Evaluation of ODOT Roadway/Weather Sensor Systems for Snow and Ice Removal Operations

PART II: RWIS Pavement Sensor Bench Test

Start date: March 12, 2002
Duration: 9 months
Completion Date: December 15, 2002
Report Date: October 30, 2002
State Job Number: 14758(0)
FHWA Report Number: FHWA/OH-2003/008B
Funding: $71,054

Principal Investigator:
Helmut T. Zwahlen

ODOT Contacts:
Technical:
Abner Johnson
Keith Swearingen

Administrative:
Monique R. Evans, P.E.
Administrator, R & D
614-728-6048

for copies of this report, go to:
http://www.dot.state.oh.us/divplan/research
or call 614-644-8173

Ohio Department of Transportation
1980 West Broad Street
Columbus OH 43223

Problem
Road Weather Information Systems (RWIS) are used by winter maintenance managers to monitor road weather condition data not available through conventional weather sources, particularly pavement temperature and status (wet or dry). Given the key role that pavement sensors thus play in RWIS, it is important to know how accurately they perform when deciding which system to adopt. Pertinent, unbiased data regarding sensors sold in the USA are not available. To provide some answers, a test under controlled conditions, using a climate chamber with carefully measured solutions of deicing chemicals (road salt (NaCl) and 30% calcium chloride solution (CaCl$_2$)) applied to several manufacturer’s pavement sensors installed in concrete blocks was proposed.

**Objectives**

The aim of this study was to verify in a controlled laboratory situation the performance and accuracy of RWIS pavement sensors manufactured by three nationally recognized manufacturers, labeled Vendor A, Vendor B, and Vendor C. These performance measurements consisted of a comparison of temperature readings from each sensor to those of calibrated temperature measurement devices at the same location, a comparison of surface status (wet/dry) readings to actual surface conditions, where possible a verification of the accuracy of the values returned by sensors regarding the degree of salinity of the liquid on the sensor, where possible a comparison of the freezing point reported by the sensor system to the expected freezing point of the solution, and where possible a comparison of the depth value reported to the actual liquid depth on top of the sensor.

**Description**

Pavement sensors from Vendor A (active (with built-in cooling element) plus active-passive), Vendor B (passive (no cooling)), and Vendor C (passive) were installed in 14”x14” concrete blocks from a 10” thick bridge deck which were then leveled and placed in a walk-in climate chamber. Each sensor communicated to a Remote Processing Unit and a server computer, which recorded relevant data, including surface status (wet or dry) surface temperature, chemical percentage or index, freezing point temperature, and liquid layer depth (as appropriate to the sensor system).

A silicone barrier was drawn around each sensor to retain liquid layers of thicknesses 0.5, 1.5, 3, and 6 mm. External calibrated temperature probes were added to each block surface where the liquid was, and thermistors were added to monitor surface temperature on each block outside the liquid area and the air temperature near each block.

Test solutions were made of distilled water and ODOT-supplied rock salt (by weight: 0% (pure water) 7%, 13%, 19%) and/or calcium chloride (by weight 17%, 30%, and 30% mixed with 23% salt brine in ratios of 3:7 and 1:9). For each of the 38 runs (32 planned (8 solutions x 4 depths) plus 6 additional), a solution was applied in the given thickness to each block, then the chamber was cooled from room temperature (average 21°C) to below freezing or the chambers minimum temperature (approximately -17°C, achieved after about 15 hours). The climate chamber could cool 5.6°C in the first 15 minutes (15.8°C in the first hour).

**Conclusions & Recommendations**

No pavement sensor system accurately reported all parameters. Each had its own strengths as detailed below.

*Surface Status:* Vendor A’s sensor was accurate 92%-97% of the time. Vendor C’s sensor was accurate 100% of the time at start of runs, but only 82% at end. Vendor B’s more elaborate scheme was accurate only 19% of the time at start and 47% at end.

*Surface Temperature:* All sensors had unsatisfactory lags compared to calibrated temperature probes during cooling. Vendor B had least lag, average maximum 4.04°C±1.16°C standard deviation at average time 157 min ± 46 min standard deviation. For Vendor A the comparable lag was average maximum 6.57°C±3.04°C at 150 min ±38 min. And Vendor C’s lag was the worst: average maximum 7.04°C±1.51°C at 128 min ±41 min. It should be noted that these lags occurred under sustained fairly rapid cooling conditions not commonly found, though possible, in Ohio weather.

*Freezing Point Temperature:* Vendor B’s passive sensor was more accurate than Vendor A’s active sensor. Vendor B’s freezing points, computed from the chemical percentage, correlated appropriately with salt concentration, showing some bias towards higher than actual freezing points at higher concentrations. Results for calcium chloride were off by 5°C or more, which may reflect the fact that the sensor was calibrated for salt, not calcium chloride. Vendor A’s freezing points did not agree well with expectations; different freezing points were reported for different depths of the same liquid. Also, freezing point reported by Vendor A’s sensor changed considerably during the course of most runs. Vendor C’s sensor was not designed to report freezing point temperatures.

*Chemical Percentage or Index:* Vendor B’s chemical percentage, reported as a percentage of saturation, was accurate for pure water and 7% NaCl, and noticeably low for 13% and 19% NaCl. Results were clearly off for calcium chloride. Vendor C’s chemical index did not correlate with salt or calcium chloride concentration in any meaningful way. Vendor A’s sensor did not report chemical concentration.
**Liquid Layer Depth:** This was reported only by Vendor B’s sensor. Initially reported depths correlated somewhat weakly with actual liquid depths.

Because of the problems with accuracy, particularly with surface status, surface temperature, and freezing point, none of these sensors are recommended in their present state of development.

**Implementation Potential**

None of the tested sensors performed outstandingly well. Vendor B has the best temperature, freezing point, and chemical concentration performance; Vendor A may have the best surface status reporting, and Vendor C has other useful features such as radio data transfer (no cables to install), reusability, and traffic counting features that were not evaluated in this study but which may also be useful for winter operations.

It is recommended that the state of Ohio postpone further deployment until the state of technology improves enough to answer the deficiencies noted here. Any future sensor deployment should be contingent on the ability of the chosen sensor to perform those functions considered necessary by ODOT.