MEDFORD VIADUCT ICE DETECTION SYSTEM

FINAL REPORT

By

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December, 1984

ACKNOWLEDGEMENT

A special thanks is extended to Mike Anhorn, District Maintenance Supervisor, Thomas Kuhlman, Assistant District Maintenance Supervisor, and their staff for collecting data and monitoring the performance of the system.

DISCLAIMER

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INTRODUCTION

The Medford Viaduct is a 3230 foot long structure which carries Interstate 5 across Bear Creek and several city streets. Two ice related accidents which occurred on the structure in December of 1984 prompted concern about its safety during subfreezing weather conditions. During the same time period, state maintenance personnel were finding success in using an ice detection system on the Fremont Bridge in Portland (Experimental Feature Final Report OR 80-01). It was felt that a similar system could help to reduce the accident rate on the Medford Viaduct by giving maintenance personnel an early warning of potential icing conditions. This would allow prompt application of sand and would signal the police to turn on ice warning signs.

The system chosen for installation was a System 16 EF, Surface Condition Analyzer (SCAN) developed by Surface Systems Inc.(SSI) The purpose of this report is to describe this system and to evaluate its reliability and effectiveness in improving the management of sanding operations and traffic.

SUMMARY

The system was evaluated over a period of two winters (1986-87 and 1987-88). These two winters did not include severe or frequent ice or snow conditions. Therefore the evaluation of system accuracy is not conclusive. The recorded observations do suggest, however, that actual detection of ice or hazardous conditions was not reliable. Some of this problem might be corrected by improved calibration of the system. Because there has been more positive experience at other bridge sites

with the same equipment, the results with the Medford system should not prejudice future decisions to install ice detection equipment. However, the operational benefits that such equipment can provide should be more thoroughly evaluated before making the decision to install.

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 surface temperature is sensed by a thermistor having an accuracy of plus or minus 0.2 °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, and precipitation. 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 above 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.

Optional equipment not installed on the Medford Viaduct can also produce readings for wind velocity, wind direction, and water level.

The Medford system was installed in November 1986 by the state electrical crew and later made operational by a representative of SSI. This system consists of:

5 Surface Sensors (Monitors surface conditions)
2 Remote Processing Units (RPU's)(Collect and transmits sensor data)
1 Subsurface Sensor
1 Air Temp. / Humidity Sensor
1 Central Processing Unit (Receives data from RPU)

Three of the surface sensors (numbers 1, 2, & 3) are installed in the south-bound right lane and two surface sensors (numbers 4, & 5) in the northbound right lane. Sensor #1 was placed on the south approach, sensor #2 was placed 100 feet onto the structure, and sensor #3 was placed 650 feet onto the structure. These sensors along with the air temperature and humidity sensors feed raw data into the RPU #1 located at the northwest corner of the viaduct. Sensor #4 was placed on the north approach and sensor #5 was placed 100 feet onto the structure. These two sensors, along with a subsurface sensor located at the southeast end of the structure feed raw data into the RPU #2 which was located also at the southeast end of the bridge.

OPERATION AND PERFORMANCE

General

The system is used by both highway maintenance personnel and the state police. Highway maintenance personnel who use the system directly have found it to be somewhat useful in prioritizing their time while managing ice problems throughout the city. The local Maintenance Supervisor, however, does not believe its benefits outweigh its costs. The state police also have a terminal connected to the system. They use it primarily to indicate when to turn on ice warning signs. After receiving an ice warning from the system, a visual check is usually done within an hour. Although the state police have done no formal tabulation of data, they have found it to be generally reliable. Conflicting opinions remain about the usefulness and overall cost effectiveness of the system. Highway maintenance personnel are generally dissatisfied with it, while the state police are satisfied.

Although this is not a highly successful installation, several measures could be taken to make it more valuable. System reliability could probably be improved in several ways: 1) Adding another sensor in the south-bound inside lane, would serve to better cover the most severe icing condition.

The most severe icing on the structure is reportedly caused by early morning shading of the deck by the median barrier at a location where there is no sensor. 2) Improved humidity sensors, now available, could make frost detection more reliable. 3) SSI Inc. has offered additional training in using the system which may open the way to benefits not previously anticipated. Training could help system users to better project (or predict) how conditions are changing. In the future if anti-icing chemicals are used, improved training of users would enable them to optimize the use of these expensive chemicals.

Equipment Reliability

During the 1986-87 winter season, the system experienced continual communication problems. The RPU was receiving sensor data but was not sending it on to the CPU. SSI personnel determined that poor radio telemetry hindered the transmission of data. Thus the equipment reported "communication-failure" on many of its readings. After the antenna was replaced the communication problem was corrected. Also during this season, temperature sensor #2 malfunctioned. Although these problems made it difficult to collect data for the entire first winter, some good data were recorded as presented on Table 1. During the second winter (1987-88) all equipment functioned reliably. These data are presented on Table 2.

System Accuracy

In order for ice detection to be successful it should detect icing conditions reliably and have as few false alarms as possible. In an attempt to find out how reliable this system is, visual observations and

TABLE 1
1986-87 WINTER

Ice Detector Sensor Readout						Visual Site Inspection				
			Temp		Hum/			Temp		
Date	Time	Surf Cond	Surf	Air	Dew	Time	Surf Cond	Sensor		Air
01/06/87	7:53	Dry	33	30	96/29	8:00	Ice	35	#2	33
01/06/87	7:50	Absorption	33	30	96/29	8:00	Ice	34	#5	33
01/07/87	4:05	Dry	25	25	93/23	4:00	Frost	16	#2	27
01/07/87	4:48	Dry	23	24	93/22	4:00	Frost	19	#5	28
01/09/87	4:48	Dry	30	30	88/27	5:00	Dry	26	#2	32
01/09/87	5:03	Dry	29	30	88/26	5:00	Dry	26	#5	31
01/14/87	5:03	Wet	35	32	91/29	5:23	Slush	35	#2	32
01/22/87	5:00	Dry	36	32	82/26	5:00	Dry	35	#2	33
01/22/87	5:03	Dry	34	32	82/26	5:00	Dry	34	#5	33
01/23/87	5:35	Wet	38	36	95/34	6:00	Wet	28	#2	38
01/23/87	5:38	Wet	37	36	95/34	6:00	Wet	28	#5	39
March/87										
03/05/87	8:03	Dry	61	63	29/30	8:30	Wet	55	#2	57
03/05/87	8:06	Dry	60	63	29/30	8:30	Wet	55	#5	57
03/06/87	7:30	Dry	44	40	85/35	8:57	Wet	44	#2	46
03/06/87	7:47	Dry	44	40	85/35	8:57	Wet	44	#5	46
03/09/87	7:17	Dry	45	41	93/39	8:30	Dry	45	#2	47
03/09/87	7:18	Dry	44	41	93/39	8:30	Dry	46	#5	47
03/11/87	6:36	Wet	46	47	62/34	9:06	Dry	43	#2	48
03/11/87	6:35	Wet	46	47	61/34	9:06	Dry	43	#5	48
03/12/87	6:00	Wet	47	45	96/43	6:00	Wet	47	#2	47
03/12/87	6:01	Wet	47	45	96/43	6:00	Wet	45	#5	47
Nov/87										
11/09/87	9:27	Dry	64	55	87/48	9:00	Dry	51	#2	52
11/09/87	8:55	Dry	57	51	92/48	9:05	Dry	59	#5	54
11/10/87	9:42	Dry	50	44	85/39	8:55	Dry	44	#2	38
11/10/87	9:20	Dry	47	43	84/38	9:10	Dry	38	#5	45
11/12/87	9:05	Wet	52	49	96/47	8:42	Drizzling	50	#2	50
11/12/87	9:05	Wet	52	49	96/47	8:53	Drizzling	50	#5	51
11/13/87	10:07	Wet	56	56	93/53	9:15	Showers	51	#2	55
11/13/87	9:37	Wet	57	54	98/53	9:15	Showers	48	#5	56
11/16/87	9:20	Dry	47	42	91/42	9:52	Dry	39	#2	47
11/16/87	9:25	Dry	47	42	91/42	10:03	Dry	49	#5	48
11/17/87	4:50	Wet	47	46	97/45	6:14	Drizzling	40	#2	47
11/17/87	4:51	Wet	47	46	97/54	6:26	Drizzling	38	#5	48
11/18/87	4:50	Dry	41	40	94/38	6:08	Clear	35	#2	39
11/18/87	10:26	Dry	56	47	95/45	6:18	Clear	39	#5	38
11/19/87	5:00	Absorption	46	42	96/40	5:41	Foggy	47	#2	42
11/19/87	4:25	Absorption	43	42	95/40	6:15	Foggy	45	#5	42
11/27/87	9:15	Dry	35	32	87/28	4:10	Frost	29	#2	30
11/27/87	8:38	Dry	33	32	86/28	4:25	Frost	29	#5	31

TABLE 2
1987-88 WINTER

Ice Detector Sensor Readout							Manual On Site				
			Temp		HUM/				Temp		
Date	Time	Surf Cond	Surf	Air	Dew		Time	Surf Cond	Sensor		Air
12/01/87	3:05	Wet	50	54	52/36		3:00	Rain	48	#2	56
12/01/87	3:13	Dry	49	54	52/36		3:16	Rain	46	#5	57
12/02/87	7:35	Wet	48	47	93/45		7:30	Rain	47	#2	48
12/02/87	7:37	Wet	48	47	93/45		7:36	Rain	48	#5	49
12/03/87	4:18	Dry	49	51	84/46		4:17	Rain	48	#2	48
12/03/87	4:17	Dry	49	51	84/46		4:35	Rain	46	#5	49
12/04/87	3:18	Wet	52	48	90/45		5:20	Rain	41	#2	47
12/04/87	3:27	Wet	51	48	90/45		5:27	Rain	41	#5	47
12/06/87	23:45	Wet	41	40	89/37		6:10	Rain	50	#2	49
12/06/87	23:45	Wet	40	40	89/37		6:13	Rain	49	#5	50
12/07/87	2:07	Wet	40	38	91/35		3:06	Snow	30	#2	37
12/07/87	3:48	Wet	38	38	93/36		3:14	Snow	28	#5	38
12/08/87	4:12	Wet	41	40	93/38		4:00	Rain	40	#2	40
12/08/87	4:13	Wet	41	40	93/38		4:18	Rain	40	#5	41
12/09/87	6:25	Wet	42	41	95/39		6:31	Wet	41	#2	42
12/09/87	6:25	Wet	42	41	95/39		6:38	Wet	40	#5	42
12/10/87	5:07	Wet	49	49	75/41		4:30	Rain	49	#2	48
12/10/87	5:08	Wet	48	48	75/41		4:37	Rain	48	#5	49
12/11/87	3:20	Dry	36	35	92/32		3:15	Foggy	38	#2	35
12/11/87	3:28	Dry	35	34	93/32		3:25	Foggy	39	#5	36
12/13/87	20:42	Dry	31	30	75/23		na	Ice	na	#2	na
12/13/87	20:18	Dry	30	30	76/23		na	Ice	na	#5	na
12/14/87	6:15	Dry	30	30	89/27		5:54	Dry	24	#2	30
12/14/87	6:17	Dry	29	30	89/27		6:04	Dry	22	#5	30
12/15/87	4:25	Dry	38	40	69/30		4:30	Dry	38	#2	41
12/15/87	4:45	Wet	37	41	52/24		4:45	Dry	37	#5	38
12/16/87	3:03	Wet	34	35	93/33		3:00	Wet	32	#2	34
12/16/87	3:25	Wet	33	33	93/31		3:20	Wet	33	#5	34
12/17/87	9:43	Dry	40	37	93/35		0:30	Dry	37	#2	35
12/17/87	9:38	Dry	40	37	93/35		1:00	Dry	36	#5	35
12/20/87	10:33	Dry	40	34	90/31		3:45	Dry	25	#2	32
12/20/87	10:23	Dry	40	34	91/31		3:55	Dry	24	#5	31
12/21/87	0:53	Absorption	38	37	93/35		5:21	Wet	36	#2	38
12/21/87	0:56	Wet	38	37	93/35		5:30	Wet	28	#5	39
12/22/87	3:18	Dry	40	39	92/36		23:30	Dry	37	#2	35
12/22/87	1:21	Dry	40	40	92/37		23:36	Dry	34	#5	36
12/23/87	3:16	Wet	34	34	93/32		4:00	Wet	34	#2	30
12/23/87	4:28	Wet	34	34	93/32		4:15	Wet	33	#5	29
12/24/87	0:36	Dry	31	30	82/25		0:30	Dry	30	#2	29
12/24/87	0:26	Dry	31	30	79/24		0:35	Dry	28	#5	28
12/28/87	4:23	Dry	37	44	48/25		2:15	Dry	30	#2	46
12/29/87	4:58	Dry	32	30	82/25		5:15	Dry	31	#2	33
12/29/87	5:11	Dry	30	30	81/24		5:30	Dry	31	#5	33
12/31/87	5:16	Wet	33	30	95/28		6:00	Wet	33	#2	30
12/31/87	6:53	Snow/Ice	32	30	95/28		6:15	Wet	32	#5	31

manual temperature measurements were recorded and compared to those recorded by the sensor system. It was discovered after recording the data that the manually recorded temperature data is of little value because the manually operated thermometer was only accurate to ± 4°F, while the system's temperature gage is designed to be accurate to ± 0.2°F. Also the manual temperature readings were taken approximately 6 feet from the sensor location. The visual surface condition observations as recorded on Tables 1 and 2 are a better measure of the system's accuracy. In all four cases where ice, snow, or frost were observed on the deck, the sensor readout did not record any adverse condition. In two of these four observations, however, (11/27/87 and 12/13/87) the visual observations were not synchronized with the sensor readouts. These two observations should therefore not be used to evaluate the system. In the other two observations (1/6/87 and 1/7/87), the system should have been able to detect ice or frost. With such a small sample size, however, this result cannot be considered an accurate indication of overall system performance. It does suggest that some calibration of sensors may be necessary. Representatives from SSI corporation have stated that the system is designed and calibrated primarily for use with deicing chemicals. In Oregon, where chemicals are not used, special calibration may be necessary. Even with such calibration, the system may not operate completely as designed without the presence of chemicals.

Although the system did not successfully detect the probability of ice or frost, on the two latter observations discussed above the system came within 1 degree of triggering the "frost" or "ice" warning. On 1/7/87 the dew point was 22 degrees Fahrenheit and the temperature was 23 degrees Fahrenheit. If the temperature had read 22 degrees Fahrenheit the "frost" warning would have been triggered. On 1/6/87 moisture was present at sensor #5 (as indicated by the "absorption" condition reading) and the temperature was only 1 degree above freezing. In either case the calibration of the sensors might have been responsible for the failure to detect ice. Also, a trained observer could have guessed that hazardous conditions were probable in these cases. By looking not only at the "surface condition" but also at the trends in surface temperature and dew point, it is possible to project future conditions. A conservative observer would also be warned that frost is likely whenever surface temperature is below 32 °F and surface temperature is close to the dew point.

Summary of Data 84 total observations

Sensor Readings	Visual Inspection	No. of Times
Wet	Wet	29
Wet	Dry	3
Wet	Snow	3
Dry	Dry	28
Dry	Wet	7
Dry	Fog	2
Dry	Frost	4
Dry	Ice	3
Absorption	Ice	1
Absorption	Fog	2
Absorption	Wet	1
Snow/Ice Alert	Wet	1

60 Accurate readings

5 Questionable readings

19 Unreliable readings

0 Accurate readings involving slick conditions

While it might be concluded from this data that the system is 77% accurate (65/84 x 100 = 77), this percentage reflects mostly dry and wet readings and not its ability to detect ice. There were not enough Snow/Ice Alert observations to determine if the system can be dependable in detecting ice.

OTHER INSTALLATIONS IN OREGON

Five other ice detection systems by the same manufacturer have been installed at other bridge sites in Oregon. Of these, four are still in operation and out of these, three have proven useful and reliable. Two are on major bridges in the Portland metropolitan area which are subject to severe and frequent icing and high winds. A third system is installed on a remote bridge west of Portland in the Coast Range which has a reputation for ice related accidents. A fourth system which is still in operation in Bend appears to be producing accurate readings but because of its proximity to the maintenance headquarters there, it is not actually needed to manage icing conditions.

Fremont Bridge

The only one of these previous installations to have a formal study is the Fremont Bridge system and it was reported to be performing well. The system is particularly useful to maintenance personnel in advising movers of large mobile homes to avoid the bridge during high winds. It is reported to detect the presence of ice, snow, or frost with sufficient accuracy and this information is used to schedule and dispatch sanding crews. Data tabulated in the report shows that the system provided warning 4 times out of the 6 when hazardous surface conditions actually existed.

Glenn Jackson Bridge

Another installation on the Glenn Jackson Bridge, though not formally studied, is also reported to be reliable and accurate in detecting hazardous surface conditions and, like the system on the Fremont Bridge, is used to warn of hazardous winds and to schedule sanding crews.

Quartz Creek Bridge

Also not formally studied or reported, the Quartz Creek Bridge installation is on a remote structure in the Coast Range west of Portland. It is located at a site which is particularly subject to ice and snow accumulation. Prior to installation of the ice detection system, the bridge had a reputation for having frequent ice-related accidents. It is informally reported to be functioning reliably and serves as an indicator of when to turn on an ice warning sign and when to dispatch sanding trucks. No serious ice related accidents have occurred here since the system was installed and system users are fully satisfied.

Swalley Canal Bridge (Bend)

This installation was initially intended to address a public controversy which resulted from an intersection design in which a potentially icy bridge was constructed on a sloping roadway with a traffic light at its base. The ice detection system was originally intended 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. Although the communication failures, which initially plagued this installation, have now been brought under control, it has never been used to change operational procedures. Sanding trucks frequently pass and sand this site while en route elsewhere during icing conditions. The system, regardless of its reliability, therefore does not serve a useful purpose as it now exists. It has been speculated, however, that it could be valuable if anti-icing chemicals were used.

Some elements of the system may also prove worthwhile after current plans are implemented to install a subsurface sensor and connect to the SSI corporation's nationwide pavement forecasting center (the SCAN-CAST system). This sensor will then be used in conjunction with other subsurface sensors to forecast hazardous surface conditions in Bend and on Highway 97 in the vicinity of Lava Butte.

CONCLUSIONS

1. The Medford installation of the SCAN system does not demonstrate the same level of reliability and accuracy that has been experienced in other locations with similar equipment.
2. In addition to the question of accuracy at individual sensor sites, there is also the concern that only 5 sensor sites may be inadequate to represent the worst condition on the entire 3200-foot structure.
3. Because the structure is located relatively close to the maintenance yard, the ice detection system does not greatly enhance maintenance operations.
4. If expensive anti-icing chemicals are used in the future, then this system might prove its value in timing of chemical placement, as proper timing of the application of such chemicals is critical to their effectiveness and economy.
5. Future proposed installations of ice detection equipment should be studied carefully and it should be realistically assessed whether the system will enhance sanding operations or traffic safety.

SUGGESTIONS FOR FUTURE EVALUATIONS

Future evaluations of ice detection systems should concentrate on obtaining a greater quantity of data which relates observed slick conditions (ice, snow, or frost) to system readouts taken at the same time. To assure that both observations are made at the same time, radio contact should be established between the field observer and the computer operator. It may not be necessary to monitor a system every day for the entire winter if a sufficient number of observations can be obtained at or near the freezing or icing condition. Daily temperature fluctuations above and below the freezing point while moisture is present would provide an opportunity to obtain meaningful information in a short time period.

Field checks of sensor accuracy are not essential to system evaluation if adequate comparisons are available between field conditions and readouts. Sensor accuracy data could help, however in the trouble shooting process if the system does not prove to be reliable. If temperature checks are performed, then they should be performed with equipment that is designed for at least plus or minus 0.2 °F accuracy.

Maintenance personnel reporting on ice detection equipment should also document any benefits realized by having the system. These should primarily include any savings in labor and materials, or improved safety resulting from the system.

CURRENT SYSTEM IMPROVEMENTS

Ice detection systems have been available for nearly a decade now and have been improved continuously. Since the Medford system was installed, some significant improvements have become available. The following new types of precipitation and humidity sensors, if installed in the Medford system, might improve its accuracy:

1.) A modified precipitation sensor. The old 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.

2.) A modified relative humidity sensor. The old sensor was a plate that when became dirty would give incorrect recordings of dew which in turn reported "absorption" readings when it should have given "frost" readings. The new relative humidity sensor is made of stretched human hair that detects changes in tension. This technology is reported by the manufacturer to be more dependable.

REFERENCES

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

2. Operations Research Section, "Ice Detection and Road Weather Information Systems: a State of the Art Report" Regional Municipality of Ottawa-Carlton, December 1985