Natural Brine as an Additive to Abrasive Materials and Deicing Salts

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Large quantities of natural oil and gas field brines are available at little or no cost at many locations in the Appalachian Region. Because these brines contain significant quantities of both sodium and calcium chloride salts, they appear to be an attractive substitute for conventional chemicals as an additive to abrasive materials and as a prewetting agent for deicing salts. Such additives are used for freezeproofing abrasive stockpiles and improving salt's performance as a deicing chemical. To evaluate the technical and economic feasibility of using brine in these applications, five abrasives (bottom ash, cinders, sand, sawdust, and limestone) were studied. It was found that the first four could be freezeproofed effectively over a wide range of initial moisture contents and at temperatures as low as 10°F when natural brine with total dissolved solids (TDS) of 265 670 mg/L was used. Overall, few trends or generalizations can be drawn between the various abrasives; each brine-abrasive combination must be considered as an individual case when freezeproofing application rates are developed. For limestone, application of brine for freezeproofing is limited by the physical properties of the aggregate. Only limestone containing less than or equal to 3 percent initial moisture could be freezeproofed. Spraying brine on the abrasive materials as a stockpile is being formed, followed by supplemental applications dictated by the frequency and intensity of precipitation, appears to be the optimum procedure for freezeproofing stockpiles. The highway agency should have brine storage tanks at its maintenance stations to assure a reliable brine supply when needed during storm periods. Laboratory tests were conducted to evaluate the use of brine as a prewetting agent for rock salt. Results of melting, penetration, and bounce-off tests for the natural brine used indicated performance almost identical to that of a 32 percent solution of calcium chloride. It was concluded that prewetted salt initiated slightly more rapid melting compared with dry salt, but there did not appear to be a significant difference. Wetted salt stayed closer to the point of contact than dry salts. As the liquid application rate increased, there was a small but not significant reduction in bounce-off.

Increased public demand for bare pavements throughout the winter months has led highway agencies to greater reliance on sodium and calcium chloride deicing agents. Advantages of sodium and calcium chlorides include ease of application, solubility in water, and effectiveness as a melting agent. In recent years, however, the costs of sodium and calcium chlorides have increased to the point where providing a bare pavement places a serious financial strain on highway agencies. Tight operating budgets and the adverse environmental impacts associated with increased salt usage have led these agencies to seek less use of traditional deicing chemicals.

For a number of years, highway agencies have used abrasive materials in conjunction with salts to provide traction and deicing. Abrasives are especially helpful in very cold weather when deicing salts are not effective and to provide a traction aid when clear plowing is not possible. Statistics compiled by the Salt Institute *(1)* indicate that use of abrasives has risen in many regions of the country as the cost of chemical deicing agents has increased.

Limited amounts of sodium or calcium chloride, or both, are usually added to abrasive materials. The salt prevents the abrasives from freezing both in the stockpiles and in the mechanical spreaders. In addition to decreasing pavement slipperiness, such a mixture also has the capability of melting snow during periods when air temperature rises.

Usually conventional dry chemicals are mixed with abrasive materials. In recent years, however, there has been increased interest in using liquid calcium chloride as a substitute for conventional dry chemicals. This liquid can be sprayed over rock salt just before application (a concept referred to as "prewetting") or it can be mixed with abrasive materials alone to provide stockpile freezeproofing and some melting capability. Although several agencies *(2–5)* have reported success with liquid calcium chloride, a primary drawback to its use is the relatively high cost of the material.

Large quantities of natural oil and gas field brines are available at little or no cost at many locations in the Appalachian Region of the eastern United States. These brines, whose major ionic species include chloride, sodium, calcium, magnesium, and potassium, are usually much more concentrated than seawater. For example, seawater contains about 20 000 mg/L of chloride, whereas the content in oil and gas field brines from the eastern United States may range from 15 000 to 350 000 mg/L of chloride. Recently completed research at West Virginia University *(6)* assessed the deicing potential of a number of West Virginia brines.

Because these brines contain significant quantities of both sodium and calcium chloride salts, they would appear to be an attractive substitute for conventional chemicals as an additive to deicing salts and abrasive materials. However, a review of the literature indicates that there is virtually no documented information on this application of natural brine. Thus, it seemed appropriate to investigate the technical and economic feasibility of using natural brine as an additive to deicing salts and abrasive mixtures. The work was a logical extension of the previously mentioned research *(6)*, which focused primarily on the deicing potential of direct application of brine to snow- and ice-covered pavements.

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STUDY OBJECTIVES

The overall objective of the research project described here was to assess the feasibility of using West Virginia oil and gas field brines as an additive to deicing salts and abrasive mixtures. Several specific objectives were established to complete this assessment:

- To mix brine with bottom ash, cinders, limestone chips, sand, and sawdust to determine application rates required to prevent freezing of stockpiles under typical winter conditions in West Virginia.
- To identify efficient procedures for mixing brine with the identified abrasive materials and, on this basis, determine the costs associated with using brine in abrasive mixtures.
- To assess the technical and economic feasibility of using natural brine to prewet rock salt and to establish appropriate application rates.

Two aspects of brine were studied primarily: as an additive to abrasives and as a prewetting agent for salt. The acquisition and characterization of the materials used in the study are discussed in the following section. This is followed by sections on use of brine to freezeproof abrasives and on brine as a prewetting agent. Included in these latter two sections are descriptions of the test procedures used along with summaries of results in both narrative and graphical form.

MATERIALS ACQUISITION AND TESTING

Brine

The brine used was obtained from one of two brine storage tanks located at the Sabraton Maintenance Station of the West Virginia Department of Highways (WVDOH). These tanks were used to provide brine for a separate but related project involved with assessing the field performance of brine as a deicing agent. This brine was a combination of four brines obtained from the following West Virginia counties and geologic formations: Raleigh (Maxon), Boone (Weir and Big Lime), Lewis (Fifth), and Wood (Oriskany).

The brine was subjected to a series of tests to determine its physical and chemical characteristics. Of prime importance to this study was the relative strength of the brine as measured by the amount of total dissolved solids (TDS), sodium and calcium chlorides (NaCl, CaCl), and the existence of any potential water-polluting heavy metals such as lead (Pb) and barium (Ba). A partial physical and chemical evaluation of the brine is as follows:

Component	*Amount (mg/L)*
TDS	265 670
Chlorides	153 630
Sodium	78 600
Calcium	19 610
Lead	4.5
Barium	3.02

Abrasive Materials

The abrasive materials studied in this project were bottom ash, cinders, limestone, sand, and sawdust. They were obtained from the original suppliers rather than from stockpiles at the Sabraton Maintenance Station for two reasons: (a) a relatively large volume was required and (b) much of the material at the Sabraton site had been freezeproofed with sodium chloride the same day that it was delivered. Thus, to ensure a large uncontaminated sample for testing, the original suppliers were selected.

The nature of some of the abrasives is important. The limestone was a high-calcium variety obtained from a local quarry. The sand used was of natural origin. The sawdust was produced from walnut, poplar, and cherry cuttings.

After being screened of all materials not passing a ½-in. sieve, the abrasives were screened by using the following sieve sizes: ⅜ in., No. 4, No. 8, No. 16, No. 50, and No. 100. Gradation curves were plotted and compared with WVDOH standards. Gradation data for the five abrasives are given in Table 1. In addition to the gradation analysis, dry bulk densities were determined for each abrasive as follows:

	Dry Bulk Density	
Abrasive	*Kg/m^3*	*Lb/yd^3*
Bottom ash	1390	2,340
Cinders	750	1,260
Limestone	1400	2,360
Sand	1400	2,360
Sawdust	205	345

USE OF BRINE TO FREEZEPROOF ABRASIVES

Freezeproofing Tests

The use of dry salts to freezeproof abrasive stockpiles is widespread. For example, West Virginia policy *(7)* calls for the

TABLE 1 GRADATION DATA FOR FIVE ABRASIVES CONSIDERED

	Percentage of Fines by Sieve Size						
Abrasive	½ in.	⅜ in.	No. 4	No. 8	No. 16	No. 50	No. 100
Bottom ash	100	95.5	75.2	51.0	29.1	6.4	3.5
Cinders	100	79.9	38.9	18.9	9.4	1.9	1.8
Limestone	99.2	96.6	51.9	19.0	10.2	3.4	1.9
Sand	100	100	100	99.7	99.2	26.6	7.6
Sawdust	99.3	98.9	96.7	90.7	38.0	1.4	0.1

addition of 100 lb of dry salt per cubic yard of abrasives. Liquid salts, both commercially prepared calcium chloride and natural brine, are also in use for freezeproofing. One oil and gas producer reported the use of natural brine on limestone piles in Pennsylvania at an application rate of approximately 6 gal/ton. It was observed that brine application quickly melted any frozen crust that may have formed and produced a workable stockpile.

During the literature review, no formal studies of abrasive stockpile freezeproofing requirements (for either dry or liquid chemicals) were found. Apparently the available published guidelines and rules of thumb were developed empirically on the basis of experience over time for a particular location. Thus, no standard test procedure was available to evaluate freezeproofing. The freezeproofing experiments developed in this study were designed to determine the feasibility of utilizing natural brine as a freezeproofing agent to ensure free-flowing abrasive supplies under winter conditions.

One of the first tasks was to determine the saturation value of the five abrasives under free-draining conditions. Addition of brine will obviously raise the moisture content of a stockpile. In order to avoid oversaturation and runoff, saturation values must be known. Saturation moisture contents obtained are as follows: bottom ash, 35 percent; cinders, 50 percent; limestone, 7 percent; sand, 24 percent; and sawdust, 250 percent. Tests on subsequent batches of the abrasives showed some variation from batch to batch.

Each of the abrasive materials was mixed with a known quantity of water to achieve a desired moisture content. Moisture contents evaluated ranged from 0 percent (no water added) to nearly saturated values. A known quantity of freezeproofing agent was then mixed with the abrasive. Application rates of 25, 50, 75, and 100 lb (dry basis) /yd^3 were used in most cases. Both brine and dry salt were evaluated as freezeproofing agents for purposes of comparison. With a cold room, the mixes were subjected to three different freezing temperatures (10, 18, and 26°F) to determine the mix proportions required to prevent stockpiles of each of the materials from freezing.

At the completion of the 24-hr freezing period, the abrasive mixtures were analyzed in the cold room to determine their workability and ability to be free-flowing. Because no literature had been found containing information on freezeproofing criteria, the investigators developed their own. The criteria involved two properties of the abrasive mixtures: (a) the percentage by weight of the abrasive retained on a 1/2-in. sieve (after moderate agitation) and (b) the hardness of the material retained. Hardness was evaluated by the resistance to the penetration into the undisturbed stockpile of a steel probe, and by the resistance to a squeezing pressure, applied by hand, of the material retained on the sieve. Although the results of these procedures may appear to be highly subjective, repetitive tests using identical mixtures and analyzed separately by each of two investigators performing these laboratory tests showed that the test results could be reproduced. The specific details of the criteria employed to determine the freezeproofing class of the abrasive mixtures are presented in the project final report *(8)*.

The results of the sieve analysis and the hardness-factor determination of the test pile allowed categorization of each of the mixtures tested into one of five freezeproof classes: A, B, C, D, or E. Mixtures in Classes A and B were defined as "freezeproofed" and considered to be free-flowing and workable. Class C represents an intermediate zone, in which the stockpile consisted of either a large chunk retained on the sieve or of hard material that had smaller amounts retained on a 1/2-in. sieve. Classes D and E were determined to be nonworkable, or "not freezeproofed."

Test Results

Space limitations preclude discussion of individual test results for each of the five abrasives tested. To illustrate the testing performed for each abrasive, the results for cinders will be presented as an example, along with a summary of results for the remaining abrasives. Figure 1 shows the linear relationship that exists between the initial moisture content of the cinders and the amount of brine that can be added without runoff. It is

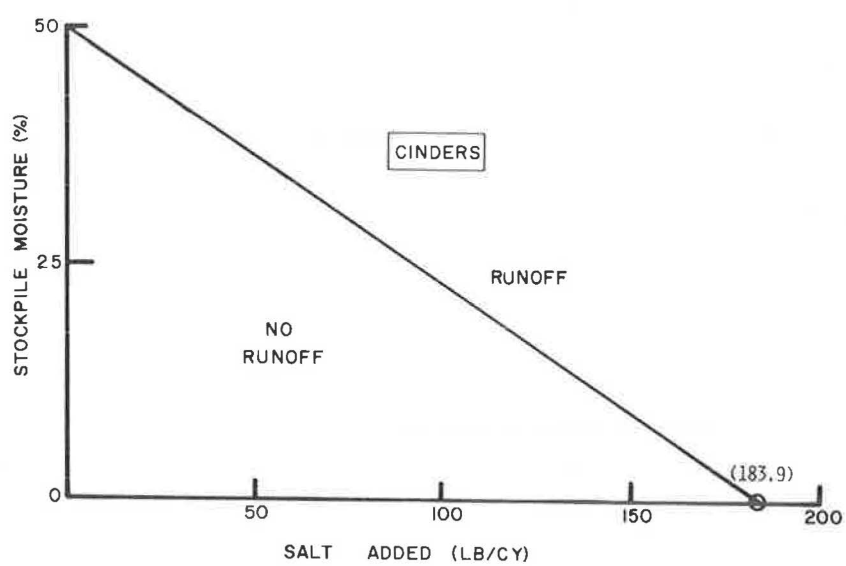

FIGURE 1 Initial stockpile moisture versus brine application rate for cinders (brine TDS = 265 670 mg/L).

TABLE 2 RESULTS OF FREEZEPROOF TESTS FOR CINDERS

Initial MC of Stockpile (%)	Brine Tests[a]																NaCl Tests: Application Rate and Temperature (°F) at Freezeproofing			
	25 lb/yd³				50 lb/yd³				75 lb/yd³				100 lb/yd³				50 lb/yd³			100 lb/yd³,
	Final MC (%)	Temperature (°F) at Freezeproofing			Final MC (%)	Temperature (°F) at Freezeproofing			Final MC (%)	Temperature (°F) at Freezeproofing			Final MC (%)	Temperature (°F) at Freezeproofing						
		10	18	26		10	18	26		10	18	26		10	18	26	10	18	26	10
0	6.8	F	F	F	13.6	F	F	F	20.5	F	F	F	27.3	F	F	F	F	F	F	F
10	16.8	F	F	F	23.6	F	F	F	30.5	F	F	F	37.3	F	F	F	F	F	F	F
20	26.8	F	F	F	33.6	F	F	F	40.5	F	F	F	47.3	F	F	F	F	F	F	F
30	36.8	–[b]	–	F	43.6	–	–	F	50.5	F	F	F	–[c]	–	–	–	F	F	F	F
40	46.8	–	–	F	53.6	–	–	F	–[c]	–	–	–	–[c]	–	–	–	F	F	F	F
45	51.8	–	–	F	–[c]	–	–	–	–[c]	–	–	–	–[c]	–	–	–	–	F	F	F
50	–[c]	–	–	–	–[c]	–	–	–	–[c]	–	–	–	–[c]	–	–	–	–	–	F	F

NOTE: MC = moisture content = weight of water/weight of solids. F = freezeproofed.

[a]Brine at 265 670 mg/L.
[b]No freezeproofing.
[c]Cinders are saturated at 50 percent moisture; therefore no brine can be added without undesirable runoff.

indicated that the maximum amount of brine TDS that can be added to dry cinders is approximately 184 lb/yd^3; this amount decreases as the initial moisture content of the cinders increases.

The results of the freezeproof testing of cinders are shown in Table 2. Both the brine and rock salt additions and their freezeproofing abilities at the three experimental temperatures are given. From Table 2, it can be seen that when the test brine is applied at a rate of 25 lb/yd^3, an additional 6.8 percent water is added. This means that no brine can be applied to an almost saturated stockpile at 50 percent initial moisture. Cinders containing more than 30 percent initial moisture can be freezeproofed with the addition of brine at the rates of 25 and 50 lb/yd^3, but only at the highest test temperature of 26°F. With the addition of 75 lb/yd^3 of brine salts, however, cinders containing 30 percent initial moisture can be effectively freezeproofed at all experimental temperatures. This appears to be the optimum brine application rate capable of freezeproofing cinders of 30 percent initial moisture and less while minimizing the amount of salt exposed to the environment.

As shown in Table 2, the 50-lb/yd^3 application rate of dry rock salt performs better than an equivalent application rate of brine. This is attributable to the lower moisture content of the stockpile in the salt tests compared with that in the brine treatment. Even at 45 percent moisture, the dry NaCl freezeproofed at all but 10°F. Applying 100 lb of rock salt per cubic yard freezeproofed all moisture contents at 10°F.

Summary curves relating the initial moisture content of the cinder stockpile and the resulting TDS at the final moisture content were prepared. Separate curves were prepared for each temperature; however, only the results at 18°F are shown in Figure 2 for sake of brevity.

A summary of the results of freezeproof testing for all five abrasives is given in Table 3 for 10°F. Included are observed stockpile in situ moisture contents for limestone, sand, and sawdust. The cinders had essentially zero moisture when collected directly from the hopper at the heating plant. Table 3 shows that four of the abrasives (bottom ash, cinders, sand, and sawdust) can be freezeproofed effectively by utilizing natural brine at temperatures down to 10°F. Application of brine for freezeproofing is limited in limestone because of its low saturation capacity of only 7 percent. As noted in Table 3, the maximum initial moisture content of limestone that could be freezeproofed by brine without runoff was only 3 percent. This value is below the in situ moisture contents actually obtained during limited stockpile sampling.

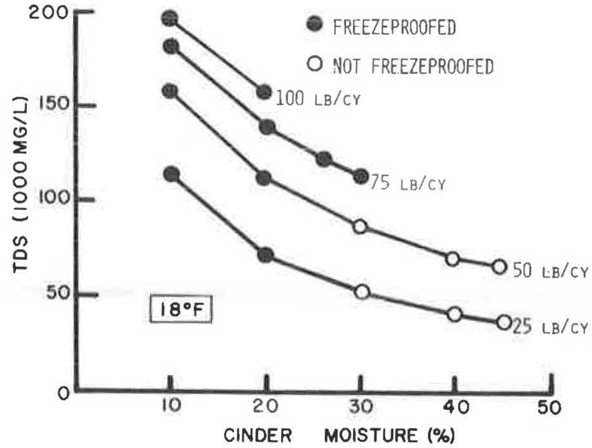

FIGURE 2 Initial moisture content of cinder stockpile versus total dissolved solids of final moisture content at 18°F.

Also shown in Table 3 are the brine application rates required (in pounds per cubic yard) and the weight of salt required per ton of abrasives (dry basis). Application rates required varied from 25 to 100 lb/yd^3, which is within expected ranges. For example, Landsness *(9)* reported the use of up to 75 lb/yd^3 of dry salt for freezeproofing sand in Wisconsin. Table 3 shows that the weight of salt per ton of abrasive varied from 22 lb/ton (limestone) to 119 lb/ton (cinders) except for sawdust, which required 290 lb/ton. The higher value for sawdust is to be expected because of its markedly different physical properties. Keyser *(10)* recommended the use of 50 to 100 lb of salt per ton of abrasive and hence the foregoing data (except for sawdust) are close to this range.

Brine Application and Economic Evaluation

Several different approaches for application and mixing of brine with the abrasives were considered. The freezeproofing procedure recommended here is one that has been used by the Pennsylvania Department of Transportation (PennDOT) in Clearfield County. Brine is sprayed on the stockpile, preferably as it is being formed. This is done by the oil or gas producer with a pump on the brine delivery truck. Small applications at several intervals are made so as to ensure that no runoff occurs. Supplemental applications may be required later as dictated by the frequency and intensity of precipitation. This method

TABLE 3 RESULTS OF FREEZEPROOF TESTING WITH BRINE AT 10°F

Abrasive	Saturation Moisture Content (%)	Stockpile in Situ Moisture (%)	Maximum Initial Moisture That Can Be Freezeproofed (%)	Brine Application Rate To Freezeproof at Maximum Moisture (lb/yd^3)	Final Moisture Content (%)	Weight of Salt Divided by Weight of Abrasive (Dry) (lb/ton)
Cinders	50	N.A.	30	75	50	119
Bottom ash	35	17–20	15	100	29.7	85
Limestone	7	3–7	3	25	7	22
Sand	24	8–20	10	50	17.3	43
Sawdust	250	72–102	100	50	150	290

requires no stockpile mixing, thus saving man hours and machine time, as compared with conventional methods of mixing dry salt with abrasives by using an endloader.

A cost estimate for freezeproofing a 900-ton pile of bottom ash at 100 lb/yd^3 was made by using both brine and dry salt. The estimate included costs for manpower and equipment following guidelines suggested by WVDOH maintenance personnel. The estimate assumes that a brine storage tank (steel) will be built at the maintenance station so as to have brine available at all times. It is assumed that the brine supplier will deliver the brine free of charge to the storage tank. If the highway agency pays for the storage tank, use of brine becomes the lower-cost alternative when dry salt costs reach \$35.60/ton. During the winter of 1985–1986, WVDOH paid an average of \$33/ton. On the other hand, discussions with oil and gas companies suggest that the companies would be willing to continue to furnish steel tanks at no cost to the highway agency, as was done during this pilot study. If this were the case, cost savings on the order of \$1,500 per year per stockpile could be realized.

BRINE AS A PREWETTING AGENT FOR SALT

Prewetting Effectiveness Tests

One of the research tasks was to develop test procedures to assess the feasibility of using natural brine as a prewetting agent. This assessment included effectiveness tests for both melting and bounce-off.

Common highway rock salt was utilized to compare the melting performance of dry rock salt (NaCl) to rock salt prewet with natural brine and with liquid calcium chloride. Performance was characterized by two criteria: (a) the volume of ice melted and (b) the average depth to which the salt penetrated into an ice block.

The rock salt used was obtained from stockpiles of the Sabraton Maintenance Station of the WVDOH. The natural brine used in the prewetting effectiveness tests was the same as that which had been used in the abrasive testing. For comparison purposes, a 32 percent calcium chloride solution (commonly used in practice) was prepared by dissolving solid calcium chloride in distilled water. The rock salt was prewet at the rate of 10 gal/ton of rock salt with either the brine or the calcium chloride just before application to the ice.

A layer of ice was frozen in 4.5-in. diameter metal test cans in the cold room (relative humidity of approximately 40 percent). Ten grams of rock salt were applied per ice sample and permitted to react with the ice for specified periods of time. Note that this application rate far exceeds traditional roadway application rates; the high application rate was chosen because preliminary testing indicated that traditional application rates produced insignificant quantities of meltwater. After each specified time period, the meltwater was decanted and collected in a graduated cylinder. Particles of salt were manually dislodged from the ice. A tire-tread depth gauge was used to measure the extent to which the rock salt had penetrated into the ice. Five separate depths were measured at random for each sample and averaged to yield depth of penetration. All tests were run in duplicate or triplicate at 18 and 8°F. Because time constraints did not permit running the experiment at all three temperatures, the two lower temperatures were chosen to provide a more severe test.

Another purported benefit of prewetted salt is that it reduces salt loss due to bounce-off. One task of the research effort was to develop a procedure for measuring the amount of bounce-off that could be used to compare dry rock salt with prewetted salt. The literature provided little guidance in the way of experimental procedures; only one published study *(11)* could be found dealing with the bounce and scatter characteristics of dry versus wet salt. The test reported was made during the summer using actual spreading equipment on an unopened section of Interstate highway. Project resource and time constraints precluded a similar approach in this case. A number of different field and laboratory procedures were tried. The procedure selected, because it demonstrated the best reproducibility, involved dropping salt from a specified height onto a bull's-eye marked on a concrete surface and measuring the fraction of salt in each ring.

Three forms of salt were used in the experiment: dry rock salt, rock salt mixed with a 32 percent calcium chloride solution, and rock salt mixed with brine solution. For the wetted salt, application rates of 8, 10, and 12 gal/ton were used. For all tests, a 10-g sample of rock salt was used. With a plastic spatula, the samples were pushed off a level surface from a height of approximately 36 in. onto a relatively smooth concrete floor. Five concentric circles drawn on the floor divided the drop zone into five ring-shaped areas, as shown in Figure 3.

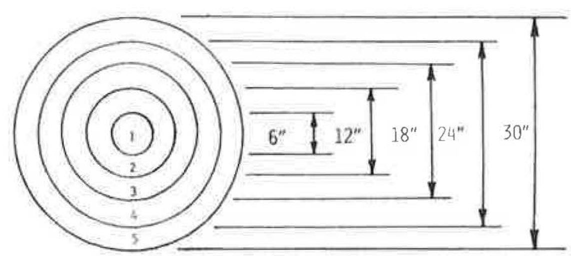

FIGURE 3 Arrangement of concentric circles used in salt bounce-off experiment.

The quality of salt accumulated in each of the five areas was collected and weighed. The fraction of the total sample in each area was determined. Five replications of the drop test were performed; the values presented in the following section represent the averages of the five tests.

Test Results

Results of the prewetting melting effectiveness tests are plotted in Figure 4. Data for the liquid calcium chloride are not plotted because they are similar to the natural brine results. The conclusions reached for the natural brine apply equally well to the liquid calcium chloride. At 18°F, in comparing dry rock salt with the two prewetted salts, the largest variation occurred at the 5-min duration. The difference between dry and wetted salt, in terms of volume of melt, decreased with time. As noted in Figure 4, the difference between the volume of melt produced by the dry rock salt and that produced by prewetted salt was less than 10 percent for durations of 10 min or more.

Although, as expected, melt volumes were lower at 8°F, the relationship between dry and prewetted salt was generally the

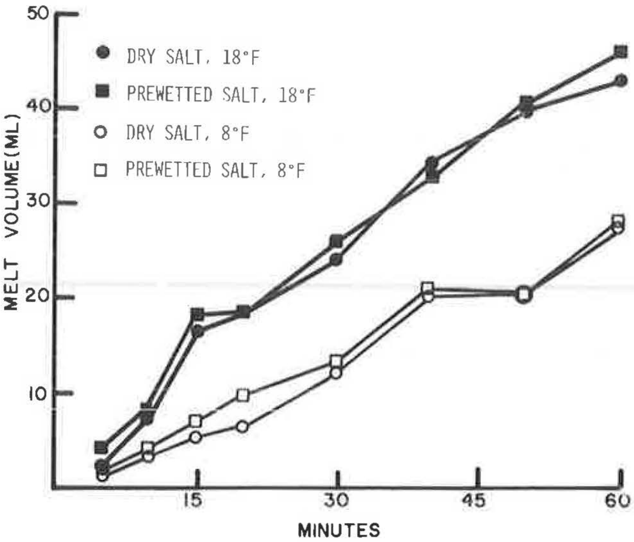

FIGURE 4 Volume of melt by brine-prewet and untreated rock salt as a function of time and temperature.

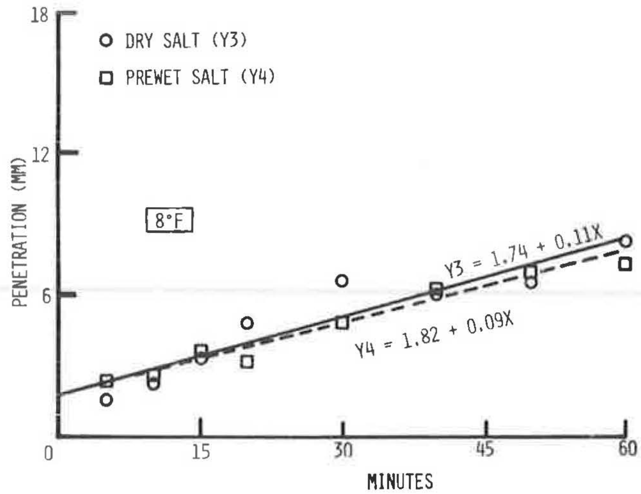

FIGURE 6 Penetration of prewet and untreated rock salt as a function of time at 8°F.

same as that at 18°F. The quantity of melt produced by the prewetted salt after 5 min was greater than that produced by dry rock salt. However, after 30 min, the amount of melt produced by the dry rock salt and the prewetted salt differed by less than 5 percent.

These results agree with what would be expected intuitively. The reason for prewetting is to initiate a melt rather than to melt more ice. Test results show that more prewetted salt went into solution than dry salt. After 5 min, however, more dry salt was available to go into solution. Theoretically, the same amount of melt should be produced by both the prewetted and dry salt. In practice, the results shown will vary with humidity and available free water on the ice or snowpack.

Plots of depth of penetration as a function of melting time are shown in Figures 5 and 6 for 18 and 8°F, respectively. At 18°F, the prewetted salt had a higher initial penetration and appeared to maintain a slightly higher rate of penetration as time went on. At 8°F, there was very little difference in rate of penetration between the dry salt and the prewetted salt.

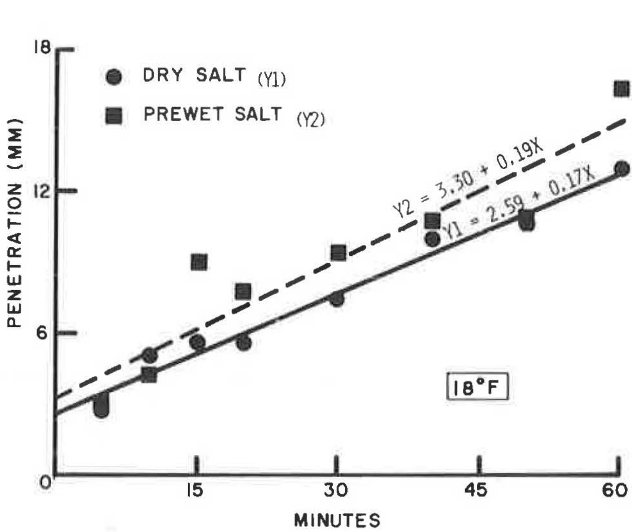

FIGURE 5 Penetration of prewet and untreated rock salt as a function of time at 18°F.

To provide a more thorough evaluation of the relationships among the four conditions examined, a least-squares regression line was fitted to each set of points. Regression lines for the dry salt and the prewetted salt at 18°F are shown in Figure 5. The general linear test for the equality of two regression lines was used (at the 95 percent level of confidence) to determine whether the regression lines for depth of penetration for dry salt and prewetted salt were the same.

Results of the general linear test for the 18°F data indicated that the linear regression functions for the two penetration lines were the same. No formal analysis was performed for the 8°F data because it could be seen that there was less difference between the dry salt and prewetted salt lines than there had been at 18°F. Thus it was concluded that there was no statistically significant difference for either the initial penetration or the rate of penetration between dry rock salt and prewetted rock salt.

Bounce-off test results are shown in Figure 7. It is apparent that the dry rock salt spread out more than the wetted salts. The percentage of dry salt in each area was more uniform than that for the wetted salts, which were concentrated near the drop point in Areas 1 and 2. Thus, it can be concluded that the wetted salts stayed closer to the point of contact than the dry salts. As the application rate for brine increased, bounce-off was reduced; results for calcium chloride were not conclusive. There was virtually no difference in bounce-off characteristics between salts mixed with brine and those mixed with calcium chloride at the 12 gal/ton application rate; there was some difference at the other application rates.

Application Procedures

The laboratory tests described earlier indicated that brines of the strength used in this procedure are feasible substitutes for

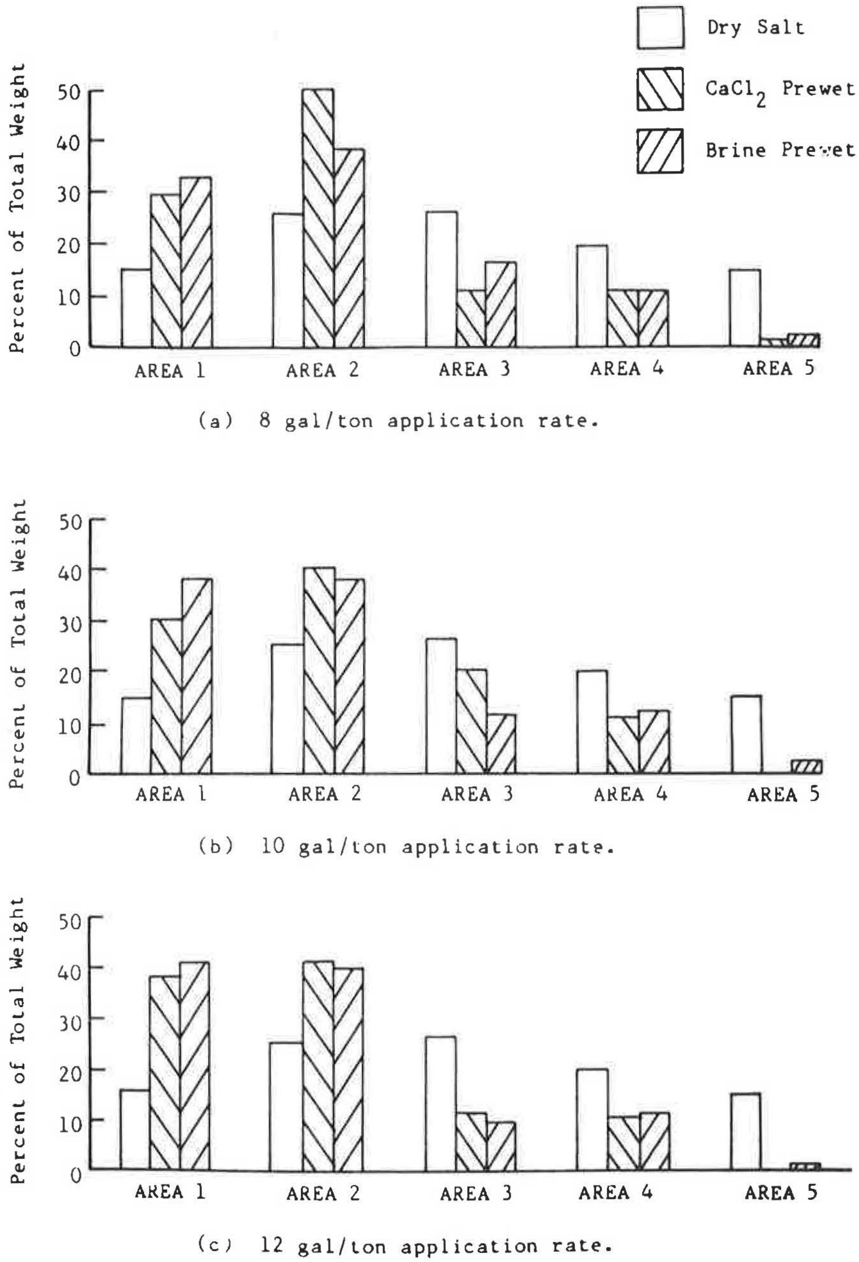

FIGURE 7 Results of salt bounce-off experiment.

liquid calcium chloride in prewetting applications. Given that an appropriate application rate can be established, it is necessary to determine procedures for prewetting the salt and applying it to the roadway. One research task examined the prewetting procedures available, assessed the technical and economic factors associated with each procedure, and recommended one that was believed to be the most appropriate for WVDOH use.

There are essentially three procedures for applying liquid chemicals to rock salt:

1. Applying the liquid to salt stockpiles, either during or after their formation;
2. Spraying the liquid on top of rock salt in the spreader truck before spreading; and
3. Using spreader-mounted equipment to spray the liquid on rock salt as it leaves the truck during the spreading operation.

Techniques are available for applying liquid before and during stockpile formation. The salt and the liquid can be mixed in a pugmill to obtain a uniformly wetted product. This material can then be formed directly into stockpiles. Alternatively, a spray bar can be mounted on a conveyor so that the liquid is sprayed onto the salt as the conveyor is loading it onto the stockpile. A system as simple as spraying brine on the untreated pile with an ordinary garden hose can also be used. However, to assure thorough distribution of the liquid, use of a special nozzle is recommended. The nozzle, consisting of about 5 ft of perforated piping, is inserted into the salt pile at 5-ft intervals as the brine is flowing to ensure that the salt pile is saturated. It is essential that wetted stockpiles be covered and stored on impervious asphalt or concrete floors.

With truckload wetting, the liquid is stored in a bulk tank. Rock salt is loaded into the spreader truck, which is then driven beneath a spray bar arrangement. Once the truck is properly located, the liquid is sprayed on the rock salt in the desired amount (either by an operator or automatically).

Spraying during the spreading operation also involves storing the liquid in a bulk tank. However, the spreader truck is equipped with a 50- to 60-gal liquid feed tank and an applicator system, which may include a pump and a spreader bar. As the rock salt is applied to the road surface, the liquid is metered to wet the salt simultaneously.

A cost estimate was prepared to determine the initial cost associated with installing a stockpile wetting system. It was estimated that an initial investment of just under $10,000 would be required to install a salt stockpile wetting system. The estimate includes a 6,000-gal fiberglass storage tank, a bituminous concrete pad, a centrifugal pump, and a length of rubber hose.

Systems for spraying brine on truckloads of salt can either be built by the highway agency or be purchased commercially. To provide a conservative estimate, costs were calculated for a commercially available automatic salt wetting system. Initial costs to install such a system, including concrete slab and utility pole, were estimated at slightly more than $17,000. Although the initial costs of this approach are substantially higher than those for stockpile prewetting, it must be remembered that, because the spray system is essentially automatic, there are no ongoing personnel costs (other than periodic routine maintenance).

Many of the early applications of wetted salt involved spraying the salt with calcium chloride as it moved through the spreader mechanism. Although truck-mounted spraying is best in terms of fully wetting the salt, the approach has a number of equipment-related limitations, for example, serious maintenance problems caused by the corrosive liquid. Because truck-mounted prewetting systems are no longer made commercially, all such systems would have to be homemade. It was estimated that installation of a truck-mounted spray would cost approximately $500 per truck (which includes supply tank, pump, valves, nozzles, and spray bar).

Although the truck-mounted system had the lowest initial cost (depending on the size of the fleet) of the three systems under consideration, it was not recommended for implementation because of the large number of maintenance and operational problems associated with it. Similarly, the stockpile-wetting approach, although having the second lowest cost, suffers from serious drawbacks, mainly the reliance on the human element to obtain a properly wetted product. If too much brine is applied, salt loss and environmental degradation can occur. The recommended system, because it is automated and provides thorough wetting, was the truck-spraying system.

CONCLUSIONS AND RECOMMENDATIONS

Salts are mixed with abrasive materials for either of two primary reasons, or for both: to freezeproof abrasive stockpiles to ensure a free-flowing supply and to enhance the performance of abrasives when applied to slippery road surfaces. The first goal is usually accomplished with significantly less salt than the second. By far the most frequent practice in achieving these goals is to mix dry sodium and calcium chloride with abrasive materials.

Use of liquid calcium chloride for both freezeproofing and highway applications has increased in recent years. Information on use of liquids for freezeproofing applications is limited at best. Though uses have been reported, almost no literature was available on application rates, storage practices, effectiveness, or potential problems associated with liquid use. It is known through personal communication and site visits with highway agencies that natural brine is being used for freezeproofing and highway applications. However, documented information relative to brine use is even more limited than that for liquid calcium chloride. Application rates, storage and handling practices, and other procedures appear to be empirically based, relying more on subjective judgment and trial and error than on an objective, rational approach.

Results of laboratory testing conducted to answer some of these questions indicated that natural brine could be used to freezeproof four of the abrasives studied (bottom ash, cinders, sand, and sawdust) effectively over a wide range of initial moisture contents and at temperatures as low as 10°F. Overall, few trends or generalizations could be drawn between the various abrasives. Each brine-abrasive combination must be considered as an individual case when freezeproofing application rates are developed.

For limestone, application of brine for freezeproofing is limited by the physical properties of the aggregate. Only limestone containing less than or equal to 3 percent initial moisture could be freezeproofed. Thus, freezeproofing of limestone stockpiles should be accomplished with conventional solid-form chemicals.

It was concluded that spraying brine on the abrasive materials as a stockpile is being formed, followed by supplemental applications dictated by the frequency and intensity of precipitation, would be the optimum procedure for freezeproofing stockpiles. The procedure has the advantage that there is no mixing of the stockpile, with resultant savings in manpower and equipment costs, in addition to reductions in the amount of dry sodium chloride needed.

A number of approaches are available for storing and applying brine for freezeproofing. The most economical method would be to have the oil or gas producer periodically spray the stockpile by using a pump on the brine delivery truck. Although this approach involves no costs to the highway agency, it can present problems if the supplier cannot provide brine on demand, as might be the case during the winter months. The investigators concluded that the highway agency should have brine storage tanks at its maintenance stations to assure a brine supply when local producers may not be able to provide the liquid. It is quite likely that the brine supplier would be willing to supply both the storage tanks and the brine at no cost to the highway agency.

Laboratory tests were conducted to evaluate the use of brine as a prewetting agent for rock salt. Examination of the melting effectiveness of prewetted versus dry salt indicated that prewetted salt initiated slightly more rapid melting compared with dry salt. However, the differences were not statistically significant. There appeared to be no advantage to using liquid calcium chloride over natural brine. Salts wetted with each agent performed almost identically in the melting and penetration tests.

On the basis of a laboratory bounce-off test, it was concluded that wetted salts stay closer to the point of contact than dry salts. As the liquid application rate increases, there is a small but not significant reduction in bounce-off. An automated system involving spraying the loaded truck appears to be the most appropriate procedure for prewetting the salt.

Before large-scale implementation of a brine freezeproofing program is undertaken a trial program is recommended for one winter at several different maintenance locations. Data could be collected on relevant conditions such as stockpile size, moisture content, temperature variation, and daily precipitation. Natural brine could be applied at the rates recommended in this paper. The timing and quantity of brine application would be monitored and compared with stockpile performance (in terms of being in a workable or frozen state) to provide field verification of the laboratory findings. Detailed records should be kept of all costs involved to provide a true accounting of the benefits of freezeproofing with brine. Assuming that the findings would be verified, it would be a relatively straightforward matter to proceed to large-scale use of brine for freezeproofing.

A laboratory study indicated that wetted salt reduced bounce-off. However, actual field trials are needed to verify the savings due to prewetting. One maintenance headquarters could be selected as a test site and a truck spraying system installed. Thus, in addition to providing an opportunity to determine the reduction in bounce-off, the study would permit a field evaluation to be made of the technical and economic benefits and costs associated with truck spray systems in particular and prewetted salt in general.

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DISCUSSION

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After reading the paper by Eck et al., I wish to call attention to several important considerations overlooked when adding brine to deicing salts.

The distinction between natural brine and oil and gas well brine needs to be made because these two types of brine are referred to interchangeably in this paper. Oil and gas well brines, which are produced inadvertently during the production of oil and gas and are the type of brine incorporated in this paper, usually contain aromatic hydrocarbons. It is because of these hydrocarbons that the state of Michigan regulates usage of this material in deicing and dust control applications.

Michigan's consent order dated January 2, 1987, requires users to submit monthly reporting records of approved oil and gas brines and to analyze for 25 inorganic chemicals as well as five organic constituents. Testing of these compounds is to be at the well separator (when physically possible), storage tank, and spreader bar on the vehicle.

Natural brines are not associated with oil and gas wells but can be found at shallow depth under the state of Michigan. The distinction between these two brines needs to be addressed in this paper.

Eck et al. also state that one method of using oil and gas well brines is to apply them to salt stockpiles either during or after their formation. However, no suggested application rate for this approach was provided, although 8, 10, and 12 gal/ton were used in the bounce-off and scatter tests and 10 gal/ton of salt was used in the melting test.

Present application rates for both salt stockpiles and salt prewetting have been established either by research or by 20 years of field use in truck salt prewetting. The normal truck salt-prewetting rate is 10 to 12 gal of 32 percent $CaCl_2$ per ton of salt and the stockpile-wetting rate is 8 gal of 42 percent $CaCl_2$ per ton of salt.

Stockpile wetting requires a high percentage of brine concentration, such as 42 percent $CaCl_2$, to prevent liquid migration through the salt pile. At brine concentrations less than 42 percent, liquid did migrate through the salt when researched under normal expected winter use. Based on our research data, we would therefore expect the brine concentration of 26.57 percent used by Eck et al. to migrate in a substantial quantity out of the salt pile.

In conclusion, if oil and gas well brines are used, they must be used only with strict care to protect the environment from hydrocarbons normally associated with this material. The environment also needs to be protected against stockpile runoff, which likely would be expected from such dilute oil- and gas-based brines.

AUTHORS' CLOSURE

We greatly appreciate the thoughtful and constructive remarks offered by Kirchner on our paper. We agree with his comments relative to the distinction between natural brine and oil and gas well brine. Certainly both brines are "natural" as opposed to being manufactured, but as Kirchner notes, oil and gas well brines usually contain aromatic hydrocarbons, which are not found in natural brines of the type he describes. We are aware of the environmental problems associated with the hydrocarbons. To date, an admittedly limited amount of testing on West Virginia gas brines shows hydrocarbon levels well below those reported from Michigan oil wells.

Kirchner is correct in noting that we did not suggest any application rates for salt stockpile prewetting. This was because, for a number of reasons, we recommended a system whereby truckloads of salt would be sprayed lightly with brine before the vehicle proceeded onto the roadway. We recognize that oil and gas well brine is more dilute than liquid calcium chloride and believe that a properly managed truck spraying system would avoid the problem of stockpile runoff. Our concern over the runoff problem is the dominant theme in the first part of the paper, which deals with brine application rates for freezeproofing abrasive stockpiles. Unfortunately, we have not conducted a laboratory experimentation program for salt stockpile prewetting analogous to the abrasive stockpile freezeproof testing. Therefore, we cannot say how much brine can safely be applied without runoff. Such a laboratory testing program would be an appropriate follow-on study to the work under discussion here.

The contents of this paper reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the state or of FHWA. These materials do not constitute a standard, specification, or regulation.

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