MoDOT

Research, Development and Technology Division

RDT 99-007

MIrror Mounted Pavement Temperature Sensor

TA97-010

April, 1999

FINAL REPORT

Test and Analysis 97-10

MIRROR MOUNTED PAVEMENT TEMPERATURE SENSOR

MISSOURI DEPARTMENT OF TRANSPORTATION
RESEARCH, DEVELOPMENT AND TECHNOLOGY DIVISION

BY: IVAN CORP, RESEARCH AND DEVELOPMENT ENGINEER'S OFFICE

Acknowledgment to: District One-Operations
Materials Lab
Federal Highway Administration

JEFFERSON CITY, MISSOURI
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The investigation was conducted in cooperation with the U. S. Department of Transportgation, Federal Highway Administration.

16. Abstract

Mirror mounted pavement temperature sensors were purchased and used in the field to see if real-time pavement temperatures would be beneficial to snow and ice removal crews. We currently use the forecast, air temperature thermometers and experience to determine when to begin chemical applications.

The RW-1 Roadwatch infrared sensors chosen for this study are made by the Sprague Company in the State of Washington. This sensor allows the operator to observe actual pavement temperatures and trends and adjust application rates based on real time data. This research project distributed 50 mirror mounted infrared pavement temperature sensors throughout the state for field use.

We originally intended to gather data using control groups, which would use the weather forecast, air temperature and experience to determine when and how much de-icing chemicals to apply. They would record the costs required to attain a level of service designated for the control groups route. The test groups would collect the same data but use real time pavement temperatures provided by infrared RW-1 Roadwatch sensors to assist in the decision on when to apply de-icing chemical. The control group quickly recognized the advantages of the sensors and asked that the temperature information be shared. In the interest of public safety, this was allowed and the control information discontinued. They were an immediate success based on operator feedback and district findings.

It is recommended that all snow and ice removal operators have access to pavement temperature information either by operating the sensor or by radio communication.

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EXECUTIVE SUMMARY

MoDOT became aware of the importance of pavement temperatures during the SHRP Research pertaining to anti-icing practices. Operators have to depend on the weather forecast and maintenance building and bank thermometers. These sources provide air temperature rather than pavement surface temperatures. This study was to determine if pavement temperature sensors would be beneficial in identifying the most efficient pavement temperature for applying salt brine or other anti-icing techniques.

The RW-1 Roadwatch infrared sensors chosen for this study are made by the Sprague Company in the State of Washington. Laboratory tests proved they are accurate as advertised to ± 1° between 38°F and 5°F. This sensor allows the operator to observe actual pavement temperatures and trends and adjust application rates based on real time data. MoDOT's field personnel have purchased 125 additional units over and above the pavement temperature sensors provided by this project. This research project distributed 50 mirror mounted infrared pavement temperature sensors throughout the state for field use. They were an immediate success based on operator feedback and district findings.

We originally intended to gather data using control groups, which would use the weather forecast, air temperature and experience to determine when and how much de-icing chemicals to apply. They would record the labor, material and equipment costs required to attain a level of service designated for the control groups route. The test groups would collect the same data but use real time pavement temperatures provided by infrared RW-1 Roadwatch sensors to assist in the decision on when to apply de-icing chemicals. The control group quickly recognized the advantages of the sensors and asked that the temperature information be shared. In the interest of public safety this was allowed and the control information discontinued.

An estimate of materials savings is $185,119 annually statewide. This excludes any savings on equipment and personnel. This was realized based on District One findings for the winter of 1997-1998. Since our data is limited, we used a one year life for the sensors and calculated a benefit/cost ratio of 9.49 which will improve as the sensors service life extends beyond one year (possible 3-4 times greater).

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INTRODUCTION

MoDOT currently depends on the weather forecast, air temperature thermometers and experience of maintenance personnel to determine when to begin applying chemicals during a winter storm event. Due to a lack of real time information, inappropriate chemical applications (lacking or excessive) are common occurrences. Real time pavement temperature allows the operator to make a better decision regarding when to apply chemicals thus eliminating premature or late chemical applications. Districts 1, 3, 4 and 6 have roadway weather information sites which provide real time conditions such as pavement temperature, air temperature, presence of precipitation and percent solution of the chemical brine. However, the number of these information sites are limited.

OBJECTIVE

By using pavement temperature sensors, identify the proper pavement temperature and timing to apply chemicals for de-icing roadways to achieve a desired level of service.

DISCUSSION OF PRESENT CONDITIONS

We currently use the forecast, air temperature thermometers and experience to determine when to begin applying chemicals. This can be a problem after severe storms. The air temperature may be considerably lower than the pavement temperature when solar energy is present in the pavement. If anti-icing procedures begin too early, materials, labor and equipment usage can be wasted. And, if the procedures begin too late, work crews can fall behind in trying to keep a roadway clear. One operator relies on a bank thermometer (on his route) to read 31° to begin applying chemicals.

TECHNICAL APPROACH

Research, Development and Technology acquired and distributed RW-1 Roadwatch infrared mirror mounted pavement temperature sensors to maintenance supervisors throughout the state. The sensors cost $390.00 each. Funds from Federal Highway Administrations, Priority Technology Program, were used to purchase the 50 mirror mounted pavement temperature sensors. These sensors were intended for use on interstates and arterial highways. This allowed maintenance personnel to advise some operators of the real time conditions (test group) while making comparisons to operators who wouldn't have real time information (control group). Materials, labor and equipment costs and level of service would be documented by each group. A review of this documentation should show if the pavement temperature sensors are cost efficient. One RW-1 Roadwatch infrared sensor was tested in our materials laboratory for accuracy.

RESULTS AND DISCUSSION

When the control group realized the dramatic improvement in chemical application timing the test group enjoyed, they asked the information be shared, and it was made available. Therefore data on materials, equipment, and labor costs from control sections statewide is unavailable.

District one recorded a savings of $26,946 (Appendix C) with the use of five sensors ($390 each). This estimated savings projected against the remainder of Missouri's climatic conditions was $185,119 (Appendix D) statewide for the 1997-1998 winter season. This equates to a state wide benefit/cost ratio of 9.49 and does not include other savings such as time and equipment usage. This ratio is based on one winter usage only and will improve as the sensor's life goes beyond one year. The sensors are new and a life expectancy cannot be assumed at this time, but we are hoping for 2 or 3 years, perhaps more. Since our data was limited, we will be conservative with a benefit/cost ratio of 9.49 and a one year life.

The laboratory test results indicate the mirror mounted pavement temperature sensors are accurate (see Appendix B).

Districts throughout the state bought an additional 125 units which indicates the benefits recognized by field personnel. During a recent trip to Champaign, Illinois, I was privileged to hear a presentation from a snow plow operator from Minnesota DOT on salt solutions. He concluded that the most important addition to the toolbox of the snow plow operators following a plow and spreader is the mirror mounted pavement temperature sensor.

CONCLUSIONS

Roadway weather information sites are very limited making real time pavement temperatures difficult to obtain. Based on the accuracy from the laboratory results and field operator comments, the real time pavement temperature assists the operator in determining proper application rates and timing. During the first winter, the real time data provided by the mirror mounted pavement temperature sensors saved District One $13,473. This increases to $26,946 when expanded for one year for District One and $185,119 state wide. The mirror mounted pavement temperature sensor is a valuable tool. Either by sensors or radio communications, all snow plow operators should have access to real time pavement temperatures.

RECOMMENDATIONS

We recommend that all operators have access to pavement temperature sensor information. Each truck does not need to be equipped with this tool as long as the operators have access to the real time data by radio communication with co-workers in the immediate area. In addition, as recommended by the Materials Lab (Appendix B), each unit should be checked in actual field conditions to verify each individual unit. Verification should be done by using a hand held sensor (Appendix D) or some other means of verifying pavement temperature.

IMPLEMENTATION

When the final report is complete, a meeting should be held for the RDT Administration Team plus the Maintenance Division. The benefits can be explained and discussed. If questions are answered and the Maintenance Division accepts the report or a modified version, the group should agree on a number of new sensors for the districts. Currently, there are 175 units statewide and we forsee an additional 425 units needed. The additional units will cost $165,750 (425 x $390) and the annual state wide savings is $185,119. Funds for these additional pavement temperature sensors should be provided from the savings from the sensors in the districts.

Appendix A

Work Plan

Proposed Work Plan

TA97-010
EVALUATION OF VEHICLE MOUNTED RW-1 ROADWATCH INFRARED SENSORS TO DETERMINE PAVEMENT SURFACE AND AIR TEMPERATURES

February 1997

Introduction:

The goal of this investigation is to gather information on air and pavement temperature sensors for both the Research. Development & Technology Division and the Maintenance Division.

The scope of this project is to evaluate and report both the positive and negative aspects of the RW-1 Roadwatch Infrared Sensor. A report will be made containing the information found along with a recommendation of any further implementation.

Background and Significance of Work:

The Maintenance Division is responsible for preventing and removing ice and snow from Missouri highways. Today, we can monitor the air temperatures, but these temperatures do not necessarily coincide with pavement surface temperatures. It is the pavement surface temperature that dictates when precipitation adheres to the pavement, therefore this is the temperature we should pursue.

Each winter season, hazardous roadway conditions due to the snow and ice pack on Missouri highways are responsible for many roadway accidents and injuries. If pavement temperature sensors can give the department an indicator on the best time to start applying roadway chemicals to the roadway, this should help in keeping the roadways clear of freezing precipitation or accelerate in its removal.

Action Plan:

We will evenly distribute 50 pavement sensors across each of the ten districts in the state. The department has approximately 100 maintenance area supervisors and 350 highway maintenance supervisors statewide. We would place the 50 sensors in the possession of half of the maintenance area supervisors. The maintenance area supervisor will have it installed either on the vehicle of a maintenance crew leader or a highway maintenance supervisor. These 50 sensors would be located in maintenance areas having either interstates or arterial routes. At the end of the test period, a report on the sensor will be prepared and a recommendation will be made. If they prove successful, we would equip each maintenance area supervisor with a sensor plus no less than half of the highway maintenance supervisors, totaling 275 sensors. Ideally, one sensor per maintenance area supervisor and one sensor per highway maintenance supervisor would be our final implementation.

Within this investigation, we will also be experimenting on how well these sensors work. We will be checking the accuracy of all sensors by comparisons with actual surface temperatures. The manufacturer claims that accuracy is within 1% of the full scale or one degree Fahrenheit, whichever is greater. We want to determine this ourselves.

The department will also keep a record of chemical usage by trucks that have these sensors and those that do not. Chemical usage should be less on a truck equipped with a temperature sensor, and we want to verify this. During each week, a tally of chemical usage will be made for each maintenance building, with this tally running from midnight on Sunday to 11:59 pm on Saturday. Using this, along with the number of events during the week, the number of trucks assigned at the building, and the number of lane miles the building has the resposibility for, the chemical usage can be standardized by the following equation:

Standardized Chemical Usage = [(# Trucks)(Amount used, gallons)] / [(# events)(# lane miles)]

This equation should give a standard number of gallons used per lane mile per truck, regardless of the number of events during the week. This standardized number could then be used to compare usage within a maintenance area, a district, or possibly even statewide, for trucks that do and do not have pavement temperature sensors.

Method of Implementation:

With each district involved in the testing of these sensors, they will all be familiar with their operation. Therefore, if additional sensors are found to be necessary, they will be evenly distributed across the state with emphasis on interstates and arterial routes.

Expected Benefits:

We believe that knowing the temperature of the pavement surface can benefit the department in helping to prevent and in removing frozen precipitation from Missouri's highways. With this benefit, winter related roadway accidents, injuries, and inconveniences should decrease. For example, suppose the air temperature to be 31 or 32 degrees Fahrenheit. This would normally sway a maintenance worker into applying deicing chemicals. However, if the pavement temperature sensor shows 35 degrees, the worker might delay the chemical application until the pavement temperature reaches 33 degrees Fahrenheit, saving the department the cost of the chemical and its application.

Staffing:

The anticipated staffing for this project will be a Senior Research and Development Engineer and one Field Testing Technician from this division. In addition. personnel from General Services would be required to install the sensor and dial on the vehicle.

Research Period:

The evaluation of this product will begin after installation of the sensors onto the vehicles and winter weather begins. We will need 3 winter months to make the field evaluation. This will begin on or about November 1. 1997. A final report will be prepared by April 1. 1998. and this report will be made available to other interested states.

Funding:

It is our understanding that the state of Vermont is trying a more expensive sensor at a cost of $2400 each. We believe that Missouri can be equally effective using a less expensive sensor. The cost of this project will be approximately $20.000 ($390 per sensor). plus 5% contingencies. provided by the Federal Highway Administration for the purchase and evaluation of the RW-1 Roadwatch Infrared Sensors.

VEHICLE MOUNTED RW-1 ROADWATCH INFRARED SENSOR
ROAD SURFACE AND AIR TEMPERATURE

ARTICLE 1 - Statement of Work

The State of Missouri shall implement a trial use of Vehicle Mounted RW-1 Roadwatch Infrared Sensors for pavement surface and air temperature. All activities will be documented in an evaluation report.

ARTICLE 2 - Work Plan

Attached is the project work plan which establishes the scope of work effort for implementation and evaluation of the Vehicle Mounted RW-1 Roadwatch Infrared Sensors. It describes the work for which the State of Missouri is responsible.

ARTICLE 3 - Period of Performance

The period of performance shall be 3 winter months.

ARTICLE 4 - Key Personnel

The State shall assign the following individual as Principal Investigator:

Name:	Ivan Corp
Title:	Senior Research and Development Engineer
Address:	5117 East 31st Street Kansas City, MO 64128
Telephone:	(816)889-6403

ARTICLE 5 - Payment

Normal Federal-aid procedures and regulations apply.

Appendix B

Laboratory Test Results

Lab Test Results
By Leonard Vader

This evaluation was to determine temperature accuracy of the mirror mounted Roadwatch Temperature Monitor by Sprague Controls Inc. at freezing temperatures.

The Roadwatch Temperature Monitor was checked for accuracy using the following method. Large test specimens of asphalt and concrete were placed in a Revco Temperature Cabinet. The cabinet was allowed to equilibrate for at least 8 hours at specified test temperatures. Specimens remained in the temperature cabinet throughout the testing procedures. With the door of the cabinet open measurements were taken of the test specimens from 2 inches through 5 feet. The readings from 2 inches through 5 feet were identical at all test temperatures. The room temperature during testing ranged from 78-80 F. The following chart and table show the testing data collected.

Temperature Chart in Fahrenheit

True Temp.	5	10	15	20	25	30	32	35	40
Concrete	4	9	15	21	26	31	33	36	42
Asphalt	4	9	15	21	26	31	33	36	42

It was noted that the infrared sensor demonstrates a cone effect. A specimen of the dimension 4 1/8 inch diameter, 1 inch depth and temperature of 32 F was placed on a room temperature tabletop. The sensor would read the specimen temperature of 33 F, corresponding to the above testing parameter, at 2 inch but would read 37 F at 14 inches. At even higher heights, the unit would display the background material's temperature.

It was also noted that the unit gave erroneous results on highly reflective materials such as stainless steel and mirrors. The sensor tended to pick up measurements of the surrounding surfaces that were reflected by the reflective material being measured. The temperatures ranged from the real surface temperature of the reflective material to the surface temperatures of surrounding materials.

The single Roadwatch Temperature Monitor check provided a quick and reproducible reading on concrete and asphalt. It shows good linearity over the test range of 5 F to 40 F. However the size and reflectivity of the surface being measured and the proximity to the sensor have a definite effect on the temperature readings. The Roadwatch Temperature Monitor should be checked in actual field conditions to verify each individual unit is working properly.

Appendix C

District 1 Report of Field Findings

Pavement Temperature Sensors
Results

To date we have received information from five regional buildings regarding their use of pavement temperature sensors. Each of them are convinced these units are beneficial, having saved them material and effort. The following summary shows the results reported.

Storm Date	Building	$'s Saved	Situation
10/26/97	South	$4386	Saved per storm
11/2&3/97	South	$3385	Saved per storm
11/14&15/97	South	$1128	Saved per storm
11/3/97	Lathrop*	$ 252	Saved one treatment in storm
12/7/97	Lathrop*	$ 504	Saved one treatment in storm
12/21/97	Lathrop*	$ 270	Saved one treatment in storm
12/22/97	Lathrop*	$ 270	Saved one treatment in storm
1/4/98	Lathrop*	$ 270	Saved one treatment in storm
1/3/98	Gallatin	$ 648	Saved per storm
1/8/98	Rock Port	$2160	Saved to date
——	Bethany	$ 200	Saved on one treatment
		$13,473	

*Submitted information for their Interstate route only.

Lathrop indicated they had also saved doing any treatments at all on the 9th of Dec. by knowing the pavement temperatures. Others indicated a better comfort level in knowing what was going on instead of having to guess. Those not turning in any information did state they were saving material with the sensors.

There is agreement in asking for one additional unit for each building in the district. This would give regionals two units and locals one. They believe this is beneficial as they are finding that different parts of their areas are experiencing different temperatures. They may need to treat on Interstate but not over on some of their other priority 1 and 2 routes due to different conditions.

Storm Summaries Turned In

10/26/97	South	Approx. 12 hour storm with trace of snow. Saved 180 yards of salt.
11/2&3/97	South	Six+ hour storm with less than 1" of snow. Saved 135 yards of salt.
11/14&15/97	South	Eleven+ hour storm. Saved 45 yards of salt.
12/3/97	Lathrop	Light flurries, wet pavement Air Temp=37, Pavement=36 Got off the road and did not treat. Saved one treatment. 14 yards.
12/7/97	Lathrop	Wet heavy snow, covered pavement. Plowed and treated. After snow done, plowed and treated again. Air Temp=34 Pavement=33-35. Directed efforts to clean up rather than checking for re-freeze or applying precautionary treatment. Saved two treatments. 28 yards.
12/21/97	Lathrop	Rain with Air Temp.=32, Pavement =32-34. Held off treating. Later treated as temperature fell. Saved one treatment of 15 yards.
12/22/97	Lathrop	Pavement still wet from rain. Air Temp.=34, Pavement=32. Waited and did not need to treat. Saved at least one treatment of 15 yards.
1/4/98	Lathrop	Foggy, light drizzle. Roads were drying. Pavement=33. Allowed to wait and not treat. Saved 15 yards.
1/3/98	Gallatin	Saved at least two treatments on priority one routes. Saved approx. 36 tons of material.
1/8/98	Rock Port	Thru this date, have saved 120 yards of material. Sensors removed the use of materials as a precaution.
——	Bethany	One treatment on priority one routes costs $200 in materials.

District One's 1997 - 1998 Test of Mirror Mounted Pavement Temperature Sensors

Test Period: October 15, 1997 to January 8, 1998

= 85 Days

Winter Season: October 15, 1997 to April 1, 1998

= 167 Days

Test Period Savings = $13,473

Winter Seasons Savings = $13,473 x 167/85 (rounds to 2) = $26,946

Appendix D

State Wide Salt Usage and Calculations for Annual Savings

1997/1998 State Wide Salt Usage (Tons)

District	Amount
1	28,700
2	23,140
3	31,675
4	27,160
5	20,000
6	18,700
7	12,500
8	16,460
9	14,932
10	3,835

Projected State Wide Savings (Salt) Using Mirror Mounted Pavement Temperature Sensors

District	Savings Factor Compared To D-1		
D-1	= 28,700 / 28,700	= 1.00	= $26,946
D-2	= 23,140 / 28,700	= 0.81	= $21,826
D-3	= 31,675 / 28,700	= 1.10	= $29,641
D-4	= 27,160 / 28,700	= 0.95	= $25,599
D-5	= 20,000 / 28,700	= 0.70	= $18,862
D-6	= 18,700 / 28,700	= 0.65	= $17,515
D-7	= 12,500 / 28,700	= 0.44	= $11,856
D-8	= 16,460 / 28,700	= 0.57	= $15,359
D-9	= 14,932 / 28,700	= 0.52	= $14,012
D-10	= 3,835 / 28,700	= 0.13	= $ 3,503
		Total	**$185,119**

Appendix E

Pictures of Hand Held Versus Mirror Mounted Pavement Temperature Sensors

Pictures of Hand Held Versus Mirror Mounted Pavement Temperature Sensors

Appendix F

RW-1 Roadwatch Pavement Temperature Sensor

Picture of RW-1 R[illegible] Pavement Temperature Sensor