Evaluating RWIS and Brine Pretreatment for Snow and Ice Removal

State takes a look at road weather information systems.

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The Office of Maintenance of the Ohio Department of Transportation (ODOT) seeks to be "second to none in snow and ice control," and to realize this goal they are instituting the full implementation of anti-icing practices across the state. The effort has included the installation of a comprehensive Road Weather Information Systems (RWIS) network and the adoption of brine pretreatment as a preventive measure by county garages.

RWIS are essentially weather stations located adjacent to the road at selected locations. They report the usual weather data such as temperature, air pressure, precipitation amount and type, etc., but they also report conditions on the pavement surface, including temperature (sometimes also a few inches underneath the surface as well), the presence of deicing chemicals, and the road status (wet, damp, or dry). Most of Ohio's recently installed pavement sensors are made by Nu-Metrics (Quixote Transportation Technologies, Inc., www.qttinc.com) and these also report specific traffic data, including average speed and traffic counts. All weather data are reported and recorded every five minutes on a central server, and every 15 minutes during the winter driving season updates are posted at ODOT's Buckeye Traffic website (www.buckeyetraffic.org/rwis/nosvg/). The practically up-to-the minute data are critical to anti-icing practice and help maintenance providers time the application of the correct type and amount of anti-icing chemicals to best mitigate the effects of incoming weather.

The key anti-icing practice is brine pretreatment. By applying the correct amount of salt brine or an alternative before the storm, the salt residue will prevent the snow or ice from forming a bond with the pavement. This gives maintenance crews some extra time, estimated at one to two hours, to fight the storm and generally makes cleanup and plowing easier. Additionally, the brine pretreatment can be applied during regular work hours, thus helping to reduce overtime costs, both at the time of application and by reduced work effort needed to keep the roads clear when the storm comes. For a sufficiently mild event, the pretreatment itself may be sufficient to keep the roads drivable.

Ohio Department of Transportation snowplow in action.

To help direct the RWIS expansion and determine the most effective anti-icing practices, ODOT has sponsored some significant research studies looking into RWIS and brine pretreatment. A research project entitled "Evaluation of ODOT Roadway/Weather Sensor Systems for Snow & Ice Removal Operations" included five different sections; the final reports and executive summaries are available on ODOT's Office of Research and Development website under Topic 2 at www.dot.state.oh.us/research/Maintenance.htm. The last parts of the project were completed in November 2006. An additional study examined the effectiveness of RWIS bridge temperature simulators, and is scheduled for completion in April 2007. These projects and the research results are summarized below.

Part 1: RWIS. The primary objectives of this phase were to assess the current state of practice and determine what weather information should be collected by RWIS sensors for ODOT to make operational decisions. Specific tasks included determining whether or not current pavement and weather sensors could be used more effectively together, and the conditions under which ODOT should install more of these integrated sensor systems based on benefit-cost analyses.

The recommendations for a statewide expansion of Ohio's RWIS network were made based on an extensive literature review, product review, lifetime cumulative cost comparison, survey of RWIS users and administrators, and site visits. Factors used to determine optimal RWIS station deployment included distance between existing RWIS stations in Ohio and surrounding states, declared snow days, and annual snowfall amounts in Ohio. Also recommended was the use of File Transfer Protocol (FTP) to work around proprietary system constraints, and placement of data from all vendors into a common database format. Although cost savings and benefits attributed to RWIS and anti-icing in the literature vary widely, there is a consensus that these systems do repay their costs in reduced maintenance expenditures and accident rates.

At a minimum, in addition to the RWIS stations already deployed in the Toledo, Columbus, and Cleveland areas, placement of 14 RWIS stations around the state was shown to be sufficient to meet basic statewide weather prediction and monitoring requirements. ODOT deployed considerably more RWIS stations to achieve a denser coverage encompassing all 88 counties in the state; as of July 2006 there were 169 sites installed, with more sites installed in the northern part of the state, particularly in the northeast between Cleveland and Ashtabula where the lake effect snow tends to be heaviest.

The researchers recommended that exact sites should be chosen by district managers or personnel in consultation with meteorology and RWIS experts to give the district personnel an additional incentive to use the RWIS. Installations at locations with typical rather than extreme weather conditions were recommended plus each county garage should be equipped with a small weather station and a simple pavement sensor near the station for the purpose of creating a weather conscious culture at the county garage level. The researchers stressed that the benefits of the RWIS network will be realized only if anti-icing methods are diligently applied using RWIS information. Performance measures for winter operations should be built into the maintenance system. The researchers also argued that having four pavement sensors, one in each lane of a four-lane highway, would provide statistically reliable results.

PART 2: RWIS PAVEMENT SENSOR BENCH TEST. At the time of the Part 1 study, reliable unbiased comparisons between pavement sensors were unavailable, and this bench test was proposed as a means for determining which manufacturer's pavement sensors were most likely to provide accurate and reliable data best suited to Ohio's needs. RWIS pavement sensors from three vendors, who participated with the condition that they not be identified by brand name in the report, were evaluated under controlled conditions in a room-size climate chamber. One vendor supplied an active (cooling/heating cycle) sensor with an active-passive sensor as a combined system, and the other two supplied passive sensors. Each sensor was installed in a concrete block cut from a bridge deck and positioned in the chamber. The sensors were tested for accuracy and precision of temperature, freezing point determination, chemical percentage or index, surface status, and liquid depth, where appropriate.

Results obtained for the three sensors varied considerably. Because of these results, none of the sensors in their current state was recommended for use at the present time.

Before the project began, ODOT had RWIS stations manufactured by SSI, Inc. (Quixote Transportation Technologies, Inc., www.qttinc.com) installed in the Cleveland, Columbus, and greater Toledo areas. After the completion of these first two parts of the project, ODOT decided to expand the network statewide using weather stations made by Vaisala (www.vaisala.com) and pavement sensors made by Nu-Metrics. Stations in the southern parts of the state, which generally have milder winter weather, did not have pavement sensors, but instead were equipped with bridge deck simulators (BDS), a 6-in. cube with an embedded temperature probe mounted on the weather station pole. The concrete block was designed to mimic the

A typical RWIS station tower located in the median of I275 near Cincinnati (top). Bottom, close-up of a bridge deck simulator.

Top, application of brine pretreatment on road via a drip bar with ten outlets at the end of the truck. Bottom, Ohio Department of Transportation brine application truck.

effects of winter weather on an exposed bridge deck and give an idea of when bridges in the area were likely to experience freezing conditions.

The next two parts of the RWIS project examined the most effective methods for brine pretreatment. Pretreatment in ODOT typically consists of an application of 40 gal per lane mile (gplm) of 23 percent by weight salt brine in ten streams on a road. The standard policy was to apply the brine twice per week when conditions warranted, i.e., when the weather was not too warm, too cold, or too wet. In colder conditions, a 30 percent solution of calcium chloride could be applied, and some counties may use other anti-icing materials, such as Ice Ban® (Chemical Solutions, Inc., www.meltsnow.com) under specific situations, such as at bridges.

Part 3: Optimization of Salt Brine Pre-Treatment Application Rates and Frequency. The objectives of this phase included a survey of other state DOT's pretreatment protocols, laboratory studies to discern brine concentrations that precluded ice formation, decay of salt residue from brine on the road surface with traffic and time, and correlation of laboratory and field data.

In the laboratory, release temperatures of the ice/surface bond at various brine concentrations were obtained utilizing conductivity and physical observation techniques. Laboratory tests with the field brine measurement instrumentation (a SOBO-20 by Boschung Mechatronic AG) provided correction factors for the field data on asphalt cement (AC) and portland concrete cement (PCC) pavements.

Brine was applied at the standard rate of 40 gplm and the salt residue measured in-situ in mass per area at five field sites encompassing at least four sections at each site. Initial losses and decay due to time and traffic were obtained. Of the five test sites, AC (micro seal), AC (NovaChip®, a paving process that places a thin, coarse aggregate hot mix over a special asphalt membrane), and a transversely grooved PCC pavement provided statistically valid data to develop residual decay equations as a function of time and traffic. Field decay of brine was incorporated into laboratory brine/ice/specimen bonding temperature findings to determine the effective ice prevention temperatures as a function of time and traffic for AC and PCC at standard application rates. The field and laboratory findings were integrated into a series of graphs for use in predicting the efficacy of brine pretreatment in terms of the expected moisture depth deposited on the roadway and the temperature for the three types of pavement.

Part 4: Optimization of Pretreatment or Anti-Icing Protocol. This phase addressed pretreatment protocol for winter maintenance of roadways using brine, further expanding on the work of Part 3. A survey of other state DOTs looked for pretreatment best practices used around the country. Surveys of all 88 of Ohio's county garages were made over two years to determine the extent to which pretreatment and other anti-icing practices were being implemented.

Field durability studies of applica-

ORITE research personnel reading road salt residue levels using a modified Boschung SOBO-20. The white lines in the traffic lane are where the streams of brine were deposited.

tions of brine at 20 gplm, 40 gplm, and 80 gplm were conducted on PCC and AC pavements in Ohio to verify the results from Part 3 and to examine the effect of application amount on durability. Over three winter seasons, pretreatments, weather events, and resulting pavement conditions were documented on a series of test sections of AC pavement on US 23 near Circleville subject to different application rates. The documentation included visual inspection of the road condition, videotaping, and during the last season some use of the road grip tester (RGT) developed for ODOT by Halliday Technologies.

In addition, extensive laboratory studies were undertaken to supplement the field investigations. Integration of all the findings resulted in a decision tree to aid in operational planning and pretreatment.

Part 5: Vehicular Speed Associated with Winter Pavement Conditions. The major objective of this phase was to develop a procedure to determine the level of service (road condition) as a function of the average traffic speed as measured by the RWIS pavement sensors. Average traffic speeds for five-minute intervals are measured by the Nu-Metrics pavement sensors. In this part of the study, these speed data were related to the pavement and driving conditions observed at two selected sites in Northern Ohio during major winter storms in 2004 and 2005. In addition speed data from two other studies were analyzed. The pavement conditions were determined by surveying motorists at rest area buildings near the RWIS station where the speed data were being collected. Visual and photographic inspections of the road condition were also conducted. It was found that the average traffic speeds were significantly lower during a major snow event even when periodic plowing and salting were conducted. The average speeds decreased almost linearly for the period of the snow storm, reached a minimum, and then climbed back slowly towards normal speeds. These average speeds appeared to be a fairly sensitive measure for judging the condition of the pavement. The motorists' judgments about the pavement condition and driving safety during a winter storm are mirrored in the speed decrease. It appears from the survey that about two-thirds of the motorists judged the deterioration of the road conditions and the inadequate level of road maintenance during these winter storms as bad or moderately bad, which may in part be a function of the particular severity of the storms that were being monitored. The responses obtained for the car and the truck drivers were fairly close to each other indicating that both groups can judge bad road conditions equally well. The observed road conditions appeared to influence the drivers in terms of how they reported the subjective level of safety and stress they experienced when driving in the winter storm.

Top, an RWIS pavement sensor is installed in a cut slab of bridge deck for the bench test. At the upper left is an independent temperature probe. At the upper right and bottom center are thermistors attached to the block for additional independent temperature readings. At lower right is a Styrofoam block supporting another thermistor registering air temperature readings. The large circle was drawn around the sensor with silicone to confine the applied liquids. Not shown are the leveling screws mounted to the bottom of the block. Bottom, view of the entire experiment in the ORITE climate chamber with pavement sensors from three vendors installed in four blocks. The block shown in the top photograph is at the left front. The tripod holds a RoadWatch thermometer.

A simple procedure was developed for winter maintenance management to determine the condition of the road based on the average speeds observed by the RWIS sensors. If the average winter speed of the traffic is equal to or greater than the historical established wet/salted pavement speed, the level of service is considered adequate. It should be noted that the winter pavement conditions can be highly dynamic. Depending on the rate of accumulation of snow, frequency of the snow plowing, and length of the snow plow route, the pavement condition can improve and deteriorate a number of times during a winter storm. Thus the level of service can get worse, even with maximum snow plowing and salting efforts in a situation with a high rate of snow accumulation. The winter speeds observed as a percentage of the wet/salted surface speed can be correlated with the level of service. A relatively finer graduation of the level of service as a function of the percentage of the average wet/salted speed is proposed in the recommendations of the report. Level of service determination using dry surface speeds is also outlined in the recommendations of the report.

Effectiveness of Simulators

During Winter 2004-2005, a correlation study was undertaken of BDS, air, bridge, and road temperatures at nine RWIS sites across Ohio. The sites were selected by ODOT and were equipped with a full RWIS station including pavement sensors in the roadway and in the bridge, and a BDS (one site had only one pavement sensor in the bridge and no roadway pavement sensors). A brief survey of county garages indicated that BDS temperatures specifically and RWIS data in general were not highly regarded or being widely used by county maintenance personnel.

The bridge and road temperatures reported by the pavement sensors were correlated to air and BDS temperatures, and air temperatures were correlated to BDS temperatures. Nighttime results were significantly better correlated than results that also included daytime data with solar radiation, as solar radiation on sunny days tended to warm bridge decks considerably. Solar radiation is not measured by Ohio's RWIS, though some comparison was made with solar radiation data collected by RWIS sites in Kentucky that were located relatively close to selected ODOT RWIS sites in the Cincinnati area. BDS temperatures generally correlated better with pavement sensor temperatures in both roads and bridges than did air temperatures, indicating that the BDS did have some value over air temperature as an indicator of bridge deck and pavement temperature. However, the exact regression relationship between BDS and road or bridge temperature was highly site-specific, so a state-wide relationship could not be determined. In addition, prediction limits were derived for each site to indicate for a given BDS temperature value the temperature ranges within which the bridge or road temperature could be estimated to lie within at certainty levels of 90 percent, 95 percent, and 99 percent. Even in the best cases, the correlation between the BDS and bridge or road temperatures were weaker than desired, leading to relatively large prediction limit ranges.

Finite element methods were used to simulate bridge deck simulator and bridge temperature behavior under actual temperature gradient profiles for each site, and parameters were found that reached good agreement. The agreement in the simulation between bridge deck and BDS temperatures could be increased considerably by quadrupling each side of the BDS block, though the mass of the resulting device may make it impractical to install. Simulation runs took well over an hour on a fast PC, so the finite element temperature simulation method cannot be practically used to provide valuable real-time temperature prediction information. GE

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