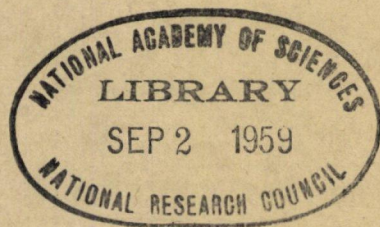


HIGHWAY RESEARCH BOARD

Bulletin 220

*Ice Melting Properties
of
Chloride Salt Mixtures*



National Academy of Sciences—

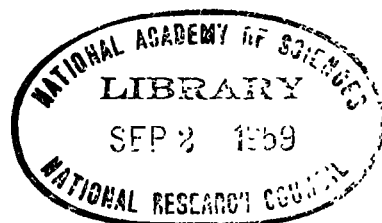
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Ice Melting Properties
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Chloride Salt Mixtures

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A Laboratory Study of Ice Removal By Various Chloride Salt Mixtures

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● A MAJOR PROBLEM of highway maintenance departments in northern areas concerns keeping roads usable during the winter months; roads made slippery by ice must be made safe for normal traffic speeds. There are two principal methods of treatment utilized by most maintenance crews on icy highways. If the immediate use of the highway is of prime importance the use of abrasives to furnish traction is one solution. In some cases this may not be a complete solution, however, as the abrasive may be whipped off by traffic or wind and the ice will remain. A more desirable treatment is to remove the ice or compacted snow which has caused the slippery condition. This can be accomplished by the application of chemicals which lower the melting point sufficiently to transform the ice into water which then drains off. The two chemicals commonly used for this purpose are sodium chloride and calcium chloride.

There is a considerable difference in the melting qualities of these two chemicals with respect to such things as effective temperatures and rate at which melting proceeds. There have been several instances where maintenance crews applied sodium and calcium chloride together and reported better results than those obtained with either one alone. The study reported herein was initiated as an attempt to obtain more information on the melting qualities of chlorides, both individually and in various combinations. Appendix A is a brief explanation of the melting process as affected by salts.

It was first attempted to devise certain laboratory tests or procedures which would be indicative of the action which might occur when salts were applied to ice on an actual highway. It was planned that if certain relationships and comparisons could be obtained by these laboratory tests, they would be checked by making observations on actual highways with treatments of similar types of salt mixtures. Although weather conditions for such field correlation studies were never obtained in the period of study, it is thought that the development of the laboratory procedures may be of some interest and value, and this paper is restricted to these tests.

The original planned study might be considered to have had 3 parts. The first consisted of certain measurements of the melting caused by application of salts to ice, with variables such as mixture composition, temperature, and dosage rate. Recognizing that there is more involved in ice removal on highways than just melting, the second part of the investigation was the attempt to devise testing procedures which give consideration to the weakening of the bond between an ice sheet and a portland cement or asphaltic concrete surface, and also to the effect of the wheel action of traffic. These 2 parts constituted the laboratory studies. The third part of the study was the intended field observations and correlation with the laboratory results.

MELTING TESTS

The first series of tests were relatively simple and consisted of determining the effect of certain variables on the amount of ice melted by dosages of sodium chloride, calcium chloride in both flake and pellet form, and mixtures of sodium and calcium chloride. The effect of such things as the thickness of the ice sheet, the quantity of salt, the temperature, and the time were investigated. An example of the type of results obtained is shown in Figure 1. From curves such as these, composite curves could be assembled to show various comparisons, such as is shown in Figure 2. Tables 1 and 2 of Appendix B present some of the data from the melting tests.

These tests gave the following general results: (1) the quantity of melting was independent of the ice thickness; (2) the amount of melting varied directly with the quantity of the added salt; (3) the amount of melting varied with the amount of calcium

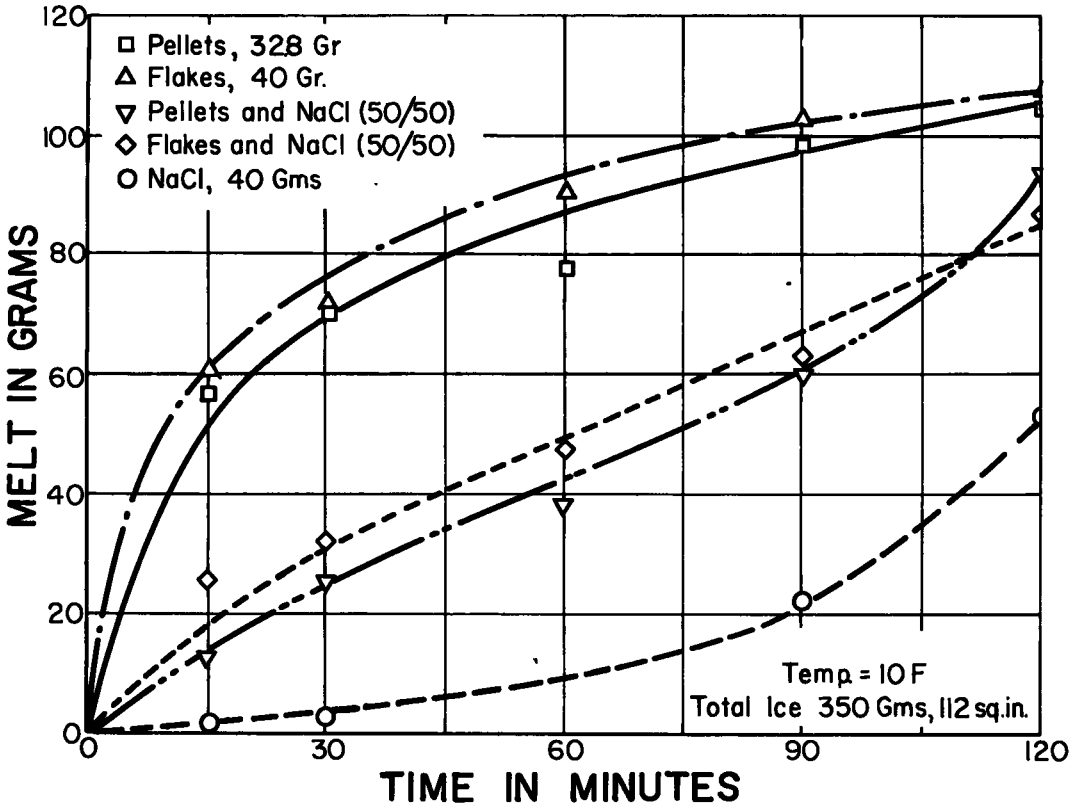


Figure 1. Typical melting test results.

chloride in sodium-calcium chloride mixtures; (4) the amount of melting in a given time was greater at higher temperatures; and (5) with calcium chloride the rate of melting was initially rapid with a subsequent slow-down, and with sodium chloride the rate was initially slow with a later speed-up, so that a time might be reached where the rate with sodium chloride equalled or became greater than that with calcium chloride; the exact comparison was dependent on the temperature.

Some attempts were also made to measure penetration rates of the crystals or pellets of the different salts. These tests, however, involved certain difficulties and the results were rather meager. It was thought that rate of penetration might have some bearing on ice removed on a road, but that this effect, if present, should be a factor which would affect the results in the drop tests and wheel tests described later.

DROP TESTS

One of the more important considerations in ice removal is the destruction of the bond between the ice layer and the road surface. Once the bond is broken it is much easier for the ice to be bladed off or thrown off by traffic. It was desirable to devise some test which would measure the relative effectiveness of chlorides to destroy this bond at various temperatures. The first of these tests was very elementary and consisted only of attempts to scrape ice from the pan after specified periods of chloride treatment. This was unsuccessful for several reasons: the human element of measuring scraping force was dominant, the metal surface on which the tests were made was very smooth and a good conductor of heat resulting in little similarity to field conditions; and a few spots where the chemical did not reach could affect the entire tests. Consequently, this test was discontinued.

Some of the shortcomings in the first test helped in the development of the "drop

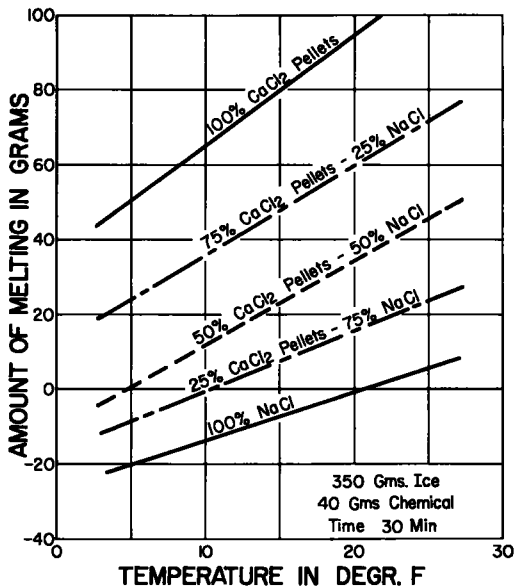


Figure 2. Melting for mixtures of calcium chloride pellets and sodium chloride. Note: In these tests the chemical was added after the pan was weighed. If this chemical was not all dissolved, a portion of it would remain on the ice at the conclusion of the test. This caused the negative value of ice melting at the lower temperature.

test." For this test a series of pans were filled with a bituminous pavement mixture which was compacted to form a surface similar to that of an actual highway pavement. The amount of material added to the pan was controlled so that the total weight was 9 lb. A 3- by 4-in. wire mesh with 1-in. openings was then placed on the center of the bituminous surface and a thin layer of ice was allowed to freeze on the surface; the ice covered and included the wire mesh. Wires were attached to the mesh and the pan was suspended from a rack by these wires (Fig. 3). A specified dosage of chemical was applied to the ice surface and the time of this application recorded. When the chloride had melted and penetrated to a sufficient degree, the weight of the pan would break the bond of the ice, causing the pan to drop away from the mesh (Fig. 4). This time was also recorded, giving the time required for the chemical to cause failure.

The failure was caused by a combination of melting and bond destruction. In many cases (Fig. 5), large sheets of ice came off with the mesh whereas in others, such as the middle mesh on the left in Figure 4, very little ice came off with the mesh. In each test, pans with 9 different salt combinations were used and the entire test was repeated at a variety of temperatures. The salt combinations used were calcium chloride flake, calcium chloride pellets, sodium chloride, and 25 to 75, 50 to 50, and 75 to 25 percent combinations of both flake and pellets with sodium chlorides. For each chemical application a graph was plotted of temperature vs time of drop (Fig. 6). These were

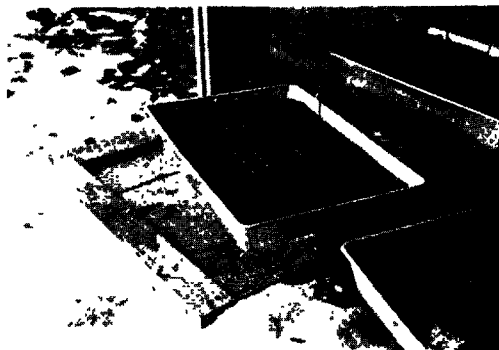


Figure 3. Drop test pan; asphaltic concrete.

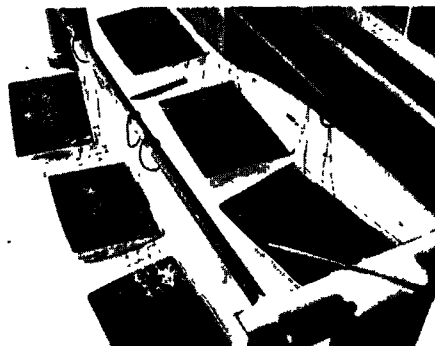


Figure 4. Drop test in progress.

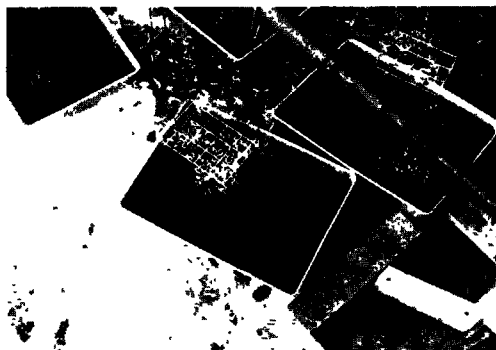


Figure 5. Ice on mesh after failure.

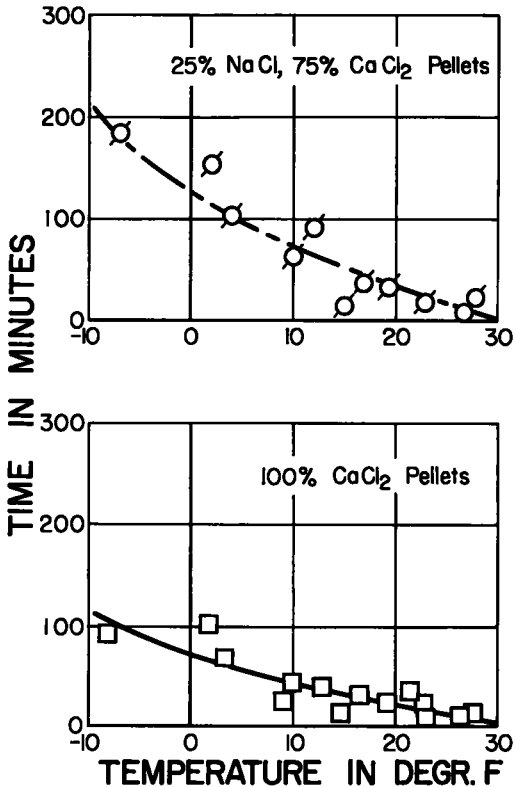


Figure 6. Typical drop test results. Bituminous surface; 40 g chemical; 200 g ice.

then combined to show the relative curves of the various treatments. These curves are shown in Figure 7.

In these tests, some difficulty was experienced with the bituminous mixture in the pans. In several cases some of the brine leaked around the edges of the pan leaving less chemical solution to act on the remaining ice. There was also considerable pitting and deterioration of the bituminous surface due to repeated freeze and thaw. In a second series of drop tests

some of these faults were corrected by using a concrete surface. Air-entrained concrete was used for better resistance to freeze and thaw and a lip was formed around the outside to prevent loss of solution during the test. One of these pans is shown during the test in Figure 8. The results of these tests were also plotted as temperature vs time (Fig. 9). These curves were again combined in groups of pellet-sodium chloride mixtures and flake-sodium chloride mixtures and are presented in Figure 10.

Several distinct trends are indicated by these graphs: (1) the time of drop increases appreciably with decreasing temperature; (2) sodium chloride has a much longer drop time than the various mixtures at the lower temperatures but this difference becomes less at temperature near the freezing point; and (3) the mixtures do not seem to affect the time of drop in any way except in direct proportion to the quantity of each chemical.

There are a few difficulties in the interpretation of these graphs. The test is of such a nature that there is a wide scattering of points when the original data are plotted. The

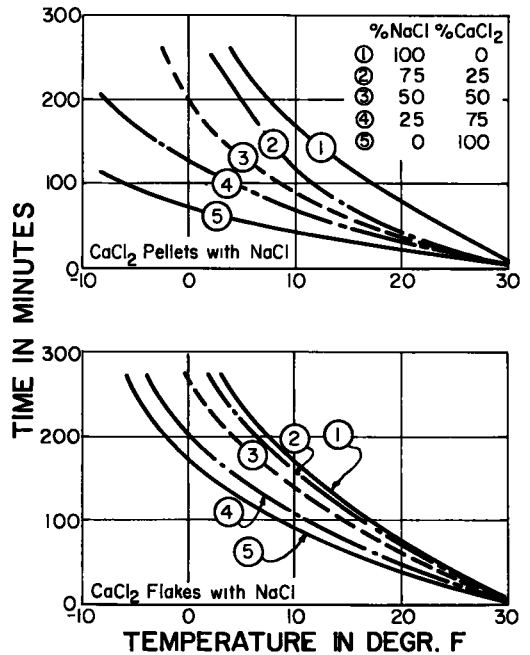


Figure 7. Composite drop test curves. Bituminous surface; 40 g chemical; 200 g ice.

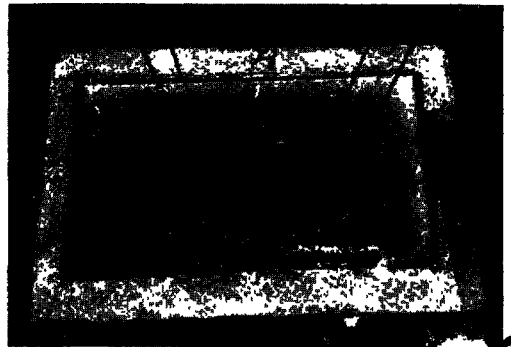


Figure 8. Drop test pan; portland cement concrete.

curves drawn through these points are thus somewhat arbitrary and should be interpreted as general trends rather than statistical analyses. In comparison of the two series of tests there are several points which must be clarified. Even though the area covered by the ice was greater in the first series, the thickness of the ice was approximately the same and the quantity of chemical was proportional to the surface area. The factor should not, then, have any effect on the time of drop. In the first series equal weights of calcium chloride pellet and flakes were used. Because of the difference in calcium chloride content in these two chemicals (94 percent in pellets, 77 percent in flakes), the weight of flakes used in the second series was increased to give an amount of calcium chloride equal to that in the pellets. This would tend to equalize the test results for these two chemicals. It should also be pointed out that the first series was run on a bituminous surface and the second series on a concrete surface. This might have an effect on the time of drop due to differences in the adhesion of ice to bituminous and concrete surfaces.

Detailed data of the drop tests are given in Tables 3 and 4 of Appendix B.

The exact significance of these generalized drop test results is not known. It had been hoped to gain some information on this by correlation with field tests on actual highways. The general results do show a logical sequence as to the effect of mixture and temperature.

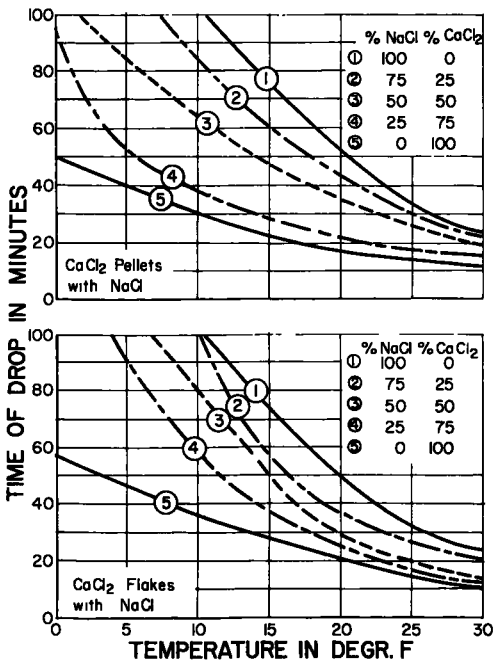


Figure 10. Composite drop test curves. Concrete surface; 150 g ice; 24 g chloride (24 g sodium chloride, 24 g calcium chloride, 29 g calcium chloride flake).

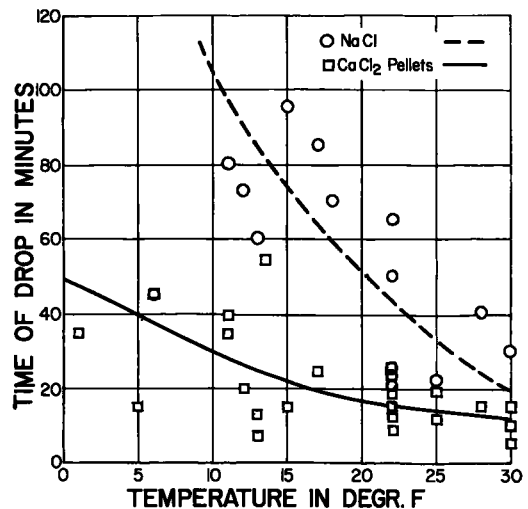


Figure 9. Typical drop test results. Concrete surface; 24 g chemical; 150 g ice.

WHEEL TESTS

One factor which was absent in both the melting and drop tests was that of traffic. Since this is important in the removal on a highway, it was believed a test should incorporate this factor if at all possible. The machine shown in Figure 11 was obtained from the Minnesota Highway Department and was adapted for this study. A ring of concrete was covered with a thin ice coating and then treated with a specified amount of chemical. After a short period to permit some penetration of the salt, the ring was set in motion and the wheel lowered onto the track to simulate the action of traffic on a highway. The ice sheet was observed periodically and estimates were made of the percentage of track area cleared. Only one treatment could be run at a time and since the machine had to be kept out-of-doors, the number of tests was limited by the length of the freezing season. The number of chemical combinations was therefore cut down to 5—cal-

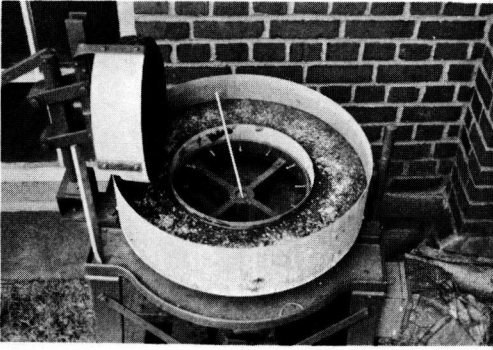


Figure 11. Wheel test machine.

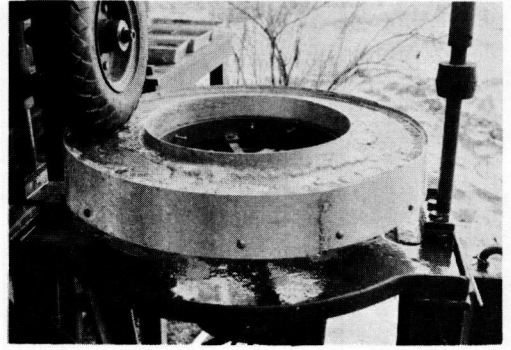


Figure 12. Circular track surface after period of testing.

cium chloride pellets, calcium chloride flake, sodium chloride, and 50-50 mixtures of sodium chloride with pellets and with flake. There was no control over temperatures; those used were the normal range of winter temperatures in Minnesota.

Two of the preliminary difficulties in this test were the loss of brine during the test and the human element in estimating the percentage of ice removal. The first of these was overcome to a reasonable degree by the construction of higher baffles around the ring, providing a better seal between concrete and baffle, and by slowing down the speed of rotation of the track. The human element in estimation was never eliminated entirely but was minimized by experience. A view of the track after a period of testing is shown in Figure 12. This gives an indication of the type of surface for which the estimates of ice removal had to be made.

After each test, the values for percent area cleared were plotted against time. These curves were then plotted on a graph along with others of the same chemical application with each curve representing a different temperature (Fig. 13). In these tests, the salt was allowed to act for 15 min before the track was set in motion. This accounts

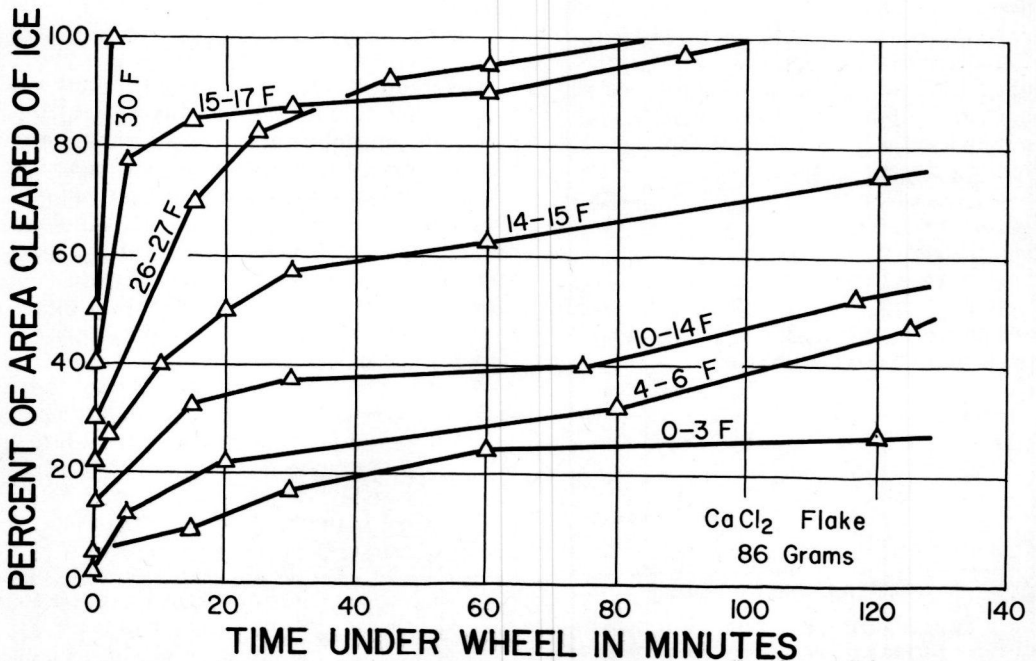


Figure 13. Typical wheel test results. Chemical application equivalent to 400 lb/mi on a 1-ft strip; ice thickness, 1/8 in.; temperature as indicated.

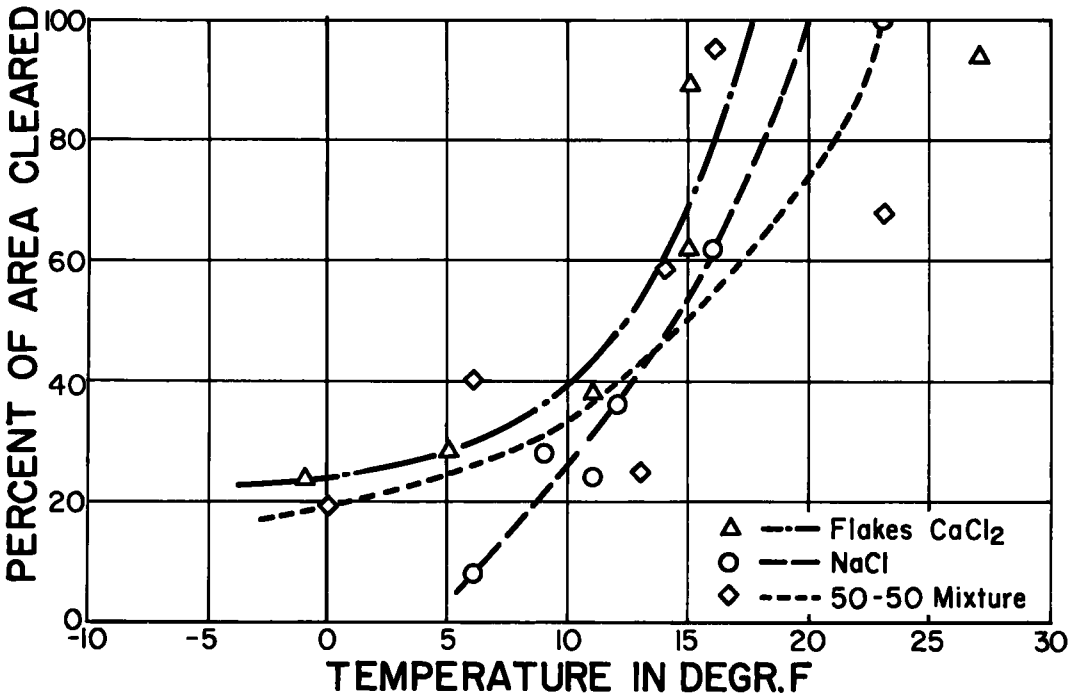


Figure 14. 60-minute removal under wheel at various temperatures.

for the percentage clear at 0 min under the wheel. As might be expected, these tests show a higher percentage of clear area in a given time at higher temperatures, although there are some irregularities. The rate at which ice removal is occurring at various times and temperatures can also be ascertained.

The curves such as those of Figure 13 were used to determine the percent of area clear at times of 30 and 60 min. These values were plotted against temperature for each of the various treatments; one of these plots is shown in Figure 14. It can be seen that there are some inconsistencies in the results, and hence the curves as drawn are considered to be average trends. Figure 15 shows the trends for the three salts (sodium chloride and flake and pellet calcium chloride) for 30- and 60-min periods. Again, some scattering of points is obvious. These may be due to variations in judgment of cleared area, but there also may have been some factors which were not measured which caused these differences. Such items as relative humidity, wind, variation of temperature during test, and variations in ice thickness may have been involved. On the 30-min curve there is seemingly very little difference in the removal at temperatures above 15 deg. At temperatures below 15 F, the flake and pellet calcium chloride give very similar results.

FIELD TESTS

The value of any laboratory test depends on its correlation to actual field results; this makes field tests an important segment of any study such as this. Arrangements were made with the Minnesota Highway Department for the application of these chemical combinations on icy highways during the winters of 1955-56 and 1956-57. Nine equal sections of pavement were staked out and a spreader was obtained which was capable of applying the chemicals in any combination desired. Traffic counts were arranged and thermometers were placed to obtain temperature of air and highway surface.

These preparations were all wasted, however, due to lack of suitable weather conditions. During the 2 winters, there were only 3 times when slippery conditions occurred. Two of these were brought about by hard-packed snow. These made proper evaluation

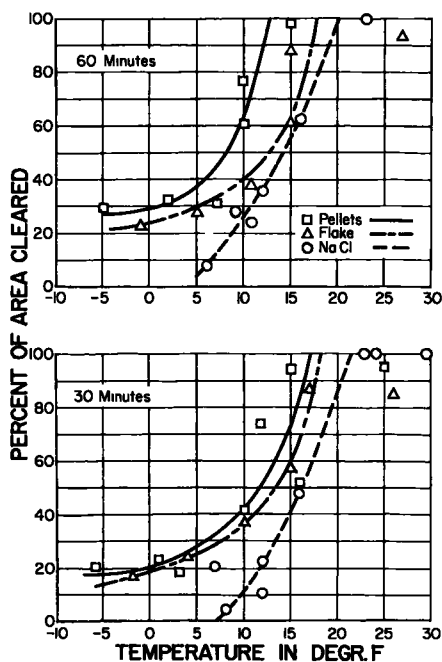


Figure 15. Ice removal by chlorides in wheel test at 30- and 60-minute intervals.

al investigation with this apparatus is suggested. A definite need exists for observations on actual highways and correlation of such observations with laboratory results.

ACKNOWLEDGMENTS

The laboratory work described herein was performed in the Soil Mechanics and Highway Engineering Laboratories of the Civil Engineering Department of the University of Minnesota. The authors acknowledge the cooperation and assistance of the Minnesota Highway Department and the Calcium Chloride Institute. C. K. Preus and Myron Jones of the Highway Department and Harry Smith and William Dickinson of the Calcium Chloride Institute particularly aided the work.

Appendix A

MECHANICS OF ICE MELTING BY CHLORIDES

The following is a brief statement or explanation of the manner in which salts melt ice. This is not intended to be a rigid or complete explanation, but is an attempt to give a layman's understanding of the physical chemistry involved. It helps to give a basis for understanding some of the physical chemistry involved. It helps to give a basis for understanding some of the actions which were found to occur in the experiments described in this paper.

The physical characteristic of chlorides which enables them to remove ice from highways is their ability to lower the freezing point of water and thus prevent and reverse the formation of ice. This lowering of the freezing point is caused by a lowering of the vapor pressure of the solution. Whenever a substance exists in 2 states which are in contact with each other, as for example water and ice, there is a constant interchange of molecules between the two states. This interchange of molecules creates what is called vapor pressure.

difficult due to variations in thickness, effect of shade late in afternoon, necessity to estimate removal and compare separated areas after lengthy intervals, and general lack of removal because of low temperatures. The third field test was on a thin film of ice at a temperature around 30 deg. On this test all applications provided excellent removal in a short time and no differentiation could be made as to the effect of varying the chemical.

SUMMARY

Laboratory test including measurements of amount of melting, a combined melting and breakage of bond between ice and slabs, and a test incorporating the added action of a revolving wheel have been used to study ice removal by sodium chloride, flake and pellet calcium chloride, and mixtures. These tests have shown that the results with mixtures of sodium and calcium chloride are practically always intermediate between those for tests with the straight salts. It is considered that the wheel test most nearly approached field conditions. There were some inconsistencies obtained in individual tests, however, and additional

If the vapor pressure of the solid is greater than that of the liquid, more molecules will leave the solid state than will return and the solution will become entirely liquid; and conversely if the vapor pressure of the liquid is greater than that of the solid, more molecules will enter the solid state than will leave and the solution will become entirely solid. The freezing point is that point at which the vapor pressure of the liquid equals the vapor pressure of the solid.

In a solution, if the solute is more soluble in the liquid than in the solid, the solute molecules will remain in the liquid, resulting in fewer molecules of solvent for a given volume and hence a lower vapor pressure. When the vapor pressure of the liquid becomes lower than that of the solid, the solid state will change to liquid until a new equilibrium point is reached. Both calcium chloride and sodium chloride are more soluble in water in the liquid state than in the solid state.

Vapor pressures decrease with a decrease in temperature and values for pure ice and for pure water have been determined for various temperatures. The amount of reduction in vapor pressure caused by the addition of various solutes has been also determined. Using this information, the freezing point of a solution can be found in the following manner:

1. Compute the strength of the solution in terms of grammolecules of salt per liter of water.
2. Using standard physical chemistry handbook tables, determine the percentage reduction in vapor pressure of this solution.
3. Find the temperature at which the vapor pressure of pure water when reduced by the percentage determined in 2 equals the vapor pressure of pure ice.

Calculations of this type have been made and show that a 10 percent calcium solution has a freezing point of approximately -5.5°C while a 10 percent sodium chloride solution has a freezing point of approximately -7°C . This indicates a greater lowering of the freezing point by sodium chloride than by calcium chloride in 10 percent solutions; this is in agreement with the fact that there are more ions present per gram in sodium chloride. Field tests indicate better results at low temperatures with calcium chloride than with sodium chloride, but these solutions are more concentrated than 10 percent. This difference is explained by the difference in solubility of the two chemicals at lower temperatures. at 0°C it is possible to dissolve only 357 g of sodium chloride in one liter of water as compared to 595 g of calcium chloride. This greater solubility produces solutions of greater strength and therefore lower freezing points than those obtainable with sodium chloride.

Two other qualities affect the melting characteristics of these two chlorides. Both are concerned with the rate of melting rather than the total amount of melting. The first step in the melting process is the formation of a liquid solution. Here the calcium chloride holds the advantage in that it forms hydrates and thus draws moisture from the air to form the initial solution much faster than sodium chloride which is not deliquescent.

The other characteristic involved is the heat of solution. Heat is required to transform ice into water and must be supplied from either the surrounding air or from the solution. Heat is also involved in dissolving a solute into a solvent and this heat is called the heat of solution. Calcium chloride in the anhydrous form produces 17,990 calories of heat when 111 g are dissolved in 7,200 g of water. The same amount of calcium chloride in the form with two hydrates (flake) produces 10,040 calories: On the other hand, to dissolve this quantity of sodium chloride in this much water would require an additional 2,400 calories from some other source. This would have its greatest effect on the initial melting when the chemical is just going into solution.

Appendix B

TABULATIONS OF LABORATORY DATA

TABLE 1
30-MINUTE MELTING TESTS

112 sq in. surface area; 350 g ice; 40 g chemical

100 % CaCl ₂ 0 % NaCl		75 % CaCl ₂ 25 % NaCl		50 % CaCl ₂ 50 % NaCl		25 % CaCl ₂ 75 % NaCl		0 % CaCl ₂ 100 % NaCl	
Temp. (F)	Am't. (g)	Temp. (F)	Am't. (g)	Temp. (F)	Am't. (g)	Temp. (F)	Am't. (g)	Temp. (F)	Am't. (g)
Pellets									
2	59	2	17	2	-4	2	-13	6	-23
9	65	9	34	9	+17	9	-5	9	-10
9	60	9	32	9	7	10	-10	11	-15
12	64	11	49	11	17	13	+2	14	-9
14	69	14	47	15	19	16	15	14	-11
14	56	16	39	18	25	18	19	17	+4
18	95	17	58	18	24	20	27	19	0
18	93	18	54	20	42	20	9	20	0
23	106	24	77	20	30	26	26	27	+6
		24	59	25	47				
Flake									
2	51	2	25	3	9	6	-14	6	-23
9	65	9	36	10	15	12	+3	9	-10
10	65	10	35	13	23	16	5	11	-15
13	72	13	44	15	24	16	7	14	-9
14	68	14	50	17	20	18	22	14	-11
14	66	15	43	18	37	20	18	17	+4
18	82	19	31	19	37	22	27	19	0
18	74	19	28	20	36	27	27	20	0
22	88	20	43	25	39			27	+6
		23	72						
		23	58						

TABLE 2
MELTING TESTS: VARIABLE TIME
112 sq in. surface area; 350 g ice

Chemical ^a	Temp. (F)	Amount of Melting in Grams			
		15 min	30 min	60 min	120 min
6	-23	26	23	36	52
7	-23	3	-	3	6
8	-23	25	41	49	69
9	-23	6	11	11	21
1	-10	21	24	41	50
3	-10	32	47	57	61
6	-10	36	49	66	76
7	-10	-	1	6	10
8	-10	44	46	60	73
9	-10	11	12	13	36
1	0	45	48	56	75
2	0	18	31	34	44
3	0	42	56	72	75
4	0	15	19	24	47
5	0	-	7	9	21
6	0	20	40	59	78
7	0	10	19	25	41
8	0	46	57	73	99
9	0	22	32	34	57
10	0	1	2	6	3
1	+10	58	71	79	106
2	+10	13	26	38	94
3	+10	61	73	91	108
4	+10	26	32	47	87
5	+10	2	3	-	54
6	+10	56	68	86	-
7	+10	24	44	54	88
8	+10	73	81	101	106
9	+10	29	45	57	65
10	+10	2	1	23	37
1	+20	68	69	86	139
2	+20	26	51	95	163
3	+20	60	92	104	141
4	+20	31	68	100	152
5	+20	20	18	43	150
6	+20	63	94	146	156
7	+20	11	31	87	153
8	+20	92	110	141	180
9	+20	49	58	70	120
10	+20	7	24	55	161

^a Note: Legend for Mixture of Chemicals

Chemical No.	CaCl ₂ Pellet		CaCl ₂ Flake		NaCl	
	%	Wt	%	Wt	%	Wt
1	100	32.8	0		0	
2	50	16.4	0		50	20
3	0		100	40	0	
4	0		50	20	50	20
5	0		0		100	40
6	100	40	0		0	
7	50	20	0		50	20
8	0		100	48.8	0	
9	0		50	24.4	50	20
10	0		0		100	40

TABLE 3
 DROP TEST DATA: BITUMINOUS PANS
 112 sq in. surface area; 200 g ice; 40 g chemical

100 % CaCl ₂ 0 % NaCl		75 % CaCl ₂ 25 % NaCl		50 % CaCl ₂ 75 % NaCl		25 % CaCl ₂ 75 % NaCl		0 % CaCl ₂ 100 % NaCl	
Temp. (F)	Time (min)	Temp. (F)	Time (min)	Temp. (F)	Time (min)	Temp. (F)	Time (min)	Temp. (F)	Time (min)
Pellets									
-8	90	-7	180	-6	300+	-6	300+	-6	300+
+2	100	+2	150	+3.5	60	+10	360	+8	300
3.5	65	4	100	10	130	12	90	10	140
9.5	25	10	60	12.5	115	13	60	13	160
10	40	12	90	13	50	17	35	15	95
13	35	15	13	15	20	23	35	19	100
15	12	17	35	17	30	28	25	19	75
17	30	19.5	30	20	30			23	55
19.5	22	23	26	23	20			27	25
22	30	27	8	23	15			28	45
23	20	28	20	27	6				
23	15			28	40				
27	8								
28	10								
Flakes									
-6	300+	-6	300+	-6	300+	-6	300+	-6	300+
10	80	5	120	7	240	8	280	8	300
12.5	105	10	80	10	80	10	110	10	140
18	60	12	65	15	180	12.5	115	13	160
23	20	18.5	70	15	90	13	140	15	95
27	8	23	20	18.5	75	15	90	19	100
		27	45	23	35	18.5	75	19	75
		28	45	27	35	23	55	23	55
				28	45	27	25	27	25
						28	45	28	45

TABLE 4
 DROP TEST DATA: CONCRETE PANS
 66 sq in. surface area, 150 g ice; 24 g chemical^a

100 % CaCl ₂ 0 % NaCl		75 % CaCl ₂ 25 % NaCl		50 % CaCl ₂ 75 % NaCl		25 % CaCl ₂ 75 % NaCl		0 % CaCl ₂ 100 % NaCl	
Temp. (F)	Time (min)	Temp. (F)	Time (min)	Temp. (F)	Time (min)	Temp. (F)	Time (min)	Temp. (F)	Time (min)
Pellets									
-2	65	-2	45	+5	85	+5	47	+6	45
-2	45	+2	100	11	55	11	100	11	110
+1	35	11	20	12	64	12	60	11	80
5	15	12	25	13	55	13	40	12	73
6	45	13	40	13	25	16	64	13	60
11	35	13	33	15	46	17	45	15	95
11	40	13	30	16	75	18	35	17	85
12	20	17	25	17	45	22	64	18	70
13	55	18	15	18	30	22	45	22	65
13	13	22	45	22	40	22	40	22	50
13	7	22	23	22	23	22	20	22	25
15	15	22	15	22	15	25	23	22	22
17	25	22	13	25	19	28	30	25	22
22	17 ^b	25	19	28	30	30	30	28	40
22	20	28	30	30	30	30	23	30	30
25	19	30	30	30	23				
25	12	30	13						
28	15								
30	15								
30	10								
30	5								
Flake									
-2	45	+5	49	+11	70	+11	100	+6	45
-2	32	11	20	12	64	12	60	11	110
0	20	12	37	13	85	13	85	11	80
+1	46	13	65	13	40	13	40	12	73
+1	37	13	14	13	7	16	64	13	60
5	28	13	4	15	66	17	45	15	95
6	25	15	85	17	45	18	35	17	85
12	20	17	45	18	20	22	40	18	70
13	44 ^b	18	20	22	30	22	23	22	65
15	68	22	45	22	23	22	20	22	50
17	50	22	40	22	15	25	22	22	25
17	20	22	23	25	19	28	30	22	22
22	17 ^b	22	14	28	30	30	30	25	22
25	19	25	19			30	23	28	40
25	12	28	15					30	30
28	30	30	30						
30	10	30	13						
30	5								

^a Total weight of chemicals was 24 g in all tests with pellets. Flake weights were increased by $\frac{29}{24}$ to give equal chloride content, but NaCl weights were not changed so total weight of chemicals in tests with flake was variable between 29 g for 100 percent flake and 24 g for 100 percent NaCl.

^b Average of five tests. All others single tests.

Ice-Melting Properties and Storage Characteristics of Chemical Mixtures For Winter Maintenance

WILLIAM E. DICKINSON, Chief Engineer, Calcium Chloride Institute, Washington, D. C.

● THE PROBLEM of keeping roads clear for travel despite snow and ice is a relatively modern one. Prior to World War II only a few progressive states had extensive winter maintenance programs. With the increased highway investment of the present, and proposed for future highways, it is appalling that the system of interstate highways, along with other vital roads and streets, is not clear and available for year-round travel.

Although public pressure alone will bring about improved winter maintenance procedures, there is consolation to maintenance engineers that better winter maintenance pays for itself. This fact was recognized as early as 1941 by Michigan highway authorities.

Comparisons of winter maintenance costs and gas tax revenue from 1937 to 1941 in Michigan show that revenue for the eight non-winter months increased 16 percent, whereas the winter revenue increased 33 percent. An additional \$1.3 million in revenue represented additional mileage traveled, made possible by improved winter road conditions. These safer driving conditions were brought about by an increase of only \$600,000 in the winter road maintenance budget.

There are three basic procedures in winter maintenance, as follows:

1. Plowing.
2. Sanding.
3. Chemical application.

This report deals with the use of chemicals, the two customarily used being calcium chloride and sodium chloride. They offer distinct advantages of availability, low cost, and effectiveness. Well-established properties are as follows:

Property	Calcium Chloride	Rock Salt
Lowest freezing point	-58 F	-6 F
Moisture attraction	Deliquescent; attracts moisture from air and goes into solution	Non-deliquescent; does not attract moisture for solution
Heat of solution	Positive; liberates heat as it goes into solution	Negative; requires or takes on heat as it goes into solution

The ice-melting capacities of the two chemicals are shown in Tables 1 and 2, which reveal that, given unlimited time, sodium chloride melts more ice than Type 1 calcium chloride¹ down to 10 F (based on Type 2 calcium chloride this would be approximately 20 F). As to the rate of ice melting, the data show a considerably higher rate for calcium chloride.

With this established information on ice-melting properties of the two chemicals,

¹ ASTM-D98 and AASHO-M-144: Type 1—regular flake, 77 percent min. CaCl₂; Type 2—concentrated flake, pellet or other granular, 94 percent min. CaCl₂.

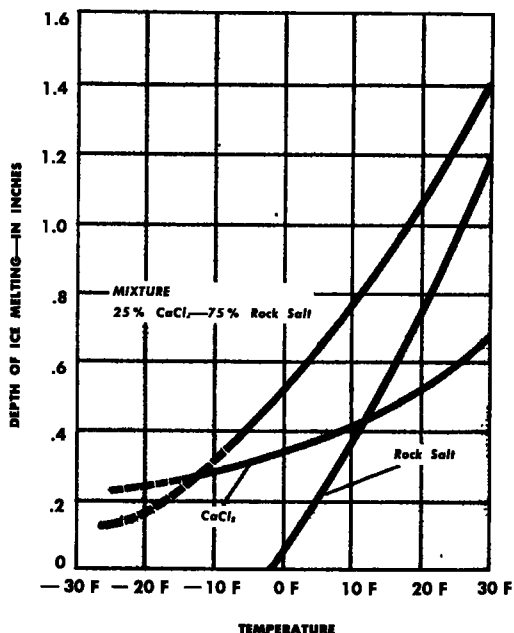


Figure 1. Depth of ice melting at 2 hr, by particles of equal weight.

and with increased use of chemicals in the field, it was logical that engineers would try to take advantage of the best properties of each by using them in combination. Initial field reports of the use of mixtures were variable, but encouraging enough for the Calcium Chloride Institute to undertake a research program, first in the laboratory and later in the field, to try to establish expected results under various conditions. An initial study showed that a 3-parts-salt-to-1-part-calcium-chloride mixture melted a greater depth of ice in 2 hr at all temperatures down to -10°F than did either of the two chemicals used alone (Fig. 1).

The next step in the studies was sponsorship of research at the University of Minnesota, the Ohio State University and

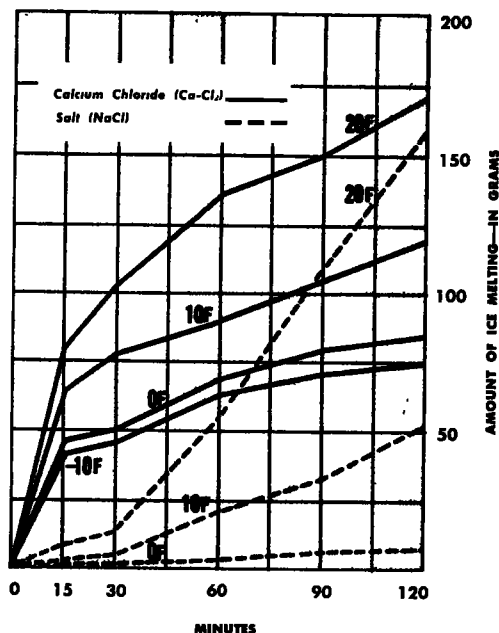


Figure 2. Amount of ice melted in 15 to 120 min; 350 gm ice in 7- by 11-in. pan; 40 gm chemical (based on 100 percent NaCl or CaCl_2). No NaCl reaction at -10°F .

TABLE 1
ICE-MELTING ABILITY OF CHEMICALS ON
A WEIGHT BASIS

Temp. $^{\circ}\text{F}$	Ice Melted per pound of Chemical (lb)	
	77% Flake CaCl_2	Pure NaCl Granules
30	31.1	46.3
25	10.4	14.4
20	6.8	8.6
15	5.5	6.3
10	4.8	4.9
5	4.4	4.1
0	4.0	3.7
-6.5	3.7	3.2
-10	3.5	-
-20	3.2	-
-30	2.9	-

TABLE 2
POUNDS OF ICE MELTED PER POUND OF CHEMICAL¹

Temp. $^{\circ}\text{F}$	15 Min		30 Min		1 Hr		6 Hr	
	Cal. ²	Sod.	Cal. ²	Sod.	Cal. ²	Sod.	Cal. ²	Sod.
0	1.3	0.07	1.7	0.1	2.0	0.3	2.3	1.9
10	1.7	0.5	2.0	0.9	2.4	1.6	2.8	3.8
20	2.5	1.6	3.1	2.6	3.8	4.1	5.3	7.5
26	2.6	1.8	3.4	2.9	4.4	4.3	7.1	9.5

¹ Chemical applied at the rate of 0.8 lb per sq yd.

² Type 1 calcium chloride (77% min. CaCl_2).

in Michigan, tied in with field experiments. Except for Michigan, field testing was lacking; but the total contribution of the studies was considerable. For example, at the University of Minnesota, as reported by Kersten et al. (1), tests were run on the amount of ice melted in 15 to 120 min at varying temperatures. These tests confirmed the faster ice-melting action of calcium chloride at all temperatures and the greatly reduced effectiveness of salt at lower temperatures (Fig. 2).

Field studies in Michigan (see Appendix) showed that there was an average increase of 63 percent in clear area on icy pavements 2 hr after applications of a mixture of 67 percent salt and 33 percent calcium chloride. Indications are that at a shorter time interval, mixtures would be more effective even at the high temperatures encountered (25 F to 31 F) where salt normally does its best job. With lower temperatures and other factors entering in, the greater effectiveness of calcium chloride-salt mixtures would undoubtedly be more pronounced.

Due to a lack of cooperation from the weather, the field experiments conducted at Ohio State University in cooperation with the Ohio Department of Highways were limited. Eberhart's (2) review of the research previously done represents a valuable reference as to basic properties of calcium chloride and sodium chloride, some of which has been previously referred to. A further contribution in the Ohio report (2) is an analysis of the importance of relative humidity as a factor influencing the length of time required to initiate the melting process by chemicals.

The report analyzes the ability of each of the chemicals to attract moisture at various relative humidities. It states that calcium chloride melts ice faster because of its greater moisture-attracting ability and that the presence of moisture acts to speed the initial ice melting. Sodium chloride requires a relative humidity of 75 to 100 percent to attract moisture easily. Calcium chloride will attract moisture easily with relative humidities of 46 to 60 percent at temperatures of -15 F to +32 F. The vapor pressure of saturated calcium chloride solutions is less than the vapor pressure of saturated salt solutions at any temperature and calcium chloride melts ice faster at any temperature.

While these sponsored studies were under way considerable field information was being gathered. One of the best sources of information on the use of chemicals and



Figure 3. Maintenance personnel of the Ohio Turnpike Commission check free-flowing pile of chemical mixture after several weeks storage under tarpaulin.

TABLE 3
RESULTS OF FIELD TEST A, BULK STORAGE TESTS, DRY ROCK SALT AND TYPE 1 REGULAR CALCIUM CHLORIDE

Conditions of Tests:

Stockpiles in abandoned structure 500 ft from Detroit River, open on sides, but protected by roof from direct rain or snow.
Stockpiles placed on tar paper on dirt floor.
Stockpiles varied from 500 to 800 lb of mixed materials.

Building sufficiently open to maintain same temperature and humidity as outside.
Stockpiles placed October 14, 1957 and observed monthly for 6 months.
Mixing done in small concrete mixer.

Test Pile	% Dry Rock Salt	% Calcium Chloride	Condition After Six Months
1	100	0	No loose salt layer on top of crust. 1 - 1½-in. extremely hard crust, (difficult to break). Free flowing underneath.
2	85	15	1-in. loose salt layer on top of crust. ¾-in. hard crust, (easily broken). Free flowing underneath.
3	75	25	¾-in. loose salt layer on top of crust. ¾-in. hard crust, (easily broken). Free flowing underneath.
4	65	35	1-in. loose salt layer on top of crust. ¾-in. medium hard crust, (easily broken). Free flowing underneath.
5	50	50	½-in. loose salt layer on top of crust. ¾-in. soft crust, (easily broken). Free flowing underneath.
6	0	100 Type 2	½-in. gummy material on top of crust. 1-in. hard crust, (easily broken). Free flowing underneath.
7	0	100 Type 1	No loose layer on top of crust. 1½-in. soft crust, (easily broken). Free flowing underneath.

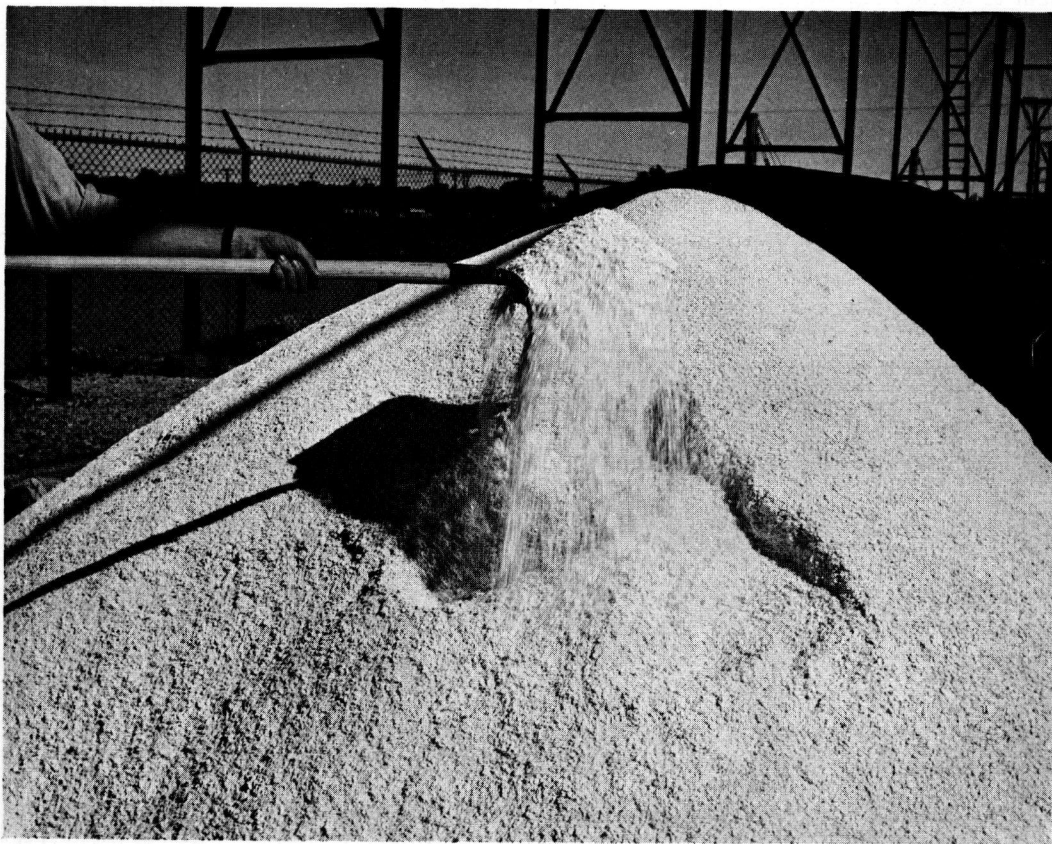


Figure 4. Completely dry and free-flowing condition of Type 1 calcium chloride after several months outside storage under polyethylene cover.

mixtures under excellent control has been the Ohio Turnpike. L. G. Byrd, Maintenance Engineer, has experimented with various combinations during the past three years. The present winter maintenance procedures on the Turnpike are based on the use of both direct chemicals, salt-calcium chloride mixtures (Fig. 3), abrasives, and plowing. There are four basic storm conditions which merit one of these treatments. These are described and issued as a basic guide for each maintenance section on the Turnpike, thus utilizing the best procedure available for conditions encountered.

STORAGE

Having established the value of mixtures under certain conditions and with an increasing interest in their use from the field, the next problem was how to make the combinations easy to use. Initially the two chemicals were mixed at the time of use. This was not the most desirable method, as storms tend to strike in the middle of the night. The ideal situation would be to have the chemicals premixed and immediately available for use. The question then arose as to whether bulk calcium chloride and salt mixtures could be stored successfully.

The Calcium Chloride Institute, through its members, investigated the problem during the winter of 1958. Calcium chloride can be stored in bulk when protected from direct precipitation. Indications are that practical proportions (2 to 1, or 3 to 1) of salt to calcium chloride can be premixed and stored without difficulty (Fig. 4) with the following restrictions:

TABLE 4
RESULTS OF FIELD TEST B, BULK STORAGE TESTS, ROCK SALT WITH VARYING MOISTURE CONTENT AND TYPE 2 CONCENTRATED CALCIUM CHLORIDE

Conditions of Tests:

Stockpiles in an exposed location on a lime lake in Ohio, protected by tarpaulin for the only cover
Stockpiles placed directly on hardened lime lake.

Stockpiles placed March 26, 1958, and observed and photographed on April 24 and May 29.
Stockpiles were 1,000 lb of mixed materials
Mixing done in small concrete mixer.

Test Pile	% Moisture in Salt	% Salt	% Chloride	Condition After One Month	Condition After Two Months
1	0	90	10	1-in. salt layer on surface. 1-1/2-in. crust. Free flowing underneath.	1-in. salt layer on surface. 2-in. hard crust. Free flowing underneath.
2	0	80	20	1/4-1/2-in. salt layer on surface. 1/2-in. crust, (easily broken). Free flowing underneath. Some calcium chloride on surface.	1-in. salt layer on surface. 1 1/2-in. crust, (easily broken) Free flowing underneath. No calcium chloride on surface.
3	2	75	25	1/4-1/2-in. salt layer on surface. 1/2-in. crust. Free flowing underneath. Some calcium chloride on surface.	1/4-in salt layer on surface. 1 1/2-in. hard crust. Free flowing underneath. No calcium chloride on surface.
4	4	75	25	1/4-in. salt layer on surface. 1-2-in. crust. Free flowing underneath (slight set).	1/4-in. salt layer on surface. 1 1/2-2-in. crust. Material slightly set just underneath the crust. Interior free flowing.
5	4	65	35	1/4-1/2-in. salt layer on surface. 1/2-3/4-in. crust. Interior free flowing with hard clusters, (easily broken.)	1/4-in. salt layer on surface. 3/4-in hard crust. Interior free flowing with hard clusters, (easily broken).
6	6	65	35	1/4-1/2-in. salt layer on surface. 1/2-1-in. hard crust. Interior firm but breakable. Some calcium chloride on surface.	1/4-in. salt layer on surface. 3-4 in. hard crust on surface. Secondary crust of 3-in. that is firm but breakable Interior free flowing. No calcium chloride on surface.
7	6	72	28	1/4-1/2-in. salt layer on surface. Pile set to a depth of at least 5 in. Difficult to break.	1/4-in. salt layer on surface. Pile completely set.
8	6	55	45	1/4-in. salt layer on surface. 1-in. crust. Underneath fairly free flowing but contains small hard clusters.	1/4-in. salt layer on surface 3-4-in. hard crust. Interior free flowing but contains some small hard clusters.



Figure 5. General view of Field Test B, with various mixture stockpiles that had been tarpaulin covered and observed for two months. Storage tests were also conducted in sheds at rear.

1. Salt (and calcium chloride) must be dry (less than 2 percent surface moisture).
2. The mixed chemicals must be protected from direct rain.

Details of the field tests on bulk storage are shown in Tables 3 and 4. Field Test A involved various proportions of dry salt and calcium chloride, stored in open piles under a roof, the building being open on the sides. Results from Field Test A (Table 3) are summarized as follows:

1. In all cases, materials underneath the crust remained as dry and workable as when placed in position. The crust served as a protecting cover.
2. With the exception of the 100 percent rock salt, the crust, although quite hard in some cases, was sufficiently thin to allow easy break-through to the protected portion. The loose material on the surface over the crust (in the cases of salt and chloride mixtures) appeared to be made up of salt particles. Apparently the calcium chloride dissolved and moved away from the surface, forming a crust below the surface and leaving salt particles on the surface.
3. The condition of the stockpiles did not change much, if any, after a month or so. There was indication that after two or three months the crust thickness decreased somewhat on piles No. 2 through No. 5. In fact, these four piles all had the same crust thickness of $\frac{3}{4}$ in. on the average at the end of the fifth and six months.
4. Both Type 1 and Type 2 calcium chloride stored better outside under shed cover than did straight rock salt.
5. Mixtures of dry salt and Type 1 calcium chloride stored better outside under shed cover than did straight salt.

Field Test B involved various combinations of salt and calcium chloride. The moisture content of the salt varied from 0 to 6 percent. Piles were in the open, tarpaulin covered, on bituminous pads. Results from Field Test B (Table 4) are summarized as follows:

1. The proportion of 20 percent calcium chloride to 80 percent salt containing little or no moisture resulted in a mixture which withstood two months storage very well (Fig. 5). The $1\frac{1}{2}$ -in. crust which formed was easily broken and the material underneath the crust was free-flowing. The proportion of 10 percent calcium chloride to 90 percent salt resulted in a 2-in. crust, which was very hard and difficult to break. The material under the crust was free-flowing.
2. The mixture of 25 percent calcium chloride and 75 percent salt containing 2 per-

cent moisture resulted in a $1\frac{1}{2}$ -in. hard crust after two months storage. The crust was difficult to break; material underneath was free-flowing (Fig. 6).

3. The mixture of 35 percent calcium chloride and 65 percent salt containing 4 percent moisture resulted in a $\frac{3}{4}$ -in. hard crust. The interior was free-flowing, but contained a few hard clusters. The proportion of 25 percent calcium chloride to 75 percent salt resulted in a $1\frac{1}{2}$ - to 2-in. crust, which was also very hard. The material just underneath this crust was slightly set, but the interior was free-flowing.

4. The mixture of 28 percent calcium chloride and 72 percent salt containing 6 percent moisture resulted in a pile that was completely set. The proportion of 35 percent calcium chloride to 65 percent salt resulted in a 4- to 6-in. hard crust with a secondary crust of 3-in. thickness which was firm but breakable. The interior was free-flowing. The proportion of 45 percent calcium chloride to 55 percent salt resulted in a 3- to 4-in. hard crust. The interior was free-flowing, but contained some small, hard clusters.

Tentative recommendations for storage of mixtures based on these field tests are: Type 1 or Type 2 calcium chloride can be used in the following proportions with rock salt containing moisture up to 4 percent:

1. For salt containing little or no moisture, a 4-to-1 or 3-to-1 mixture of salt to calcium chloride should be used to achieve good storage characteristics.

2. For salt containing 2 percent moisture, a 2-to-1 mixture of salt to calcium chloride is indicated. This will give a $\frac{1}{2}$ -in. crust and be free-flowing underneath.

3. Up to 4 percent salt moisture, a 3-to-2 mixture of salt to calcium chloride is indicated. This will give a crust not exceeding $\frac{3}{4}$ in., and with the interior material free-flowing.

Thorough field mixing is recommended, as the tests were based on almost ideal mixing methods.

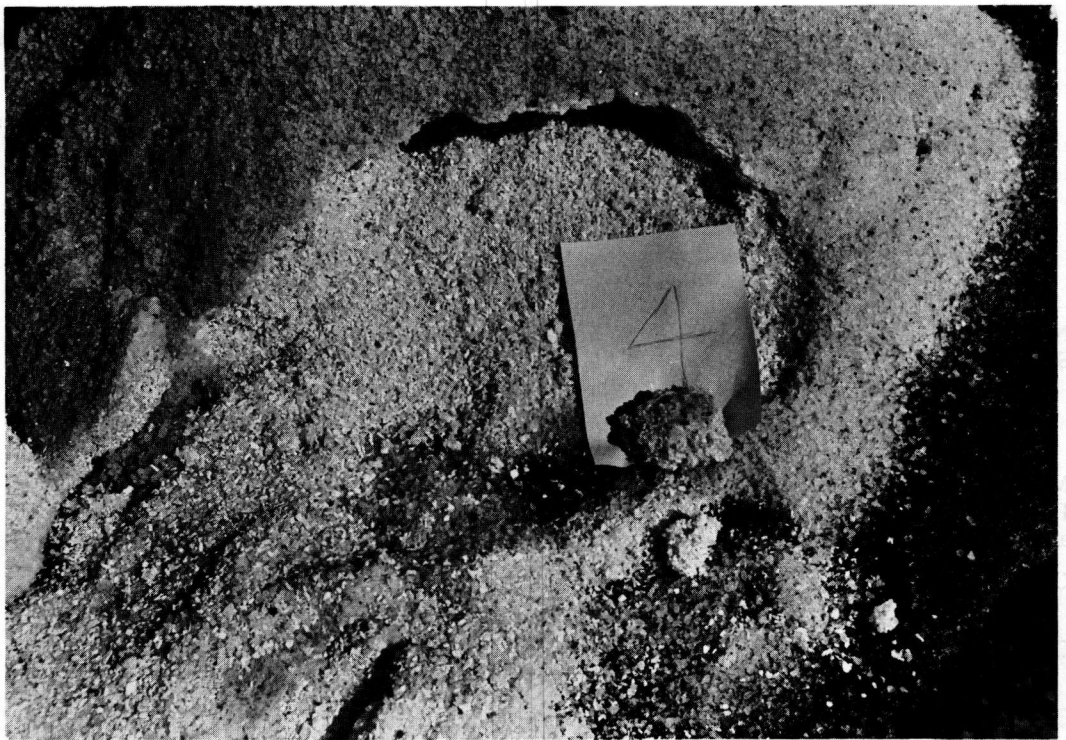


Figure 6. Condition of test pile 4 in Field Test B, with mixture of three parts dry salt to one calcium chloride under 1- to 2-in. crust.

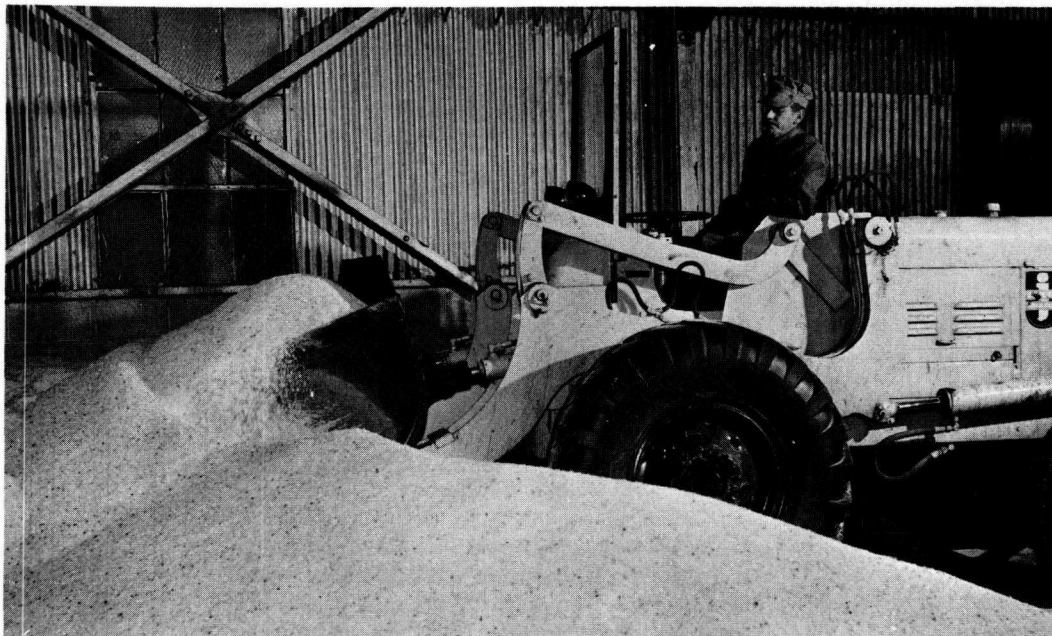


Figure 7. Front-end loader is used to pre-mix bulk salt and calcium chloride at the Sidney Division, Ohio State Highway Department.

As indicated by Test B, for rock salt containing high moisture content (above 4 percent and up to 6 percent), a 1-to-1 mixture of salt and Type 2 calcium chloride should be made.

The successful storage of mixtures under the foregoing restrictions is based on sound reasoning. Calcium chloride added in increasing amounts to salt with increasing moisture contents absorbs the excess moisture and keeps material underneath free-flowing.

Evidence of the interest in mixtures, and opportunity to learn more from field experience is found in a number of tests during the winter of 1958. Some of the major ones are indicated in Table 5.

TABLE 5

Location	Description
New York Thruway (Weedsport Section)	30 miles to use 3 salt-1 calcium chloride. Involves 4,800 tons of mixtures. Mostly direct, but in combination with abrasives when desired. To be compared with adjacent 10-mile section, where straight salt will be used.
Massachusetts Department of Public Works (near Walpole and Norwood)	Five 4,000-ft sections. Four chemical sections with variable proportion and quantities per mile. One section with sand and chemical mixture.
Connecticut Highway Department	Four test sections in two districts, with chemical mixtures direct and in combination with abrasives.
Ohio Highway Department	Sidney Division is premixing on 2:1 basis for comparison with straight salt (Fig. 7).
City of Philadelphia	Calcium chloride being mixed with salt for faster action.

In addition to those listed, many cities and states are experimenting with chemical combinations on a less formal basis.

Another test series under way involves heavy chemical treatments of abrasives. Direct chemical application is increasing, but there is always a need for abrasives under certain conditions of traffic and weather. Storage characteristics of abrasives with greater than the normal amount of chemical treatment are still needed.

The tests can be outlined as follows:

1. Materials proportions (by weight):

9 abrasive—1 chemical.
3 abrasive—1 chemical.
1 abrasive—1 chemical.

2. Moisture contents of abrasives:

Sand and limestone—0, 3, 6 percent.
Cinders—0, 7, 14 percent.

3. General:

Size of piles—1,000 lb total weight.
Storage—open, no cover.
Blank—1 untreated pile, dry when stored.
Observations—monthly through winter to determine crusting and condition of pile underneath. Temperature and precipitation from nearest weather station.

Thus, in addition to the information reported here, there will be additional findings from the tests continuing during 1959. Meanwhile it is felt that maintenance engineers can profit from a relatively new procedure involving mixtures of chemicals. It has already been most helpful in answering the needs for improved, high-speed maintenance on modern heavily-traveled streets and highways.

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Appendix

CALCIUM CHLORIDE SALT MIXTURE FOR TREATMENT OF ICY PAVEMENTS

H. G. MINIER, Superintendent-Manager, Washtenaw County Road Commission, Ann Arbor, Michigan—Field tests were conducted on selected sections of roads and streets in Washtenaw County, Michigan, during January and February 1957. Washtenaw County is in the southeastern part of the Lower Peninsula of Michigan. The University of Michigan is located at the county seat, which is Ann Arbor. The average winter temperatures range from about 25 F to 35 F. There are 14 or 15 snowstorms that exceed 1 in. of snow, plus many others which are less than 1 in. or a freezing rain variety which call for the use of chemicals.

Both bituminous and concrete surfaces were tested. Mixtures of rock salt and calcium chloride Type 1 (flakes) and Type 2 (pellets) in several proportions were spread on the selected sections. Separate crews and equipment were used for the study. The chemical materials were pre-mixed and bagged by the manufacturer to insure accurate

control of the quantities. The material used was purchased by the Michigan State Highway Department. The rate of application and method of spreading followed regular Michigan practices for the area.

Engineering students from the University of Michigan recorded information on weather, road conditions, mixtures used, traffic, and results each time a mixture application was made. Accurate weather data (such as humidity, temperature, wind, sky conditions, and snowfall) were obtained from the weather station at near-by Willow Run Airport.

Data were obtained on seven separate storms during the period of study. However, an analysis was made on only five storms, as it was felt that the heavy snowfall (5 to 7 in.) and drifting during the remaining two storms would be inconsistent with the results of the other five. The temperature range, averaged between the start of the snowfall and the second hour check after application of the mixture, varied between 31 F and 25 F for the five storms, and the humidity varied between 94 and 74 percent. The snowfall for the five storms varied between 1.1 and 2.0 in.

There were no marked differences noted between the results obtained on either concrete or blacktop pavement. However, the results are too inconsistent to evaluate any great difference between the addition of 25 or 33 percent calcium chloride to salt. It was found also that there was no great difference between the use of calcium chloride pellets and calcium chloride flakes.

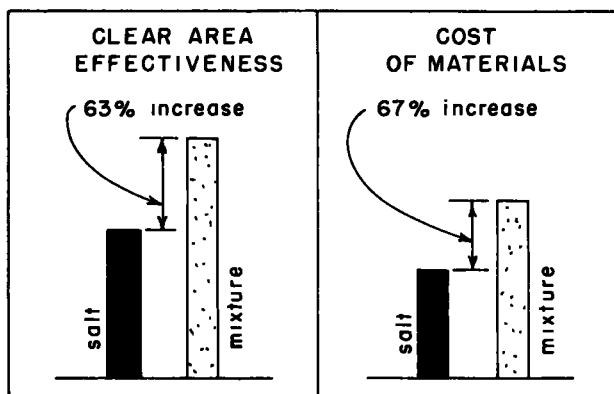


Figure 8. Comparison of clear pavement area and costs between the salt alone and the 2-to-1 salt-calcium chloride mixture.

The clear pavement area two hours after application, based on the average of five storms and both pavement types, was 62 percent for the 66 percent-salt-33 percent-calcium-chloride-flakes mixture and 38 percent for the salt alone. In other words, there was 24 percent more clear pavement at the end of two hours using the 2-to-1 salt-calcium chloride mixture, or the calcium chloride-salt mixture was 63 percent more effective than the salt alone.

Effectiveness, however, must be balanced with the economic aspects of the situation. During the tests all sections received the equivalent of 500 lb per mile per application. The costs of the materials applied at that rate amount to \$2.75 per mile for salt and \$4.58 per mile for the 2-to-1 salt-calcium chloride mixture. Figure 8 is a comparison between clear pavement area and costs. For the 63 percent increase of effectiveness, the cost of material increases 67 percent.

Other sections of the country would show different comparisons adjusted to the price differential between salt and calcium chloride. Washtenaw County is fortunate to be located so close to the salt mines at Detroit.

Because of the number of variables (such as humidity, temperature, sky coverage, snowfall, time, traffic, and type of pavement), a correlation between a variable or variables and mixtures cannot be evaluated with any consistency on the limited number of tests. The tests did bear out the laboratory studies, in that the mixtures of salt

and calcium chloride were more effective than salt alone. Under the conditions of these tests the best results were obtained from the mixture of 2 parts salt and 1 part calcium chloride flakes, by weight.

Further tests should be conducted in this study. As mentioned earlier, there are too many variables to compare and evaluate to reach a conclusion based on the five tests. There is inconsistency in the results; however, correlations are beginning to appear which further tests should bear out. The data to be collected in these tests should include the following:

1. Weather Conditions:
 - (a) Temperature.
 - (b) Humidity.
 - (c) Sky conditions (cloudy or clear).
 - (d) Wind velocity.
2. Pavement Conditions:
 - (a) Ice or packed snow.
 - (b) Thickness of ice or packed snow.
 - (c) Uniform or variable.
3. Treatment:
 - (a) Time of day.
 - (b) Proportions used on each section.
 - (c) Length of sections.
 - (d) Rate of application.
4. Traffic:
 - (a) Vehicles per hour.
 - (b) Average speed.
 - (c) Type of vehicle.
5. Results:
 - (a) Length of time to clear.
 - (b) Variation in removal pattern.
 - (c) Photographs.

The necessity for close observations should be stressed. There should be no doubt as to what information is required, or the way it is recorded. Evaluation of the pavement condition after application should be standardized to insure consistency of observations between different observers or different storms. The success of future studies is dependent on the accurate observation of the pavement condition and close timing of the inspections.

THE NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare. The ACADEMY itself was established in 1863 under a congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an adviser to the federal government in scientific matters. This provision accounts for the close ties that have always existed between the ACADEMY and the government, although the ACADEMY is not a governmental agency.

The NATIONAL RESEARCH COUNCIL was established by the ACADEMY in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the ACADEMY in service to the nation, to society, and to science at home and abroad. Members of the NATIONAL RESEARCH COUNCIL receive their appointments from the president of the ACADEMY. They include representatives nominated by the major scientific and technical societies, representatives of the federal government, and a number of members at large. In addition, several thousand scientists and engineers take part in the activities of the research council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the ACADEMY and its RESEARCH COUNCIL thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the government, and to further the general interests of science.

The HIGHWAY RESEARCH BOARD was organized November 11, 1920, as an agency of the Division of Engineering and Industrial Research, one of the eight functional divisions of the NATIONAL RESEARCH COUNCIL. The BOARD is a cooperative organization of the highway technologists of America operating under the auspices of the ACADEMY-COUNCIL and with the support of the several highway departments, the Bureau of Public Roads, and many other organizations interested in the development of highway transportation. The purposes of the BOARD are to encourage research and to provide a national clearinghouse and correlation service for research activities and information on highway administration and technology.
