Part IV: Optimization of Pretreatment or Anti-Icing Protocol

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Principal Investigator: Gayle Mitchell

ODOT Contacts:
  Technical: Keith Swearingen
  Diana Evans
  Administrative: Monique R. Evans, P.E.
  Administrator, R & D
  614-728-6048

Ohio Department of Transportation
1980 West Broad Street
Columbus OH 43223

Problem
Providing safety on roadways during inclement winter conditions is a challenge for state highway agencies. Preventive/proactive measures such as pretreatment/anti-icing in conjunction with field detection and weather forecasting systems are gaining more emphasis. ODOT promulgated a draft Snow and Ice Pretreatment Plan in January 2003 that was used statewide beginning that winter season. The Plan specifies two pretreatment applications per week based on six warranting conditions. This plan needed further validation and potential adjustment depending on research findings.

Objectives
The objectives are as follows:
1. Review and summarize ODOT’s 2002-2003 winter snow/ice pretreatment experience for useful strategic information and conduct additional assessments of winters 2003-04 and 2004-05 pretreatment experiences
2. Expand and update the Phase III survey of other state DOTs and report on the best practices and effectiveness and efficiency of pretreatment protocols
3. Conduct a literature review of anti-icing practices and effectiveness and available instrumentation for measuring brine residual and summarize findings
4. Investigate the losses of sodium chloride mass on laboratory test specimens with respect to surface porosity and roughness
5. Validate the findings from Phase III
6. Document field conditions and effectiveness of brine (NaCl) pretreatment application on asphalt and concrete pavements
7. Correlate rate of depletion of salt with traffic, time and weather conditions.
8. During field tests collect and include available RWIS information for subsequent use in predictive modeling.
9. Review and investigate weather forecasting models such as the MDSS for potential comparison to findings from the anti-icing tests.

10. Incorporate real-time friction tests at pre-treated and non-treated sections of pavements during winter weather events to determine anti-icing effectiveness with increased friction.

11. Prepare an anti-icing Decision Tree or Expert System to aid in operational planning that includes current and predicted weather and traffic conditions.

### Description

To address the objectives four methods were utilized: 1) surveys of personnel at state departments of transportation (DOTs) and ODOT county garages, 2) field studies of the durability of brine on PCC and AC pavements, 3) inspections of pretreatments during winter weather events, and 4) laboratory tests on PCC and AC cores. Each of these is discussed.

#### Surveys of Transportation Personnel Relative to Pretreatment

A survey was developed and sent to the 50 state DOTs; it covered topics related to frequency of pretreatment, protocols, chemicals, and perceptions of effectiveness. The survey yielded 16 responses with 15 state DOTs indicating they pretreated. A 25-question survey was developed with ODOT input and sent to ODOT county managers following Winter 2003-2004. The survey was repeated the next year with eight additional questions added. In both years, 69 of 88 counties responded, though the distribution the second year was weighted more towards northern counties.

#### Field Durability Studies of Pretreatment

**Durability on PCC (ATH 50)**

Durability experiments were conducted September 14-16, 2004, on the eastbound driving lane of US50 in Athens County, a transversely grooved PCC pavement. Traffic was closed initially on three sections with nominal brine application rates of 20, 40, and 80 gallons per lane mile (gplm) (47, 94, and 188 liters per lane kilometer (lplkm)), and four sections with application rates of 40, 20, 40 and 80 gplm (94, 47, 94, and 188 lplkm) received prompt traffic. Brine was applied using applicator T-6-801, which had been calibrated by the researchers. Traffic data were obtained from a portable counter-classifier temporarily installed by ODOT.

Measurements of salt residue were made with two modified Boschung SOBO-20s along marked diagonals across the pavement as time and traffic accumulated. Also, measurements were made initially on the ten brine lines.

**Durability on AC (PIC 23)**

On October 4, 2005, in the northbound driving lane of US23 in Pickaway County, between mileposts 11 and 12, brine was applied on the AC pavement using calibrated distributor T-6-801 in two cycles of four application rates each. Traffic data were obtained from a portable counter-classifier temporarily installed by ODOT.

Each cycle comprised four applications of brine, with nominal brine application rates of 20, 40, and 80 gplm (47, 94, and 188 lplkm) at 36 mph (58 km/h) followed by a second application at 40 gplm (94 lplkm) at 24 mph (39 km/h) in each cycle. The application of 40 gplm (94 lplkm) at two different speeds was intended to assess the effect of truck slipstream on the distribution of salt. The first cycle was protected from traffic until the brine was dry. Measurement of salt residue were made with modified SOBO-20s along diagonals and on brine trails in each section after zero, 23.5 and 46 hours of exposure to air. The second cycle was open to traffic as brine was applied and measurements were made after 1.5, 23.5 and 47.5 hours.

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**Inspections of Pretreatments during Winter Weather Events**

Weather event observations of the effects of specific brine pretreatment application rates covered three winters beginning February 2004 and ending March 2006. The test site comprised all four lanes of PIC-23 between approximately milepost 11 and 16. The observations were designed to discriminate among the treatments and provide input for recommendations to ODOT on pretreatment protocol.

Brine was applied in one mile increments at rates of 40, 80, 20, and zero gplm (94, 188, 47, and 0 lplkm) and speed of 45 mph (72 km/h). In the winters of 2004-5 and 2005-6 a fifth section was inserted before the zero gplm (0 lplkm) section with 40 gplm (94 lplkm) applied at 24 mph (39 km/h). The other three applications were applied at 36 mph (58 km/h).

The procedure for each event began with the initial pretreatment. A researcher would ride in the applicator truck. After allowing the brine pretreatment to dry, the researcher would inspect the state of the pretreated road. When the anticipated winter weather was imminent, researchers drove to the test site and conducted further inspections of the road as the weather event progressed until the event ended or the test road was salted by ODOT.

Forms were developed to record the pretreatment and inspection observations, which included temperature and humidity readings, visual determinations of the number of brine lines, amount of traffic, weather, and condition of the road. These inspection records were augmented with ODOT RWIS data (2004-2006), ODOT road grip tester (RGT) data (2003-2004 and 2005-2006), video recordings (2004-2006), and estimates of the traffic counts since pretreatment based on ODOT Technical Services data (2003-2006). The field observers also wrote narrative reports of each weather
event. Data were obtained on 17 pretreatments and 10 subsequent storm events, recording over 50 inspections during the three winter seasons.

Laboratory tests on PCC and AC cores
Measurement of salt residue on core samples of grooved and smooth PCC pavement were made with a modified SOBO-20 and by soaking off the residue and weighing the salt. A correction factor for under reading by the SOBOs on grooved cores was estimated.

Ten cores from AC roads around Ohio, including PIC-23, were obtained and characterized by various methods including roughness, permeability, and fluid intake. Controlled amounts of standard brine were applied to the cores and salt residue was measured with the SOBOs. Pretreated core samples were subjected to low temperature and then their behavior observed when water was sprayed on. Cross-correlations were made in an effort to determine which asphalt properties might have an impact on brine pretreatment efficacy.

Results and Conclusions
Surveys of Transportation Personnel Relative to Pretreatment
Of the 15 responding state DOTs that pretreated, five pretreated prior to an event, three noted a frequency of twice a week, two had variable frequencies, and five did not answer the question. About half had a pretreatment protocol. Ten states used salt brine as their primary chemical with application rates ranging from 15 to 90 gplm (35 to 212 lplkm); one state used salt brine mixed with liquid corn salt, and four western states used magnesium chloride. Nearly half of respondents considered pretreatment very successful, while 40% responded moderately successful; 86% considered pretreatment successful in passively intervening at the onset of an event. Pretreatment was rated as very effective by 66% against frost formation, 53% against ice formation, 13% against snow accumulation, 47% for faster clean up, and 33% for pavement drying up faster. When asked how long pretreatment held off hazardous road conditions, responses ranged from 1 to 4 hours without a clear consensus. Bridge decks were generally considered to yield the best results for pretreatment. Nearly half thought there was an economic benefit for pretreatment but no numerical data were provided. Benefits cited were reduced personnel hours, less total salt used, and reduced accidents.

Regarding the surveys of Ohio counties in 2003-2004 and 2004-2005, slightly over half of the 69 responding counties were applying brine in the range of 40-49 gplm (94-115 lplkm) in both seasons, with a slight increase in the average application rate between the two surveys. For 2004-2005 half of the respondents indicated they verify the application rate by dividing brine consumed by miles driven, while another 18% said they calibrated the equipment but did not specify the method; this contrasts with only about a total of one half of respondents using any verification in the previous year. More respondents rated pretreatment as “highly effective” at higher temperature ranges. Regarding the effectiveness of pretreatment against frost, ice, snow accumulation, and clean up, 2003-2004 responses for “very effective” were 49%, 27%, 16%, and 38% respectively; these values changed in 2004-2005 to 70%, 34%, 13%, and 36% respectively. About 60% for both years said pretreatment held off hazardous road conditions for about 0.75 to 1.5 hours. Counties indicated a strong desire to keep the decision to pretreat at the local level, and indicated a general satisfaction with the program.

Field Durability Studies of Pretreatment
Durability on PCC (ATH 50) Initial salt measurements were about a third less than expected because the measuring instruments under read due to the presence of grooves in the pavement. After exposure to about 48 hours of weather and nearly 7800 vehicles the adjusted mean brine measurements in most sections declined to under 3 g/m² (0.0098 oz/ft²) except for the nominal 80 gplm (188 lplkm) application which stayed above 10 g/m² (0.0328 oz/ft²). Data obtained for a 40 gplm (94 lplkm) application for this same section of road in 2002 were compared to the 2004 data and there was generally good agreement. The decay in areal salt densities seemed to be reasonably represented by an exponential function.

Durability on AC (PIC 23) Salt applied as brine was satisfactorily accounted for in the first set of diagonal measurements. The decay of the salt with exposure generally conformed to the 1:2:4 ratios of the application rates except for the 40 gplm (94 lplkm) slow application in the second cycle, which displayed almost the same high residue over time as the 80 gplm (188 lplkm) application. This suggests that the slipstream effect is far from negligible. Durability curves were developed using mean areal salt densities obtained from brine line and diagonal data as a function of time and traffic. An exponential function was used to model the decay.

Inspections of Pretreatments during Winter Weather Events
Despite the inclusion of three winter seasons, in the end the data from this part of the study were not sufficient to provide significant information for advising ODOT on pretreatment protocol. The weather was generally mild. Only one event, December 19, 2004, provided any discrimination among the test sections when the untreated section appeared to have ice while the pretreated sections gave some traction. No RGT was available for that event, and friction was qualitatively evaluated by...
braking the research vehicle. Visual evaluation of the brine lines during snowfall proved difficult, as even a moderate amount of snow would hide the brine lines. For this reason, the video record of the December 19, 2004 event did not show clear differences among the test sections. Snow was the only type of weather observed after pretreatment in the three winters.

RGT data were intended to provide an objective indicator of differences among the test sections. In Winter 2003-2004, the prototype RGT truck provided data whose utility was limited by the design of the device, which was still under development. In Winter 2005-2006 the refined RGT was used, which recorded averaged data at ten-second intervals, thus resulting in 5-7 readings per one-mile (1.6 km) test section. Friction data recorded during the events did not show any significant differences among any of the test sections.

Laboratory Studies
A correction factor for the depressed SOBO readings on grooved concrete was determined. Laboratory results for AC cores indicated that an increase in application rate is needed to compensate for aged and/or distressed pavement. An attempt was made to develop a relationship between fluid intake, permeability, or roughness and applied salt areal density, but the results were not clear enough to provide definitive guidance.

Recommendations
Durability
Based on this study and using mean diagonal areal salt density measurements, the exponential fit for salt residue on the PCC had an exponential decay lifetime of about 48 hours, while that for salt residue on AC had a lifetime of about 18 hours. Using a safety factor of 25% of the initial standard application rate of 40 gplm (94 lplkm), the minimum average amount of salt present on the road, as measured by diagonal readings, would be 1.78 g/m² (0.0058 oz/ft²). On the PCC pavement studied this threshold would be reached at about 66 hours, while on the tested AC pavement this would be reached in 25 hours. Thus, based on this study, it is best to pretreat within a day of the anticipated weather event. If it is not possible to pretreat this close to the event, for instance because the event is forecast to occur late in a weekend, then a higher application rate can be expected to increase the salt residue proportionately.

Scheduling and Decisions to Pretreat
Based on the surveys, there appears to be a need to inform county personnel of the forecasting resources available for planning snow and ice operations. RWIS data, both current and archived, needs to be more readily available to winter maintenance decision makers throughout ODOT. Also, ODOT’s RWIS data needs to be integrated into a Maintenance Decision Support System (MDSS) to leverage the investment in RWIS equipment.

For this study Nowcast calls from the radio room to PIC were almost too late to be of use. Of much greater value were a number of weather web sites featuring near-real-time Doppler radar displays on the computer and radar weather stations on cable TV. Local ODOT personnel may not require as much lead time on weather warnings as the research team did, but a review may be warranted.

It would aid in pretreatment decisions if the daily weather forecast contractor would provide probabilities of frost in addition to snow and sleet forecasts.

A decision tree outlining the steps in deciding to pretreat and amount to apply was formulated with a 32 hour horizon, designed to cover a full 24 hour day plus an 8 hour work shift. It is recommended that winter maintenance decision makers use the tree once a day when a forecast comes in. They also need to be constantly aware of weather conditions and adjust activities accordingly.

Technical and Administrative
County garages should be encouraged to check calibration of each applicator yearly and after major adjustments or replacement of components. The settings and relationships described in the report for truck T-6-801 may not apply to other vehicles.

Evaluation of the effect of slipstream showed that at high speed considerable brine never reaches the traveled lane and the strength (salt density) of the brine trails is significantly reduced when compared with very low speed application. Equipment and/or methodologies should be evaluated for their ability to conserve material by defeating/mitigating the slipstream effect.

Implementation Potential
The decision tree can be disseminated to county garage personnel along with instructions for its use. In addition some of the practical recommendations outlined above could be implemented.

Ongoing training to encourage the use of RWIS data and refinement of pretreatment applications are needed for the state to fully realize the benefits of its investment in RWIS and pretreatment equipment.