-inch corner after only 4 days, while Nos. 1, 5, 6, and 7 failed on the 1-inch corner only after 28 days. Approximately the same order of failure was observed for the second test. However, it is seen that when 4 days of vacuum saturation are interposed between every 3 days of heat, the failure point is accelerated. It may therefore be concluded that loss of pliability depends not only on heat but also on wetting.

Summary

Samples of asphalt shingles made by seven manufacturers and available in the Ottawa area were subjected to cyclic conditions of drying in the oven at 160°F. and wetting by immersion in water under partial vacuum. It was found that samples 2 by 6 inches absorbed 1.5 to 5.9 gm. of water in 4 days of vacuum saturation accompanied by a dimensional increase of from 0.4 to 1.1 per cent.

On repeated cycles of drying and wetting the samples exhibited an irreversible shrinkage ranging from .02 to .07 inch.

When the samples were subjected to cycles of drying at 160°F. and wetting by immersion in water under normal atmospheric conditions, similar results as described above were obtained except that the rate of change was about half.

The reverse side of a shingle was found to be more susceptible to moisture pick-up as observed in these tests, the extremes for product No. 7 being 1.7 gm. of water through the weather side and 3.2 gm. through the reverse side.

Loss of pliability was found to depend on both heat and moisture. There was a wide range in the ability of the different products to retain their pliability. One shingle, No. 4, became very brittle after only one cycle of wetting and drying, or 4 days of heating at 160°F. No. 4 was, however, a thick-butt shingle, and the exposed area was put to this test so that this must be taken into consideration.

Further experimental work has been planned to sort out the factors of composition which may be responsible for the above properties and their variations. An analysis of the shingles for their components according to A.S.T.M. D228-54T has been undertaken. An extensive study of the composition of the saturants by solvent separation, and a study of their differences in water absorption is planned.

TABLE I

CHANGE IN LENGTH (inches x 10⁻³) OF 6-INCH SPECIMENS OF ASPHALT SHINGLES WITH WETTING AND DRYING

————— Wetting Period
 Drying Period

Days	Product No. 1	Product No. 2	Product No. 3	Product No. 4	Product No. 5	Product No. 6	Product No. 7
0	- 69	- 40	- 27	- 52	- 64	- 67	- 51
1	- 16	- 18	- 23	- 16	- 44	- 19	- 37
2	- 7	- 4	0	- 4	- 17	- 4	- 12
3	- 4	- 1	- 5	- 1	- 7	- 4	- 2
4	0	0	0	0	0	0	0
5-6	:	:	:	:	:	:	:
7	- 88	- 62	- 43	- 94	- 96	- 84	- 84
8	- 39	- 32	- 31	- 84	- 73	- 23	- 68
9	- 29	- 25	- 22	- 47	- 55	- 16	- 49
10							
11	- 22	- 18	- 9	- 37	- 39	- 11	- 34
12-13	:	:	:	:	:	:	:
14	-103	- 70	- 50	-107	-113	- 87	-110
15	- 66	- 54	- 44	- 82	-103	- 66	- 97
16							
17	- 44	- 38	- 29	- 64	- 68	- 32	- 55
18	- 38	- 36	- 19	- 63	- 62	- 31	- 47
19-20-21	:	:	:	:	:	:	:
22	-108	- 77	- 58	-122	-124	-101	-120
23	- 74	- 60	- 52	-102	-112	- 82	-107
24	- 58	- 48	- 40	- 85	- 91	- 51	- 77
25	- 49	- 38	- 32	- 81	- 76	- 50	- 61
26-27	:	:	:	:	:	:	:
28	-115	- 86	- 63	-130	-132	-103	-128
29	- 85	- 66	- 57	-110	-121	- 86	-115
30	- 68	- 54	- 53	- 96	-109	- 61	- 94
31	- 62	- 47	- 46	- 89	- 94	- 53	- 78
32	- 56	- 37	- 33	- 81	- 82	- 49	- 68
33-34	:	:	:	:	:	:	:
35	-119	- 90	- 67	-143	-141	-106	-129
36	- 88	- 69	- 62	-116	-125	- 95	-118
37	- 72	- 54	- 55	- 97	-113	- 68	- 99
38	- 67	- 50	- 49	- 89	-100	- 60	- 83
39	- 62	- 47	- 39	- 84	- 87	- 56	- 73
40-41	:	:	:	:	:	:	:
42	- 47	- 39	- 29	- 81	- 72	- 49	- 62
43	- 47	- 39	- 28	- 77	- 71	- 49	- 62
44	- 47	- 39	- 27	- 75	- 70	- 49	- 62
45			- 25	- 73	- 69		
46			- 25	- 71	- 68		
47-48	:	:	:	:	:	:	:
49	- 46	- 39	- 25	- 71	- 68	- 49	- 62

Reference point is length after vacuum saturating for 4 days.

TABLE II

CHANGE IN WEIGHT (grams) OF 2- BY 6-INCH SPECIMENS OF
ASPHALT SHINGLES WITH WETTING AND DRYING

————— Wetting Period
..... Drying Period

Days	Product No. 1	Product No. 2	Product No. 3	Product No. 4	Product No. 5	Product No. 6	Product No. 7
1	+3.965	+1.789	+0.657	+1.583	+1.201	+2.520	+1.047
2	+5.097	+3.645	+0.982	+3.640	+2.163	+3.897	+1.531
3	+5.564	+3.725	+1.342	+3.776	+2.635	+4.222	+2.827
4	+5.837	+3.880	+1.582	+4.140	+2.822	+4.380	+2.998
5-6							
7	-0.353	-0.381	-0.661	-0.423	-0.334	-0.380	-0.511
8	+4.163	+2.736	+1.009	+3.117	+1.826	+3.098	+1.954
9	+4.807	+2.969	+1.311	+3.321	+2.168	+3.437	+2.521
10							
11	+4.988	+3.353	+1.626	+3.715	+2.949	+3.712	+2.844
12-13							
14	-0.437	-0.514	-0.747	-0.531	-0.382	-0.445	-0.617
15	+3.401	+2.263	+0.454	+2.372	+1.306	+1.988	+1.438
16							
17	+4.636	+3.034	+1.257	+3.074	+2.305	+3.287	+2.534
18	+4.644	+3.064	+1.289	+3.266	+2.140	+3.354	+2.777
19-20-21							
22	-0.471	-0.519	-0.812	-0.542	-0.403	-0.479	-0.632
23	+3.250	+2.053	+0.505	+2.065	+1.198	+1.725	+1.448
24	+3.882	+2.739	+0.875	+2.697	+1.580	+2.682	+2.219
25	+4.212	+2.870	+1.134	+2.884	+1.922	+2.851	+2.571
26-27							
28	-0.501	-0.549	-0.818	-0.582	-0.408	-0.471	-0.643
29	+3.278	+2.112	+0.184	+2.055	+0.948	+1.596	+1.089
30	+3.948	+2.607	+0.351	+2.587	+1.400	+2.351	+1.686
31	+4.177	+2.768	+0.616	+2.823	+1.565	+2.641	+1.914
32	+4.329	+2.830	+0.711	+2.956	+1.647	+2.721	+2.167
33-34							
35	-0.493	-0.568	-0.851	-0.587	-0.418	-0.496	-0.641
36	+3.452	+2.065	+0.083	+1.934	+1.020	+1.409	+1.126
37	+3.890	+2.695	+0.351	+2.597	+1.184	+2.180	+1.722
38	+4.225	+2.784	+0.550	+2.789	+1.453	+2.393	+2.095
39	+4.235	+2.872	+0.697	+3.047	+1.524	+2.552	+2.288
40-41							
42	+4.656	+3.020	+0.981	+3.188	+1.792	+2.854	+2.583
43	+4.844	+3.045	+1.054	+3.247	+1.895	+2.857	+2.572
44	+4.817	+3.024	+1.098	+3.327	+1.912	+2.948	+2.647
45			+1.350	+3.287	+1.967		
46			+1.172	+3.333	+1.929		
47-48							
49	+5.120	+3.148	+1.362	+3.443	+2.028	+3.114	+2.809

Reference point is weight as received.

TABLE III

SUMMARY OF RESULTS OF PLIABILITY TESTS

No. of Days of Heat	* 1		2		3		4 ***		5		6		7	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
0	p	p	p	p	p	p	1/2" f	1/2" f	p	p	p	p	p	p
1														
2														
3		1/2" vsc		1/2" f			1/2" vsc		1" f		p		p	p
4	p		1/2" f		p		1" f			p	p		p	
5														
6		1" vsc		1" f			1" vsc			1/2" vsc		1/2" vsc		1/2" vsc
7	1/2" vsc		3/4" f		1/2" vsc					p		p		1/2" vsc
8														
9		1" sc					1" f			1/2" f		3/4" vsc		1" sc
10														
11	1/2" f		1" f		1/2" f					p		1/2" vsc		3/4" vsc
12		1" f									1" sc		1" f	1" sc
13														
14	1" vsc				1" f					3/4" vsc		3/4" sc		1" sc
15										1" f				1" f
16														
17														
18	1" sc									1" vsc		3/4" f		1" f
19														
20														
21	1" f									1" sc		1" sc		
22														
23														
24														
25										1" f		1" f		

* Numbers designate shingles of different manufacturers.

*** Exposed area of thick-butt type shingle.

Letters A - condition of heating in oven at 160°F.

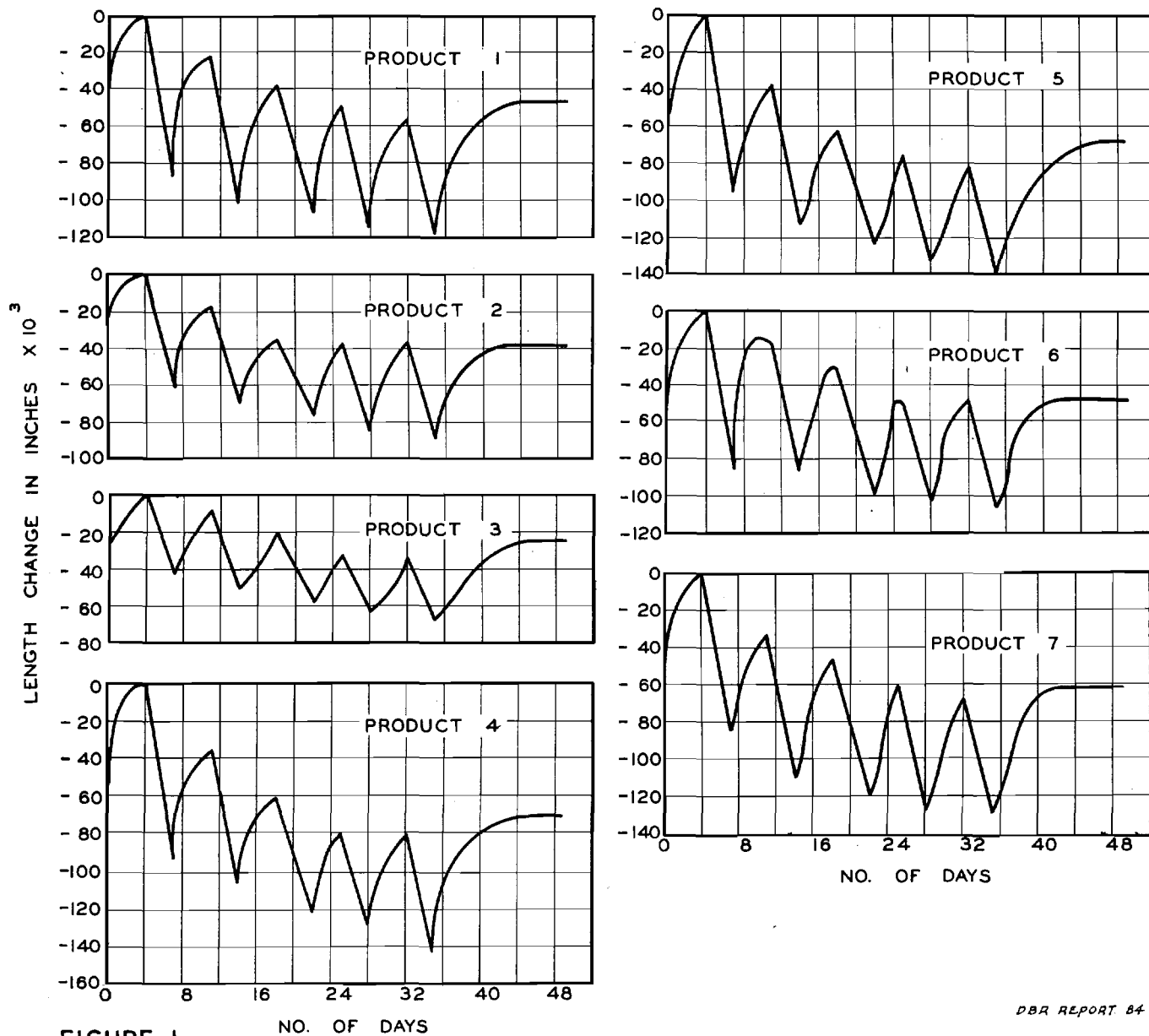
B - cyclic condition of heating in oven at 160°F.
and wetting by water under partial vacuum.

p = passed

f = failure

vsc = very small crack

sc = small crack



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FIGURE 1

EFFECT OF CYCLIC WETTING (PARTIAL VACUUM SATURATION) AND DRYING ON DIMENSIONS OF 6 - INCH SPECIMENS OF ASPHALT SHINGLES.

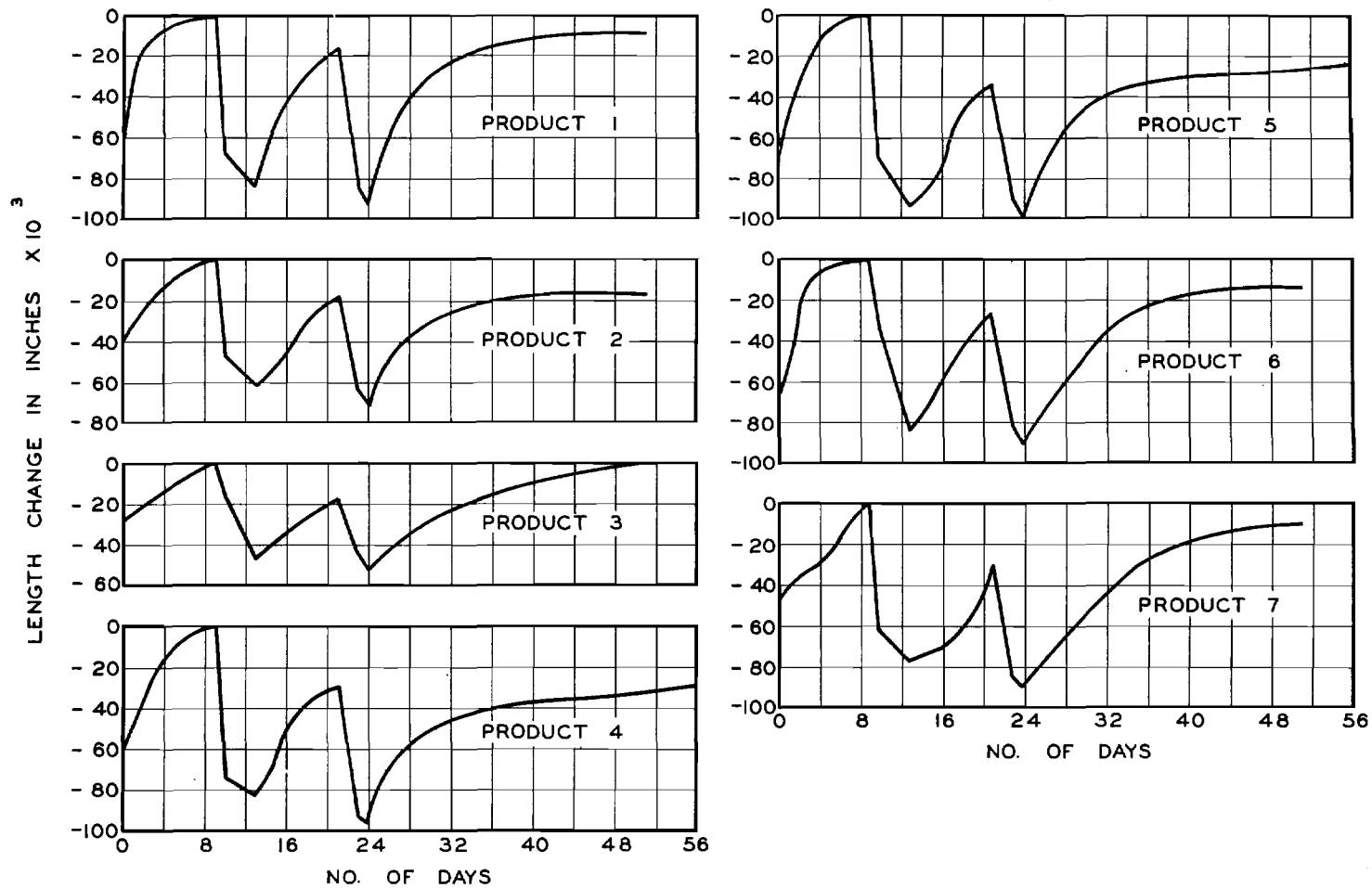


FIGURE 2

EFFECT OF CYCLIC WETTING (IMMERSION) AND DRYING ON DIMENSIONS OF 6 - INCH SPECIMENS OF ASPHALT SHINGLES.

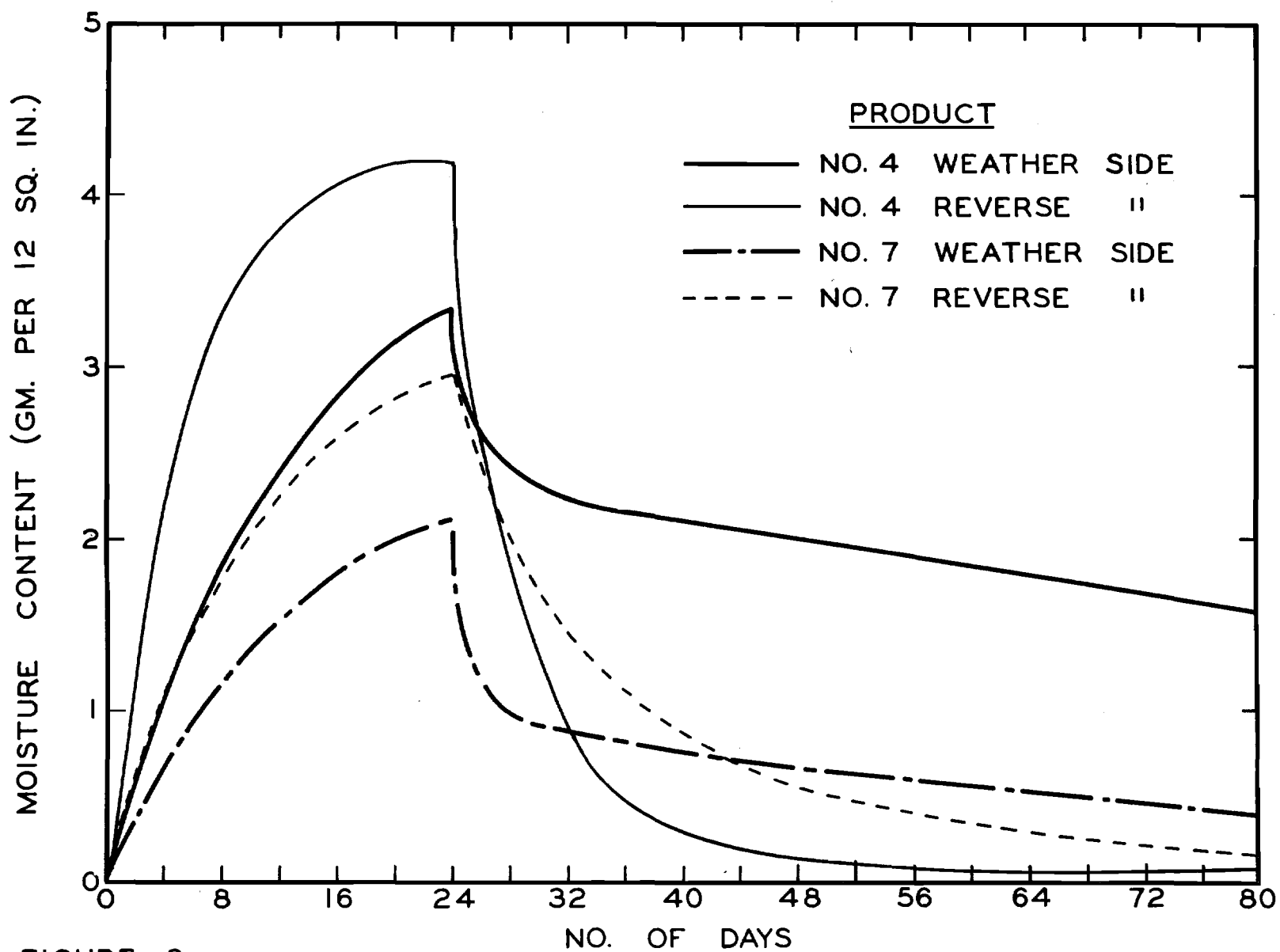


FIGURE 3

COMPARISON OF THE ABSORPTION & LOSS OF WATER FROM EACH SIDE OF ASPHALT SHINGLES.