

Performance of Asphalt Pavements Subjected to De-Icing Salts

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This paper describes a laboratory investigation on the performance of asphalt pavement subjected to the common de-icing salts. Various tests were made on the specimens immediately after they were prepared and after 10, 50 and 100 daily test cycles. Comparisons of the test results indicated that the repetitive daily applications of the de-icing salts to melt ice from the surfaces of specimens had no significant effects on specimen stabilities, or on the penetration, softening point, or ductility of asphalt recovered from the specimens. No loss of aggregate from any specimens occurred during the tests.

No detrimental effects of the de-icing salts on the asphalt pavement specimens subjected to the testing conditions used for the investigation were indicated by the test results. The study offers evidence that well-designed and well-constructed asphalt pavements are not damaged by sodium and calcium chloride salts used for ice and snow control.

•INCREASED ATTENTION to the removal of snow and ice from pavements has resulted from the growing demand for clean, bare pavements during the winter. The use of chemicals and abrasives for snow and ice control has increased. The widespread use of sodium and calcium chloride salts for this purpose has also caused growing concern about the effects of these common de-icing salts on pavements.

The performance of asphalt pavements subjected to these salts was studied in a laboratory investigation conducted by the Asphalt Institute. Asphalt pavement specimens were subjected to repetitive daily test cycles simulating the field conditions existing when de-icing salts are applied. A mixture of sodium and calcium chloride salts was used to melt ice frozen on the surfaces of pavement specimens during the test cycles. Similar pavement specimens, which were salt-free, were subjected to freezing and thawing conditions and to water, freezing and thawing, during the daily test cycles. Tests were made on the specimens at various intervals to measure stability, loss of aggregate, and properties of the asphalt extracted and recovered from the specimens. These test values, and comparisons of the test values for specimens exposed and not exposed to the de-icing salts, indicated the performance of the specimens to which the de-icing salts had been applied.

PREPARATION OF TEST SPECIMENS

An Asphalt Institute Type VIII-a sheet asphalt and two Asphalt Institute Type IV-b dense-graded asphalt concretes, each containing different aggregates, were used in the investigation. Replicate specimens of each paving mixture were prepared in accordance with procedures specified by the Marshall test, ASTM Designation D 1559. Fifty compaction blows were applied to each end of the specimens. The specimens were made

TABLE 1
MIX COMPOSITIONS

U. S. Standard Sieve Size	Percent Passing		
	Sheet Asphalt Md. Sand Agg. ¹	Asphalt Concrete	
		N. Y. Trap Rock Agg. ²	Mich. Gravel Agg. ³
1/2-in.	--	100	100
3/8-in.	--	80	80
No. 4	--	60	60
No. 8	100	42	42
No. 30	95	23	26
No. 50	45	17	13
No. 100	20	12	8
No. 200	15	8	7
% asphalt, total mixture	11.0	6.3	5.0

¹Composite contained 89.1 percent Maryland sand, and 10.9 percent limestone dust mineral filler.

²Entirely New York trap rock.

³Composite contained 72 percent Michigan gravel, 22 percent Maryland sand, and 6.0 percent limestone dust mineral filler.

with optimum asphalt contents determined by the Marshall method of mix design (1). Composition of the test specimens is given in Table 1. Table 2 gives test properties of the 85-100 penetration grade asphalt used for preparation of all specimens.

DESCRIPTION OF TESTS

Replicate specimens of each mix were divided into three groups. All groups were subjected to a daily cycle of freezing at 20 F and thawing at 50 F. Specimens in Group I were subjected only to the daily freezing and thawing cycles and were not contacted by water or de-icing salts. Forty milliliters of water was placed on the upper surfaces of specimens in Group II, and the water allowed to

freeze and thaw during each daily test cycle. De-icing salts were not applied to specimens in Group II. Forty milliliters of water was placed on the surfaces of specimens in Group III. A mixture of 5.4 g of crushed rock salt and 0.6 g of flake calcium chloride was applied to melt the ice frozen on the surfaces of specimens in the third group during each daily test cycle. The specimens in Groups II and III were fitted with water-tight rubber collars to contain the 0.2 in. depth of water or salt solution on their upper surfaces. The rubber collars were cemented to the sides of the specimens with approximately 3.5 g of the same asphalt used in the specimens.

A program-controlled temperature cabinet, providing temperature control within ± 2 F, was used to obtain repetitive daily freezing and thawing cycles. The specimens remained in the cabinet during the entire investigation, except for the short time each day when the water or the salt solution was poured from the surfaces of specimens in

TABLE 2
ASPHALT CEMENT TEST PROPERTIES

Property	Value
Penetration, 77 F, 100 g, 5 sec	90
Viscosity at 275 F, (centistokes)	291
Penetration after thin film oven test, (% of original)	58
Ductility at 77 F (cm)	150+
Softening point, ring and ball, (°F)	118
Specific gravity, 77/77 F	1.022

the second and third groups. The test specimens in the temperature cabinet are shown in Figure 1. Appendix A gives the detailed testing conditions used for the daily test cycles. In addition to the main series of specimens used for the daily test cycles, three specimens of each mix were stored on a laboratory shelf at room temperature and tested at the conclusion of the investigation.

Various tests were made on the specimens immediately after they were prepared, and after 10, 50, and 100 daily test cycles. Tests included the following:

1. Marshall stability and flow (ASTM Method D 1559).
2. Extraction and recovery of asphalt (ASTM Method D 762).
3. Penetration (ASTM Method D 5), softening point (ASTM Method D 36), and ductility (ASTM Method D 113) of the recovered asphalt.

The Marshall test was selected to measure stability, largely because the test is quite sensitive to asphalt binder viscosity changes and density changes of specimens.



Figure 1. Test specimens in test cabinet.

The penetration, softening point, and ductility tests were used to obtain direct measurements of changes in the asphalt extracted and recovered from the specimens during the investigation. Specimen weights were also recorded during the tests to provide an indication of aggregate losses. The surface-dry specimens were weighed to the nearest 0.1 g immediately after preparation and after 10 and 100 daily test cycles.

Various combinations and different application rates of sodium and calcium chloride are used for ice and snow control. The salt application rate for the laboratory tests was equivalent to 1.36 lb of salt mixture per square yard. At a temperature of 20 F, it was sufficient to melt the ice from the surfaces of specimens within 1½ hr. The salt application rate in the laboratory tests was higher than that normally used in the field. It was selected to produce a severe laboratory test, recognizing that under some field conditions high concentration salt solutions might come in contact with pavements.

TEST RESULTS

The paving mixture specimens used for the tests were representative of varying stability pavements made with typical aggregates. Marshall stability and flow values for specimens tested immediately after preparation are given in Table 3. The Maryland sand aggregate sheet asphalt had a Marshall stability of 618 lb and flow value of 16. The Michigan gravel aggregate asphalt concrete had a Marshall stability of 1,125 lb and flow value of 12, and the New York trap rock aggregate asphalt concrete had a Marshall stability of 2,093 lb and flow value of 15.

It was predicted that the Marshall stability test probably would not reflect even a slight amount of scaling or aggregate loss from the surface of the specimens. Marshall stability would, however, be greatly reduced due to severe deterioration of specimens and would also decrease due to increasing volume or decreasing density of specimens. Marshall stability would increase due to appreciable increases in the viscosity or decreases in penetration of the asphalt in specimens. For this investigation, changes in the Marshall stability of the specimens are of most interest as a direct measure of any severe deterioration, and as an indirect indication of density changes or appreciable asphalt consistency changes.

TABLE 3
TEST PROPERTIES¹ OF SPECIMENS TESTED IMMEDIATELY AND AFTER AGING
IN AIR DURING ENTIRE STUDY

Specimen	Property	Sheet Asphalt	Asphalt Concrete	
		Maryland Sand Agg.	N. Y. Trap Rock Agg.	Michigan Gravel Agg.
Tested immediately	Air voids (%)	6.0	4.1	3.4
	Stability (lb)	618	2,093	1,125
	Flow (0.01 in.)	16	15	12
	Pen. at 77 F (0.1 mm)	85	80	79
	S. P. (°F)	119.0	119.0	118.0
	Duct. at 77 F (cm)	150+	150+	150+
Aged in air	Air voids (%)	5.9	4.0	3.4
	Stability (lb)	667	2,150	1,247
	Flow (0.01 in.)	16	16	11
	Wt. gain (%)	0.03	0.16	0.02
	Pen. at 77 F (0.1 mm)	65	66	62
	S. P. (°F)	122.5	122.5	123.0
Duct. at 77 F (cm)	150+	150+	150+	

¹Values are averages for three test specimens; penetration, softening point, and ductility test values are for extracted and recovered asphalt from duplicate test specimens.

TABLE 4
TEST PROPERTIES¹ OF SPECIMENS SUBJECTED TO DE-ICING SALT TESTS

Group	Property	Sheet Asphalt Maryland Sand Agg.			Asphalt Concrete					
					N. Y. Trap Rock Agg.			Michigan Gravel Agg.		
		10 Cycles	50 Cycles	100 Cycles	10 Cycles	50 Cycles	100 Cycles	10 Cycles	50 Cycles	100 Cycles
I	Air voids ² (%)	6.0	5.9	5.9	4.0	4.1	4.3	3.3	3.3	3.2
	Stability (lb)	613	655	620	1,950	2,067	1,955	1,145	1,265	1,265
	Flow (0.01 in.)	15	16	15	14	15	14	12	11	11
	Wt. gain (%)	0.04	--	0.06	0.12	--	0.22	0.01	--	0.01
	Pen. at 77 F (0.1 mm)	72	74	72	74	75	71	73	73	70
	S. P. (°F)	120.5	121.0	121.5	122.0	121.0	121.5	120.5	120.5	121.5
	Duct. at 77 F (cm)	150+	150+	150+	150+	150+	150+	150+	150+	150+
II	Air voids ² (%)	6.0	6.1	6.2	4.1	4.0	4.5	3.4	3.5	3.5
	Stability (lb)	635	638	588	2,040	2,178	1,972	1,335	1,175	1,108
	Flow (0.01 in.)	15	15	16	16	15	15	12	11	12
	Wt. gain (%)	0.04	--	0.03	0.07	--	0.12	0.02	--	0.03
	Pen. at 77 F (0.1 mm)	72	75	74	72	73	71	72	71	70
	S. P. (°F)	120.0	121.0	120.0	122.5	121.5	121.5	121.0	121.0	122.0
	Duct. at 77 F (cm)	150+	150+	150+	150+	150+	150+	150+	150+	150+
III	Air voids ² (%)	6.2	6.0	6.3	4.1	4.3	4.2	3.3	3.4	3.4
	Stability (lb)	585	628	613	1,968	1,910	1,938	1,170	1,263	1,170
	Flow (0.01 in.)	15	16	15	14	13	14	12	12	11
	Wt. gain (%)	0.04	--	0.04	0.10	--	0.16	0.02	--	0.02
	Pen. at 77 F (0.1 mm)	74	74	74	73	75	76	71	74	70
	S. P. (°F)	120.0	121.5	120.0	120.0	120.5	121.0	121.0	120.5	122.0
	Duct. at 77 F (cm)	150+	150+	150+	150+	150+	150+	150+	150+	150+

¹Values are averages for duplicate test specimens; penetration, softening point, and ductility test values are for extracted and recovered asphalt from duplicate test specimens.

²Determined before specimens were subjected to de-icing salt tests.

Marshall stabilities for the sheet asphalt and the two asphalt concretes tested immediately and after 10, 50, and 100 daily test cycles are given in Table 4 and shown in Figure 2. There were no significant changes in the stability of any of the mixes subjected to as many as 100 applications of the de-icing salts to melt ice frozen on the surfaces of the specimens. There also were no significant differences for any of the mixes between stabilities of specimens exposed to the de-icing salts and those subjected only to freezing and thawing, and to freezing and thawing water only. The stability test results indicate no severe deterioration of specimens occurred due to exposure to the de-icing salts or to the other testing conditions. They also indicate that no appreciable

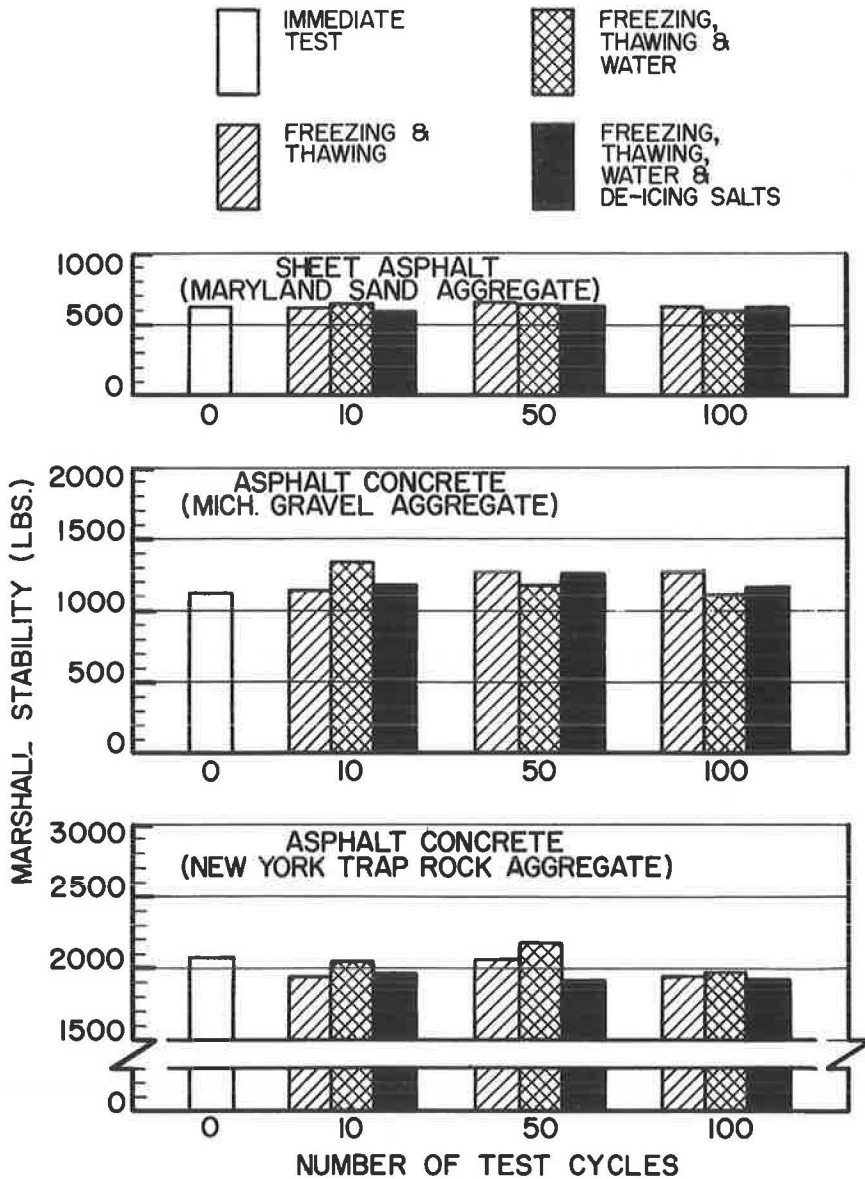


Figure 2. Marshall stability of asphalt pavement specimens subjected to de-icing salts and other test conditions.

density or volume change occurred in the specimens, and that no large changes occurred in the consistency of the asphalt in any of the specimens due to exposure to the de-icing salts.

Increases in Marshall flow values would be expected due to volume increases in specimens or severe deterioration of specimens. Marshall flow values for sheet asphalt and the two asphalt concretes tested immediately, and then after 10, 50, and 100 daily test cycles, are given in Table 4. They are also shown in Figure 3. Like the stabilities, flow values for the specimens were not affected by the de-icing salts or other testing conditions. The flow values did not change significantly during the 100 daily test cycles for any of the mixes.

Marshall stability and flow value test results for specimens stored in the laboratory at room temperature and tested at the conclusion of the investigation are given in Table 3. There were no significant differences between the Marshall stability and flow values for specimens aged at room temperature and those subjected to the de-icing salts and other testing conditions for 100 daily test cycles.

The asphalt coating the aggregate particles was the paving mixture component that had the most direct contact with water and the salt solutions during the tests. The effect of the de-icing salt solutions on the asphalt is indicated by comparison of the test properties of recovered asphalt from specimens contacted and not contacted by the de-icing salts. Recovered asphalt test properties are given in Table 4.

Penetration test values for asphalt extracted and recovered from sheet asphalt and the asphalt concrete specimens tested immediately, and after 10, 50, and 100 daily test cycles, are shown in Figure 4. Penetrations of the recovered asphalt decreased 5 to 11 points for the different paving mixtures during mixing and compaction of specimens. Further decreases of 6 to 13 penetration points occurred during the first 10 test cycles. Thereafter, penetrations did not change significantly for any of the mixes up to 100 daily test cycles. Comparison of penetrations of recovered asphalt from specimens contacted and not contacted by the de-icing salts indicates that the consistency of the asphalt as measured by the penetration test was not affected by the de-icing salts for any of the mixes.

Softening points for extracted and recovered asphalt from sheet asphalt and asphalt concrete specimens determined immediately after the specimens were prepared, and after 10, 50, and 100 daily test cycles, are shown in Figure 5. Trends in recovered asphalt consistency measured by the softening point tests agreed with consistency trends measured by the penetration tests. Increases in softening points during mixing and compaction, and a further increase during the first 10 daily test cycles, occurred. Thereafter, softening points remained approximately the same. Softening points were not significantly different for the different testing conditions, indicating that consistency of asphalt in the specimens as determined by the softening point test was not affected by the de-icing salts applied to any of the mixes.

The ductility of the original asphalt was greater than 150 cm. The ductilities of asphalt recovered from all specimens immediately after their preparation, and after 10, 50, and 100 daily test cycles for all the testing conditions, were also greater than 150 cm. The de-icing salts caused no changes in the ductilities of recovered asphalt, within the testing limit of the 150-cm ductility apparatus used.

Penetrations, softening points, and ductilities of asphalt recovered from specimens aged at room temperature during the investigation are given in Table 3. Penetrations were slightly lower and softening points were slightly higher for asphalt recovered from these specimens than for the asphalt recovered from the 100 test cycle specimens for all mixes. Apparently the higher temperature and more exposure to light caused slightly greater hardening of the asphalt in specimens aged at room temperature. Ductilities of asphalt recovered from the specimens aged at room temperature during the investigation were greater than 150 cm, the same as ductilities of asphalt recovered from all specimens after 100 daily test cycles.

The results of tests on asphalt recovered from specimens during the investigation indicated that the asphalt in the specimens was not significantly affected by exposure to the de-icing salts.

Any appreciable loss of aggregate or scaling due to the de-icing salts or other testing conditions would be indicated by a decrease in weight of the specimens. Weight

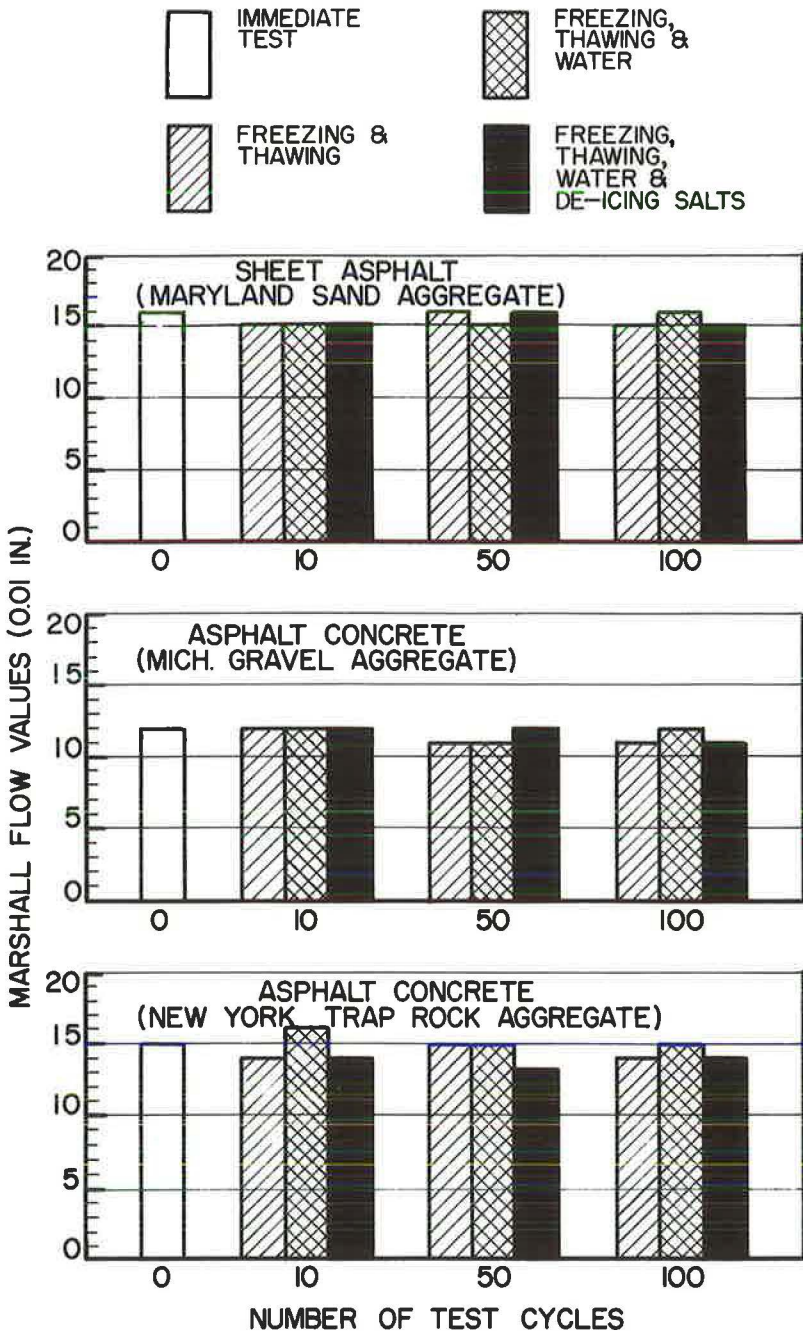


Figure 3. Marshall flow values of asphalt pavement specimens subjected to de-icing salts and other test conditions.

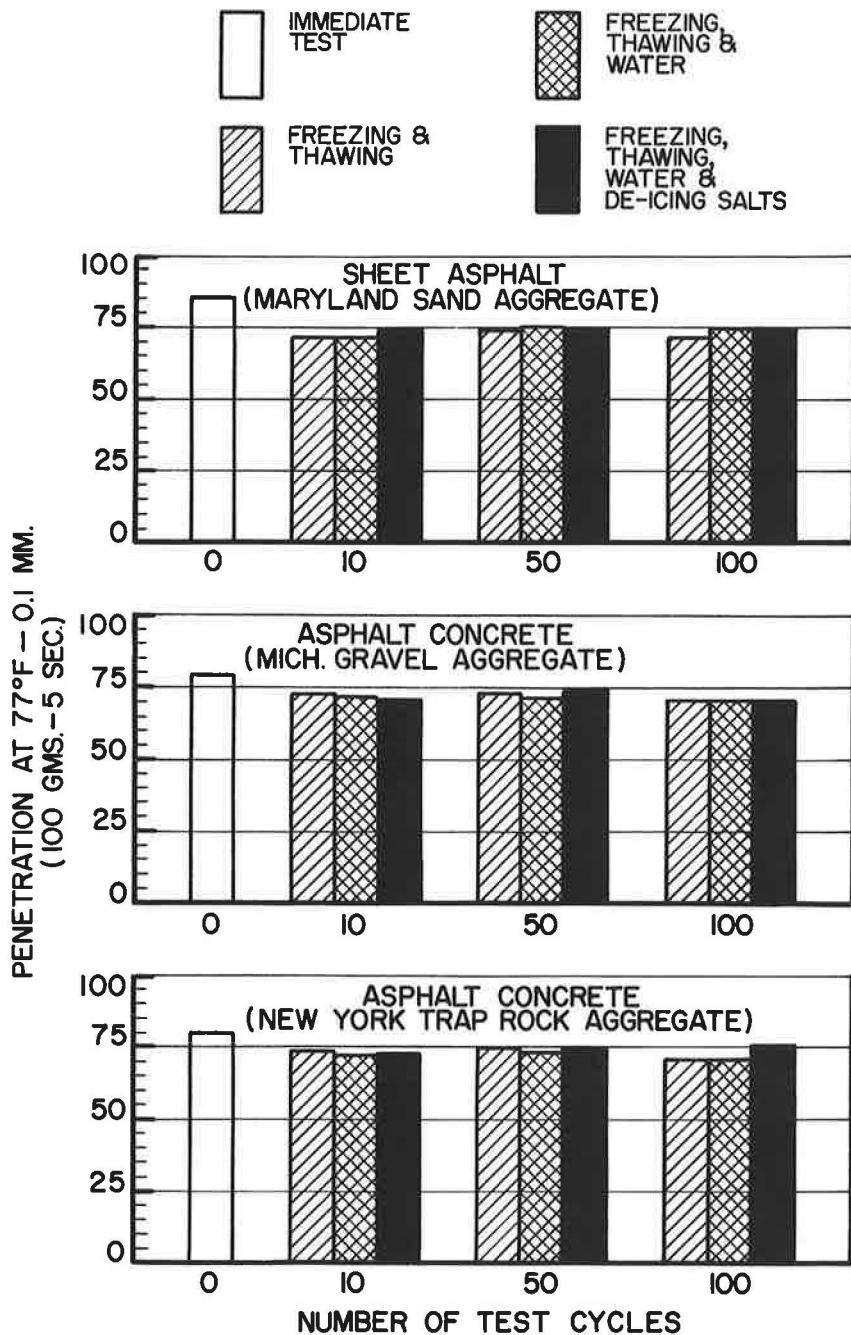


Figure 4. Penetration of asphalt recovered from pavement specimens subjected to de-icing salts and other test conditions.

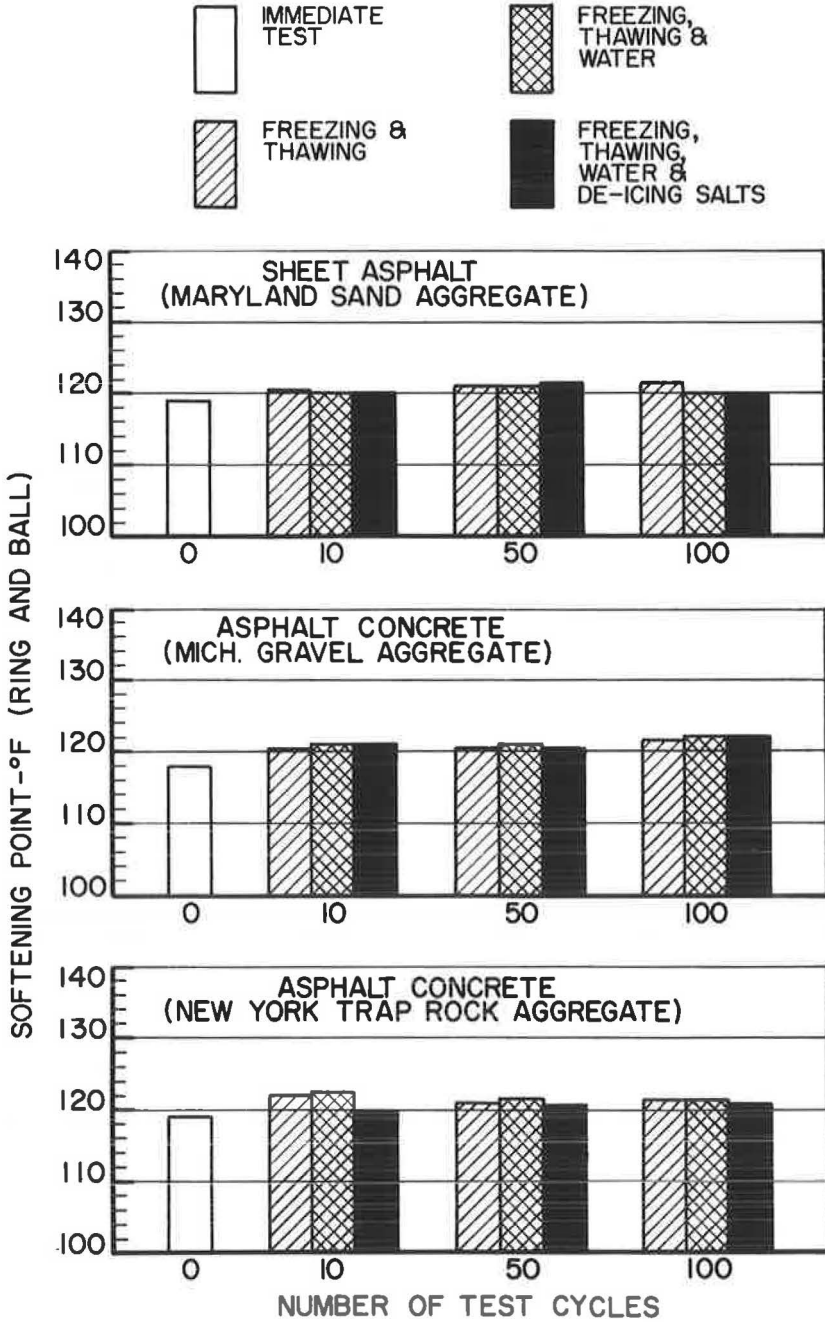


Figure 5. Softening point of asphalt recovered from pavement specimens subjected to de-icing salts and other test conditions.

changes of surface-dry specimens after 10 and 100 daily test cycles, expressed as percent of the original specimen weight, are given in Table 3. They are shown in Figure 6 for the different mixes. All specimens, for all testing conditions, and including the specimens aged at room temperature, gained in weight during the investigation. The weight gains, due to increase in moisture content of the surface-dry specimens, were very small for sheet asphalt and gravel aggregate asphalt concrete. They were only slightly higher for trap rock aggregate asphalt concrete. There were no appreciable differences in weight gains of specimens subjected to the different test conditions. It is evident from these results that no loss of aggregate occurred due to specimen exposure to the de-icing salts. The small weight gains were due to the normal increase in the moisture contents of the specimens exposed either to water or the atmosphere. No loose particles or losses of aggregate from the surfaces of specimens were observed when the water or salt solutions were poured from the surfaces of specimens during the investigation.

Differences became noticeable in the surface appearance of specimens subjected to the different testing conditions at about 50 daily test cycles. The surfaces of all specimens exposed to water and to the de-icing salts became slightly lighter in color. There was little difference, if any, between the appearance of specimens subjected to these two test conditions. The surface appearance of these specimens was quite similar to the surface appearance of asphalt pavements exposed to outdoor weathering. The surfaces of all specimens were photographed after 10, 50, and 100 daily test cycles. Michigan gravel aggregate asphalt concrete specimens, typical of the appearance of the other mixes, are shown in Figures 7, 8, and 9 after 10, 50, and 100 daily test cycles, respectively. The numbers under the specimens designate the testing condition. Freezing and thawing only are designated by the number 1. Freezing, thawing, and water are designated by the number 2; and freezing, thawing, water and de-icing salts are designated by the number 3. The slight changes in the appearance of the asphalt-coated aggregate particles on the surfaces of specimens contacted by water and by the de-icing salts were not reflected in the test properties of asphalt recovered from the specimens. Because no losses of aggregate particles occurred, the slight changes in surface appearance of specimens were not associated with retention of aggregate particles on the surfaces of specimens by the asphalt binder.

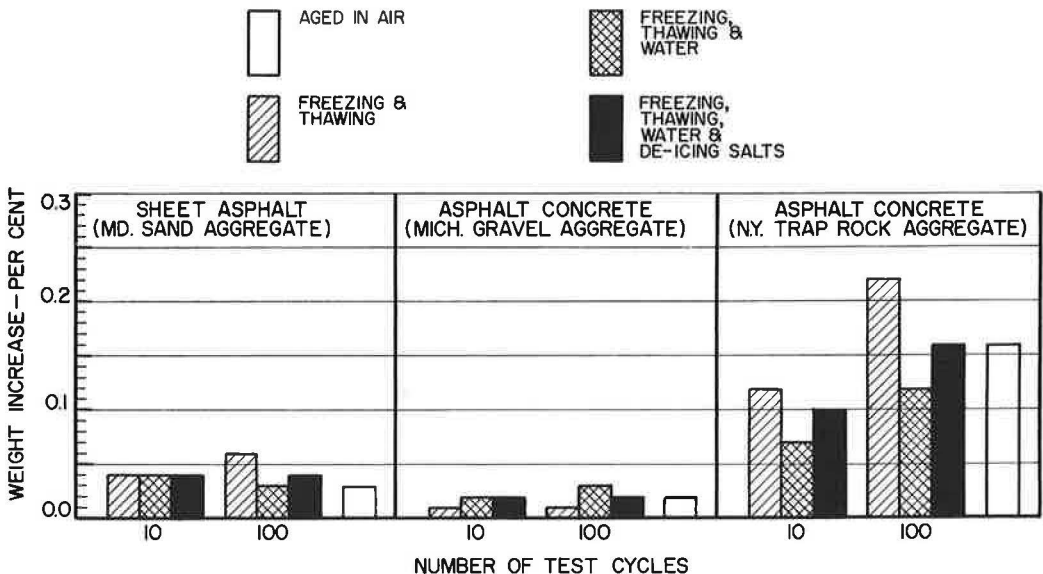


Figure 6. Weight changes of asphalt pavement specimens subjected to de-icing salts and other test conditions.

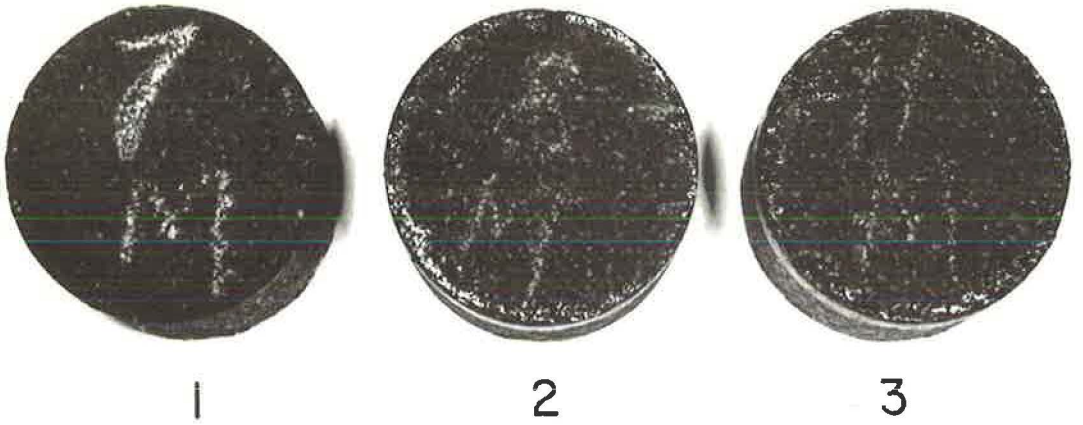


Figure 7. Asphalt concrete samples after 10 cycles.

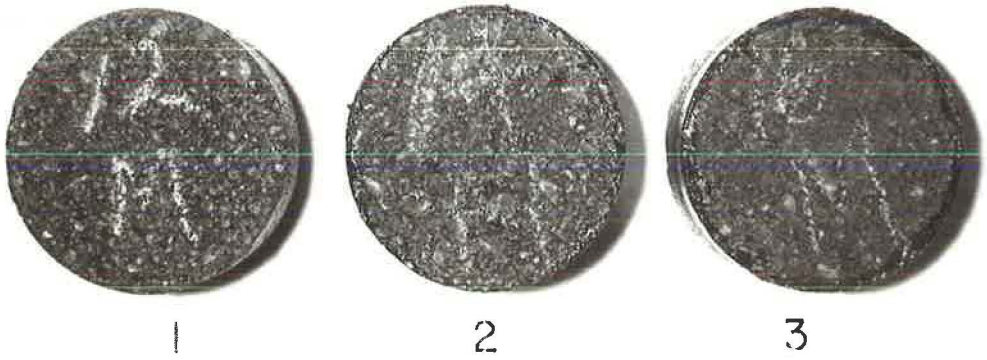


Figure 8. Asphalt concrete samples after 50 cycles.

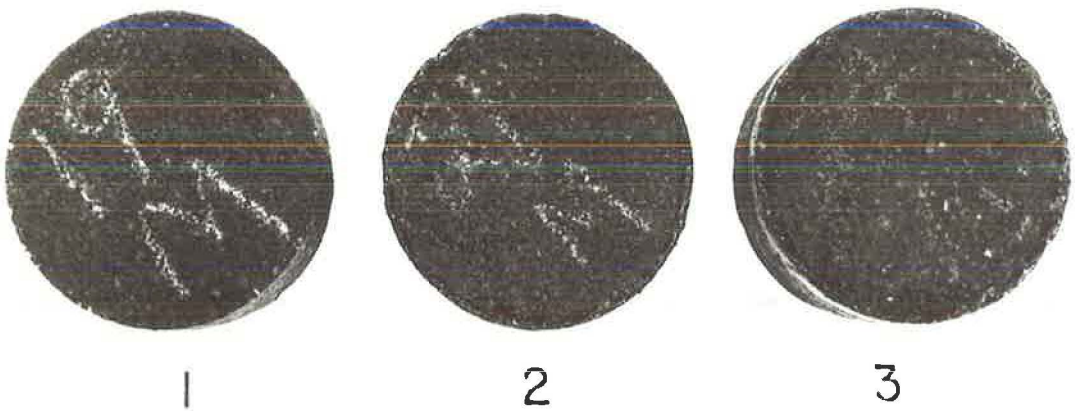


Figure 9. Asphalt concrete samples after 100 cycles.

SUMMARY AND CONCLUSIONS

The investigation described in this paper was made to study the performance of asphalt pavements subjected to the common de-icing salts. Typical sheet asphalt and dense-graded asphalt concrete paving mixture specimens were subjected to daily test cycles simulating field conditions existing when de-icing salts are used on pavements.

It was found that as many as 100 daily applications of a mixture of sodium chloride and calcium chloride salts to melt ice from the surfaces of pavement specimens had no significant effect on the specimens. The stabilities of the specimens were not affected, and no loss of aggregate or scaling occurred. Test properties of asphalt recovered from the specimens were not affected by the de-icing salts. The results of the laboratory tests indicate that the performance of similar well-designed and well-constructed dense-graded aggregate asphalt concrete and sheet asphalt pavements would not be affected by repeated applications of sodium chloride and calcium chloride salts for winter snow and ice control.

REFERENCE

1. "Mix Design Methods for Hot-Mix Asphalt Paving." Asphalt Institute, Manual Series 2.

Appendix

DAILY TEST CYCLES

All test specimens in Groups I, II, and III were placed in the temperature control cabinet, maintained at a temperature of 20 F, the evening before the tests began. The daily 24-hr test cycles started the following day at 9:00 AM. Testing conditions and the procedures for handling the specimens during each daily test cycle were as follows:

1. At 9:00 AM, with the cabinet temperature at 20 F, 40 ml of water was placed on the upper surfaces of specimens in Groups II and III.
2. At 11:30 AM, with the cabinet temperature at 20 F, a mixture of 5.4 g of crushed rock salt and 0.6 g of flake calcium chloride was placed on the ice frozen on surfaces of specimens in Group III.
3. At 1:00 PM, the cabinet temperature was increased at a rate of approximately 0.67 F per min until, at 1:45 PM, the cabinet reached and maintained a temperature of 50 F.
4. At 3:00 PM, specimens in Groups II and III were rapidly removed from the cabinet and the water or salt solutions poured from their surfaces. The specimens were replaced in the cabinet maintained at a temperature of 50 F.
5. At 9:00 PM, the cabinet temperature was decreased at the rate of approximately 0.67 F per min, until at 9:45 PM, a temperature of 20 F was reached. The 20 F temperature was maintained during the completion of the daily test cycle until 9:00 AM the following day.
6. The specimens were left in the cabinet maintained at a temperature of 20 F during weekends and holidays.