SWALLEY CANAL
ICE DETECTION SYSTEM

Experimental Feature
Final Report
OR 85-02

by

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ABSTRACT

This report evaluates the reliability of information provided by a "SCAN 16" surface condition analyzer. SCAN systems are designed to inform highway maintenance personnel when frost, ice, and snow are present on a roadway surface or bridge deck. The system evaluated here was installed on a bridge deck in a part of Oregon where frost, snow, and ice are frequently a hazard to traffic.

The evaluation of performance data suggests that the system cannot reliably report hazardous conditions on the deck. Local maintenance personnel, however, believe that they can make correct inferences from the system's output. Although it is not currently used to dispatch maintenance crews, a recent expansion of the system may change this. Sensors have been installed at a more remote location and now forecasting, as well as reporting of current conditions, is possible.

ACKNOWLEDGEMENT

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DISCLAIMER

The contents of this report reflect the views of the authors who are solely responsible for the facts and accuracy of the material presented. The contents do not necessarily reflect the official views of the Oregon Department of Transportation. The report does not constitute a standard, specification or regulation. The Oregon Department of Transportation does not endorse products or manufactures.

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INTRODUCTION

The ice detection system reported here is a "SCAN 16", Surface Condition Analyzer. The system, developed by Surface Systems Inc. (SSI), measures atmospheric and pavement conditions as well as the amount of deicing chemical present and warns of conditions conducive to ice forming on pavements. This report discusses a system that was installed in Bend Oregon in 1986. It is located on the Swalley Canal Bridge located on US Hwy. 97 at M.P. 136.48. This installation is the fifth installation of its kind in Oregon and the third to be evaluated in Oregon as an Experimental Feature for the FHWA Experimental Projects Program [1,2].

Initially this installation was intended to address a public concern over safety. A signalized intersection was designed at the base of a sloping bridge. The public was concerned that any ice or snow on the bridge would present a hazard as log trucks attempted to stop at the traffic signal while travelling downhill. The ice detection system was originally intended to be used to determine when to switch the traffic light to "all flash" when ice was present on the bridge. After construction, traffic considerations did not allow this specific use of the system. Hookups to signs and signals is discouraged by the equipment manufacturer unless the actual switching is done by a person using his own judgement.

SUMMARY

The system has performed to the satisfaction of the District Maintenance Office who did the actual field evaluation. However, the data supplied by that office did not confirm that the system could reliably report the presence of ice, frost, or slush on the bridge deck. In 6 out of the 7 cases where adverse conditions were visually observed, the system failed to accurately report the observed condition. In some cases, this occurs because, at temperatures below 20°F, the snow is too dry to be detected by the system. One factor contributing to this problem is that de-icing or anti-icing chemicals are not used in Oregon. This system was designed to be used in conjunction with chemicals.

At this particular site, no cost saving was anticipated, as the system was justified on the basis of safety and public concern. Because of the site's close proximity to the maintenance station there is no need to use it to dispatch sanding trucks. This site is frequently sanded by trucks en route to other areas during icing conditions.

Recently, the system has been expanded to allow prediction of future conditions as well as reporting of current conditions. To support this, more sensors have been installed at a remote site where a potential exists for a saving in both cost and time when dispatching sanding trucks.

SYSTEM DESCRIPTION

The core of the SCAN system is the surface sensor. This is a disk shaped unit made of molded epoxy which is mounted in the pavement with its top surface flush with the pavement surface. The material and the surface coloring are designed to match the thermal properties of the pavement itself. The temperature sensing device is a thermistor having an accuracy of plus or minus 0.2 degrees C. The presence of deicing chemicals and moisture or ice are sensed by a capacitance device that detects changes in the dielectric constant of the sensor's surface. In addition to the surface sensors, the system has sensors for air temperature, humidity, precipitation, and wind velocity. The output reading for surface condition is generated by a computer program which incorporates all of the sensor information. Final output can indicate any of the following status readings for each sensor:

DRY: An absence of precipitation or moisture at the surface sensor.

WET: Precipitation/moisture present in liquid form on the surface and surface temperature above 32 degrees F.

DEW: Moisture present on surface, the dewpoint has been reached and surface temperature below 32 degrees F.

FROST: Frost present on surface, the dewpoint has been reached and surface temperature below 32 degrees F.

FROST ABOVE DEWPOINT: Frost conditions have been reached and the surface temperature is no longer at or below dewpoint.

ABSORBTION: Moisture present on the surface in an insufficient amount to present a hazard.

ABSORBTION @ DEWPOINT: Moisture present on the surface in an insufficient amount to present a hazard and dewpoint has been reached.

CHEMICAL WET: Precipitation/moisture present in liquid form on the surface and the surface temperature at or below 32 degrees F. (Indicates the presence of deicing chemicals).

SNOW/ICE ALERT:

A. Precipitation/moisture in liquid form on surface starting to freeze.

B. Precipitation/moisture on the surface which has frozen.

SENSOR DOWN: An inoperative sensor.

COMMUNICATION FAILURE: Disrupted communication between the RPU and CPU.

The Bend system consists of:

- 1 Remote Processor Unit (RPU) (Collects and transmits sensor data)
- 3 Surface Sensors (Monitors surface conditions)
- 1 Subsurface Sensor
- 1 Air Temperature Sensor
- 1 Relative Humidity Sensor
- 1 Precipitation Sensor
- 1 Wind Velocity/Direction Sensor
- 1 Central Processor Unit (Receives data from RPU)
- 1 Computer Terminal
- 1 Printer
- 1 Remote Terminal
- 2 Portable Terminals

Sensor Locations are as follows:

Sensor #1	south-bound approach inside lane
Sensor #2	north-bound approach outside lane
Sensor #3	north-bound deck outside lane
Sensor #4	Subsurface north-bound approach

These sensors along with the air temperature, humidity sensor and wind sensor feed raw data into the RPU #1 located at the south end of the structure.

EVALUATION AND PERFORMANCE

The formal evaluation of system reliability is only possible for data from the winter of 1988 - 89, as reported in Table 1. During the previous 2 winters informal field observations were made. These earlier observations, however, were not documented or correlated with system readings.

1986-87 Evaluation: A mild winter resulted in data with limited weather variation but a recurring reading error was noticed. It was observed that on several occasions the detection system reported the pavement as being "DRY" when actually packed snow was present on the pavement surface. The misreading was first thought to be a result of the manufacturer specification that suggests sensor calibration be made with salt water. (This is recommended because the system is designed to work with deicing chemicals). Later the system sensors were re-calibrated with the use of water without salt to more realistically predict conditions found in Oregon where deicing chemicals are not used. It is standard practice to use cinders or sand to provide a surface with adequate friction.

1987-88 Evaluation: The District Maintenance Office reported that they were satisfied with the accuracy of the system except that it continued to give a reading of "DRY" when actually a packed snow condition existed.

One theory for this misreading is that Bend, being a High Desert Mountainous Region, often receives "dry snow" (Snow that falls with a low moisture content at temperatures below 20 degrees F.). As the snow falls, traffic compacts it creating a slippery and dangerous road condition. It appears that this present system's ability to detect low amounts moisture in cold weather is limited. Thus it read, "DRY" during these "dry snow" falls. The maintenance personnel who operate the system have become familiar with the conditions that produce the false reading and do not consider it a problem. In general, when it is snowing and below 20°F, they know that "packed snow" is likely in spite of the "DRY" reading.

<u>1988-89 Evaluation:</u> Data was collected from the system and visual observations were made. A direct comparison of field observations versus system readings is presented in Table 1 and summarized in Table 2. In 6 out of the 7 cases where adverse conditions were visually observed, the system failed to accurately report the observed condition. In some cases this may occur because, at temperatures below 20°F, the snow is too dry to be detected by the system. The following discussion compares the system reading to the observed conditions as listed.

<u>Frost</u>

On 12/15/88 the system reported only a "DRY" condition and did not indicate the presence of pavement frost as observed in the field.

Snow & Ice

On 12/23/88, 1/10/89 and 2/2/89 it failed to report the observed packed snow condition. On the first two of these dates, however, it apparently reported the condition correctly after the temperature rose above 32°F. On 12/22/88 the system gave a correct reading for snow/ice conditions. The correct reading may have been delayed, however, due to a communication failure. On two other occasions, 12/23/88 and 1/10/89, the reading may have been correct. However the actual conditions on the deck were not observed in the field.

Dry and Wet conditions

The system gave correct readings for all observed dry and wet pavement conditions.

It was also noted in the same winter that the pavement sensors had started to show accelerated wear. This is believed to be a direct result of studded snow tire use.

OTHER BENEFITS OF THE SYSTEM

The District maintenance office has found other uses for the system which include: Using the temperature information when scheduling paving work during the summer months and storing data on weather, and providing information on pavement surface condition that may be valuable in future litigation.

CURRENT SYSTEM UPDATE AND IMPROVEMENTS

Because local personnel are satisfied with this system, they have decided to expand it. This expansion allows advance forecasting of pavement surface conditions. A subsurface sensor has been installed at the bridge location and the system is now tied into the SCAN*CAST Center located in St. Louis, Missouri. Data is transmitted to the center via leased phone lines where it is reviewed by experienced meteorologists. The center uses this data along with forecasts, warnings and maps from the National Weather Service and the Federal Aviation Administration to produce a bulletin. The SCAN*CAST Bulletin provides a forecast of pavement temperature and pavement wetness. These data are projected graphically to predict when ice will form or when snow will begin to stick.

The temperature forecasting model is based on the heat-balance equation [3];

$$RN + H + S + LE = 0$$

RN = net radiation
H = heat exchange with the air
S = heat exchange with the road structure
LE = latent heat exchange

The forecasting model is initialized from the actual pavement temperature and the actual sub-surface temperature at the SCAN site.

An additional remote processing unit has been installed near Lava Butte 13 miles south of the maintenance shops. This is necessary because of the more severe weather at the higher elevation of Lava Butte. This new system consists of three pavement sensors and has been tied into the upgraded SCAN*CAST System. It is anticipated that this forecasting capability will save time and money in dispatching sanding trucks to this remote site.

Since the Bend system was installed, some significant improvements have been made to the precipitation and humidity sensors. The old precipitation sensor was a grid mesh that would detect precipitation when it fell onto the mesh but did not detect the precipitation if it fell through the mesh. The new precipitation sensor is an optical sensor that detects movement of moisture particles. The old relative humidity sensor was a plate that would give incorrect recordings of dew when it became dirty. This would cause the system to give inaccurate readings during "FROST" conditions. The new relative humidity sensor is much more accurate. It is made of stretched human hair that detects changes in tension.

CONCLUSIONS / RECOMMENDATIONS

1. The Bend system is well liked by its users but there is no evidence to show that it consistently provides reliable readings.

2. Because the structure is located relatively close to the maintenance office, the ice detection system does not greatly enhance maintenance operations or safety.

3. The temperature data proves to be useful in scheduling paving work in the summer.

4. The temperature and surface condition data is all stored on computer and may be valuable in future litigation.

5. When expensive anti-icing chemicals are used in the future, then this system may prove its value in timing of chemical placement. This system is designed to be used primarily in conjunction with anti-icing chemicals.

6. Future proposed installations of ice detection equipment should be studied carefully and it should be realistically assessed whether the system will enhance sanding or anti-icing operations or traffic safety.

TABLE 1

1988-89 WINTER

Ice Detector Sensor Readout						Visual Site Inspection		
			Temp					Temp*
Date	Time	Surf Cond	Surf	Air	Dew	Time	Surf Cond	Air
11/28/88	19:21	Dry	35	34	25	19:17	Dry	34
11/29/88	1:21	Dry	27	33	25	1:10	Dry	29
11/29/88	15:39	Dry	42	43	20	14:35	Dry	42
11/29/88	18:24	Dry	35	41	21	18:10	Dry	38
11/30/88	1:05	Dry	27	33	23	1:30	Dry	30
11/30/88	15:55	Dry	47	53	11	14:40	Dry	53
11/30/88	17:70	Dry	41	42	15	17:45	Dry	40
12/01/88	0:40	Dry	27	37	19	1:30	Dry	30
12/03/88	3:10	Dry	31	34	22	3:00	Dry	32
12/03/88	20:05	Dry	35	34	22	20:05	Dry	33
12/04/88	1:40	Dry	28	32	24	1:30	Dry	28
12/04/88	19:07	Dry	34	33	24	19:12	Dry	32
12/05/88	1:45	Dry	33	39	23	1:30	Dry	35
12/14/88	17:12	Dry	30	25	10	17:02	Dry	28
12/15/88	1:57	Dry	21	25	17	3:40	Frost	21
12/16/88	7:51	Dry	14	10	03	3:05	Dry	14
12/18/88	23:33	Dry	35	39	23	20:55	Dry	39
12/18/88	1:36	Dry	23	30	12	1:30	Dry	27
12/21/88	7:49	Comm./Fail	27	29	21	2:15	Snow	26
12/22/88	9:36	Snow/Ice	31	33	27	9:36	Pack/Snow	-
12/23/88	1:45	Dry	26	29	23	1:40	Pack/Snow	25
12/23/88	9:47	Snow/Ice	30	31	20		**	
01/10/89	8:47	Dry	24	28	21	8:00	Pack/Snow	30
01/10/89	10:17	Snow/Ice	32	35	27		**	
01/10/89	14:10	Wet	38	36	26	14:00	Slush	35
02/02/89	8:05	Dry	4	-5	-15	8:05	Pack/Snow	4
03/05/89	8:08	Wet	36	38	35	8:00	Rain/Wet	39
03/05/89	13:28	Wet	52	46	42	14:00	Rain/Wet	40
03/16/89	8:29	Wet	41	35	32	8:30	Rain/Wet	38

*This reading is not valid as a standard for evaluating system accuracy as the thermometer used was not as precise as the SCAN thermometer.
**No inspection but "Pack/Snow" likely.

TABLE 2
1988 - 89 WINTER SUMMARY

Sensor Readings	Visual Inspection	No. of Times
Dry	Dry	17
Dry	Frost	1
Dry	Pack/Snow	3
Comm./Fail	Snow	1
Wet	Wet	3
Wet	Slush	1
Snow/Ice	Pack/Snow	1

REFERENCES

1. Scholl, Lew, PE & Rusnak, James, "Medford Viaduct Ice Detection System" Oregon State Highway Division, December 1988

2. Petrak, A. & Martin K., "Ice Detection Systems" Oregon State Highway Division, January 1986

3. Kelley, Joe; Trask David; Hunt Olga, "SCAN provides data for ice/snow control and forecasting" Surface Systems, Inc. ICAO Bulletin, April 1987