

ELECTRIC HEATING OF I-84 IN LADD CANYON, OREGON

Final Report

SPR 304-461

ELECTRIC HEATING OF I-84 IN LADD CANYON, OREGON

Final Report

SPR 304-461

by

Mark D. Joerger
Felix C. Martinez
ODOT Research Unit

for

Oregon Department of Transportation
Research Unit
200 Hawthorne Ave. SE, Suite B-240
Salem OR 97301-5192

and

Federal Highway Administration
400 Seventh Street, SW
Washington, DC 20590-0003

June 2006

1. Report No. FHWA-OR-RD-06-17		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Electric Heating of I-84 in Ladd Canyon, Oregon				5. Report Date June 2006	
				6. Performing Organization Code	
7. Author(s) Mark D. Joerger and Felix C. Martinez				8. Performing Organization Report No.	
9. Performing Organization Name and Address Oregon Department of Transportation Research Unit 200 Hawthorne Ave. SE, Suite B-240 Salem, OR 97301-5192				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No. SPR 304-461	
12. Sponsoring Agency Name and Address Oregon Department of Transportation Research Unit and Federal Highway Administration 200 Hawthorne Ave. SE, Suite B-240 400 Seventh Street, SW Salem, OR 97301-5192 Washington, DC 20590-0003				13. Type of Report and Period Covered Final Report	
				14. Sponsoring Agency Code	
15. Supplementary Notes					
16. Abstract When highway grades in mountainous areas and superelevation on curved sections are combined with adverse winter weather conditions, these sections of highway can become particularly hazardous for large truck traffic. This report covers the design and installation of a system of electric heating cables in a problem section of interstate highway in eastern Oregon. The area has winter weather conditions severe enough to cause treacherous traction conditions in spite of treatment with sand and magnesium chloride. The heating system covers a bridge deck that transitions to a steep uphill grade while making a superelevated turn and continues for 7,700 ft (2,347 m) up the incline. A section of the report discusses problems with the system and planned upgrades and changes.					
17. Key Words WINTER MAINTENANCE, HIGHWAY SAFETY, WINTER DRIVING, STEEP GRADES, SNOW AND ICE CONTROL, HEATING SYSTEMS				18. Distribution Statement Copies available from NTIS, and online at http://www.oregon.gov/ODOT/TD/TP_RES/	
19. Security Classification (of this report) Unclassified		20. Security Classification (of this page) Unclassified		21. No. of Pages 25	22. Price

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS				APPROXIMATE CONVERSIONS FROM SI UNITS			
Symbol	When You Know	Multiply By	To Find	Symbol	When You Know	Multiply By	To Find
<u>LENGTH</u>							
in	inches	25.4	millimeters	mm	millimeters	0.039	inches
ft	feet	0.305	meters	m	meters	3.28	feet
yd	yards	0.914	meters	m	meters	1.09	yards
mi	miles	1.61	kilometers	km	kilometers	0.621	miles
<u>AREA</u>							
in ²	square inches	645.2	millimeters squared	mm ²	millimeters squared	0.0016	square inches
ft ²	square feet	0.093	meters squared	m ²	meters squared	10.764	square feet
yd ²	square yards	0.836	meters squared	m ²	meters squared	1.196	square yards
ac	acres	0.405	hectares	ha	hectares	2.47	acres
mi ²	square miles	2.59	kilometers squared	km ²	kilometers squared	0.386	square miles
<u>VOLUME</u>							
fl oz	fluid ounces	29.57	milliliters	ml	milliliters	0.034	fluid ounces
gal	gallons	3.785	liters	L	liters	0.264	gallons
ft ³	cubic feet	0.028	meters cubed	m ³	meters cubed	35.315	cubic feet
yd ³	cubic yards	0.765	meters cubed	m ³	meters cubed	1.308	cubic yards
NOTE: Volumes greater than 1000 L shall be shown in m ³ .							
<u>MASS</u>							
oz	ounces	28.35	grams	g	grams	0.035	ounces
lb	pounds	0.454	kilograms	kg	kilograms	2.205	pounds
T	short tons (2000 lb)	0.907	megagrams	Mg	megagrams	1.102	short tons (2000 lb)
<u>TEMPERATURE (exact)</u>							
°F	Fahrenheit	(F-32)/1.8	Celsius	°C	Celsius	1.8C+32	Fahrenheit
<u>TEMPERATURE (exact)</u>							

*SI is the symbol for the International System of Measurement

ACKNOWLEDGEMENTS

The authors would like to acknowledge the members of the Technical Advisory Committee for their oversight and guidance of this study:

Hau Hagedorn, ODOT ITS
Mike Barry, ODOT Maintenance
Curtis Cryer, ODOT Bridge
James D. Garrard Jr., ODOT Bridge

The authors would also like to thank the members of the ODOT Research Unit for their sage advice and technical assistance in the data analysis and preparation of this report.

DISCLAIMER

This document is disseminated under the sponsorship of the Oregon Department of Transportation and the United States Department of Transportation in the interest of information exchange. The State of Oregon and the United States Government assume no liability of its contents or use thereof.

The contents of this report reflect the view 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 or the United States Department of Transportation.

The State of Oregon and the United States Government do not endorse products of manufacturers. Trademarks or manufacturers' names appear herein only because they are considered essential to the object of this document.

This report does not constitute a standard, specification, or regulation.

ELECTRIC HEATING OF I-84 IN LADD CANYON, OREGON

TABLE OF CONTENTS

1.0 INTRODUCTION.....	1
1.1 PROBLEM STATEMENT.....	1
1.2 SOLUTIONS CONSIDERED.....	1
1.3 PROJECT LOCATION AND DESCRIPTION.....	2
1.4 WEATHER CONDITIONS.....	3
2.0 DESIGN.....	7
3.0 CONSTRUCTION.....	9
4.0 SYSTEM PROBLEMS.....	11
5.0 OPERATION AND PLANNED CHANGES.....	13
6.0 CONCLUSION.....	15
7.0 CONTACTS.....	17

List of Figures

Figure 1.1: Project location map.....	2
Figure 1.2: Project grade.....	3
Figure 1.3: Bridge cross-section showing superelevation.....	4
Figure 1.4: Weather conditions in the project area.....	4
Figure 2.1: Bridge and eastbound approach.....	7
Figure 2.2: Cross-section of roadbed showing saw cuts for cable inlay.....	8
Figure 3.1: Electric heating cables on bridge deck.....	9
Figure 3.2: Electric heating cables in tire paths.....	10
Figure 4.1: Damaged heating cables.....	11
Figure 5.1: Melted snow on tire paths due to heating cables.....	13

1.0 INTRODUCTION

1.1 PROBLEM STATEMENT

Highway design is intended to address the different climate, topographical and geometry conditions which may be encountered in the field. In some instances these conditions can be very demanding, and the roadway designer must adjust the design to overcome the challenge. This situation is seen frequently on highways traversing mountain passes. One of the parameters of highway design is the “superelevation” or banking of the roadway to compensate for high speed driving on curved sections. Another such parameter is the grade which, in some elevated areas such as mountain passes, may be as steep as 6%. Although the average automobile driver may not be too concerned by the roadway geometry described above, large trucks can be challenged by a combination of steep grades, small radius curves and steep superelevations. When adverse winter weather conditions are added to these geometric factors, specific sections of highway can become particularly hazardous for large truck traffic.

One such problem section of highway occurs on Interstate 84 a few miles south of La Grande, Oregon in an area known as Ladd Canyon. This area has winter weather conditions severe enough to cause treacherous driving conditions in spite of treatment with sand and anti-icing chemicals. The problem area begins with eastbound traffic transitioning to an uphill grade slightly in excess of 6% while simultaneously making a superelevated left-hand turn that crosses a bridge. This area is particularly susceptible to icing conditions. Trucks typically gear down for the grade at this point, adding to the complexity of the transition.

The typical adverse-weather incident in this area occurs just beyond the bridge, where trucks encounter poor traction conditions and slide across the adjacent lane and shoulder into the center concrete barrier. The highway could be closed several times a year as a result of this type of crash. The adverse weather also would contribute to delays in getting tow vehicles into the area. Each closure could last several hours.

1.2 SOLUTIONS CONSIDERED

The typical response to the problem of poor winter traction is to snowplow the roadway, treat it with sand and anti-icing chemicals, and require vehicles to use traction devices. However, the conditions in the Ladd Canyon area become severe enough that these treatments alone cannot keep the traffic moving safely.

Hot water pavement heating systems were considered as a possible solution. Hot water systems are being used successfully in several areas throughout Oregon. Such a system would be very expensive to retrofit to an existing highway, although the solution would make economic sense if the roadbed required replacement.

The selected solution called for electrical heating treatments of the bridge deck and the right-hand eastbound traffic lane. The bridge deck would have both of the uphill eastbound lanes heated with electric cables embedded within a microsilica overlay. Additionally, the right lane eastbound would have four electric heating cables placed in longitudinal saw cuts in each of the wheel tracks for a short distance preceding the bridge and for the entire length of the steep grade – a total distance in excess of 8,000 ft (2,438 m).

1.3 PROJECT LOCATION AND DESCRIPTION

The project is located on Interstate 84 between mile posts (MP) 270.80 and 272.09, approximately 11 miles south of La Grande, Oregon. In this area, the interstate runs north to south with 2 travel lanes in each direction. The eastbound and westbound lanes are divided by a concrete barrier. Figure 1.1 shows the project location.

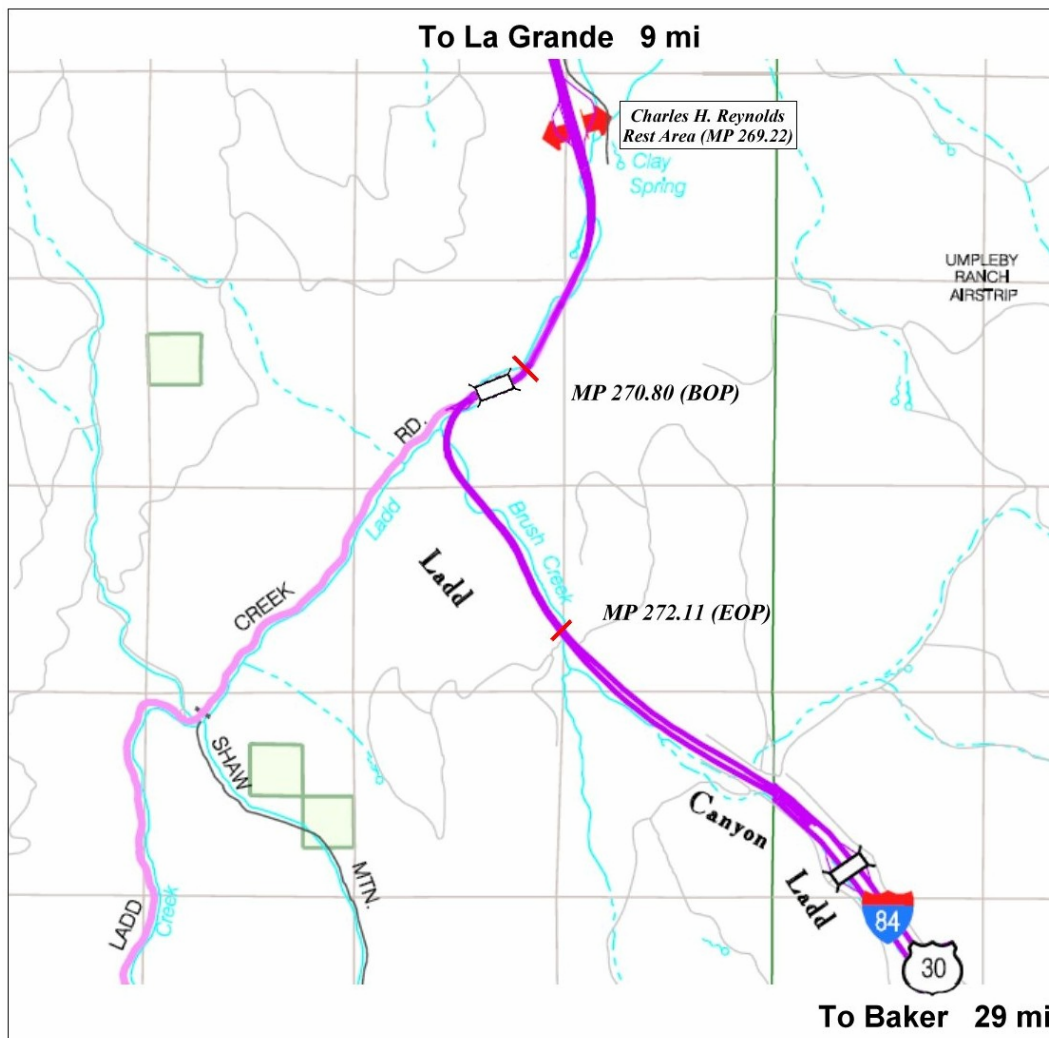


Figure 1.1: Project location map

The lanes are reinforced Portland Cement Concrete (PCC) pavement 12 ft (3.7 m) wide. The left shoulder is made from hot mix asphalt concrete (HMAC) 4 ft (1.2 m) wide. The right shoulder is 10 ft (3.0 m) wide HMAC. The grade throughout the length of the project is very steep and varies only slightly. At the beginning of the project (MP 270.80), the grade is 6.16% (Figure 1.2). At MP 271.05 there is a change to 5.88%, and at MP 271.39 another change to 6.05%. At MP 271.93 the transition from 6.05% to an almost flat grade of 0.82% begins. This transition is 1,200 ft (365.8 m) long and ends at MP 272.16. The average grade for the project is 6.03%.

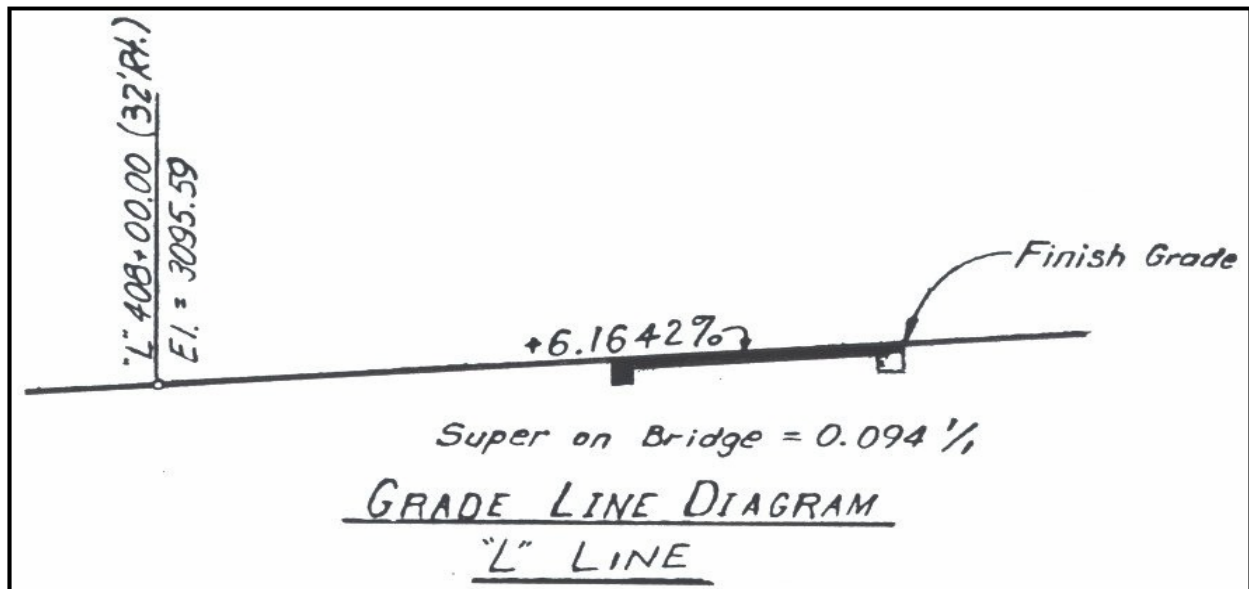


Figure 1.2: Project grade

A box girder structure (Bridge No. 09686) is located at the bottom of the hill (MP 270.87). This structure is 179 ft (54.5 m) in length and 91.5 ft (27.9 m) wide. The depth of the box girders is 4 ft (1.2 m). The bridge is located in the center of a 1,332 ft (406 m) radius turn and has a superelevation across the surface of the deck of 9.4% constant throughout its length. Design speed is 55 MPH. The uphill grade on the structure is 6.16%, which presents a problem for loaded trucks, as they may not be able to meet the design speed. See Figure 1.3 below.

1.4 WEATHER CONDITIONS

The La Grande weather station, 11 miles (17.7 km) to the north and nearly 400 ft (122 m) lower in elevation (at 2,760 ft (841 m)), reports average low temperatures below freezing from November thru March with average snowfall above 3 inches (7.6 cm) in December and January (see Figure 1.4 below).

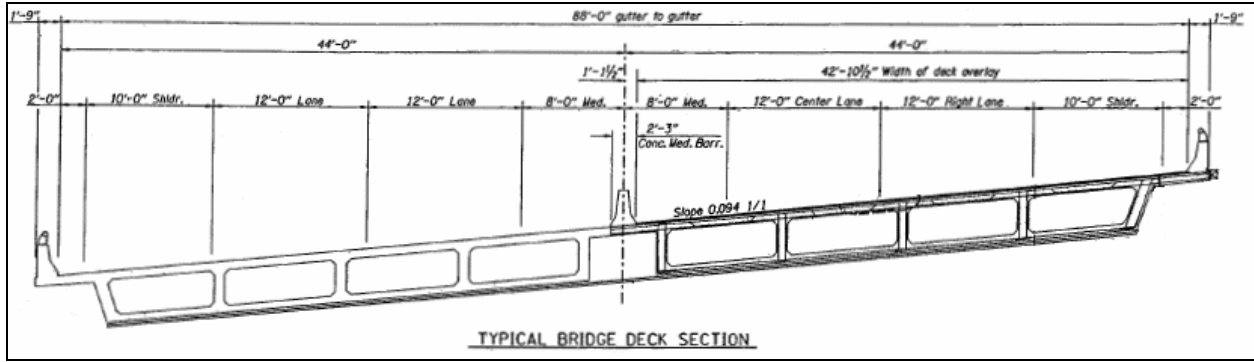


Figure 1.3: Bridge cross-section showing superelevation

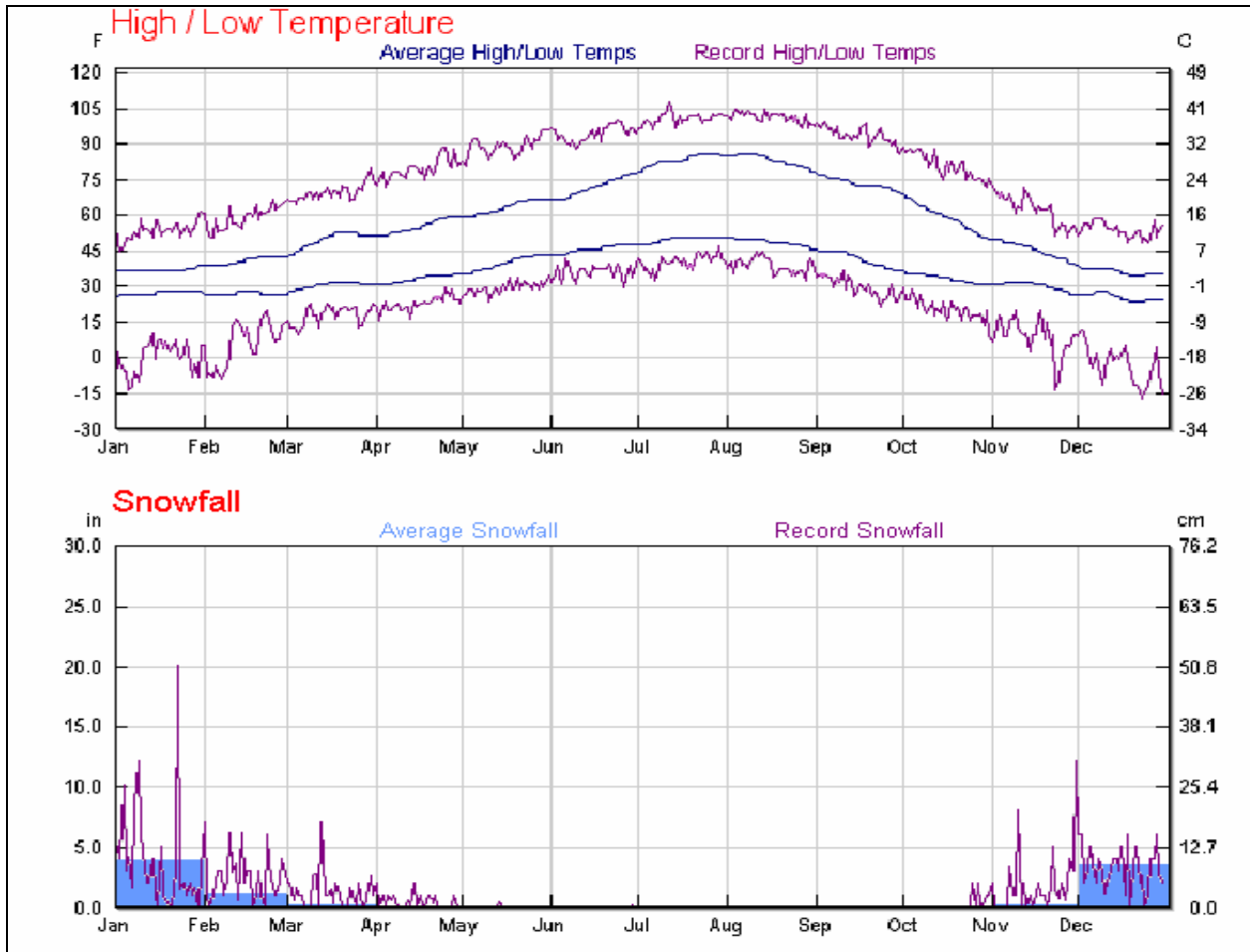


Figure 1.4: Weather conditions in the project area

During the winter season the combination of the parameters mentioned above is a hazard when temperatures drop to freezing levels. Trucks transitioning to the uphill section of the highway shift to lower gears as their speed decreases. At slow speeds the superelevation of the roadway surface exerts a net lateral force to pull vehicles toward the inside of the turn. As the bridge deck and roadway become slippery, trucks may slide sideways across the left shoulder and into the center concrete barrier or spin-out on the grade. This scenario causes several highway closures per year during adverse winter weather conditions, with each closure typically taking several hours to clear.

2.0 DESIGN

The design of the project began with a thermal cable bridge deck microsilica overlay. As the Project Development Team (PDT) looked at the problem in more detail, it became obvious that the heated overlay would only be a partial solution to the problem and that project limits would have to be extended to cover almost the entire length of the steep grade. The bridge and eastbound approach are shown in Figure 2.1.

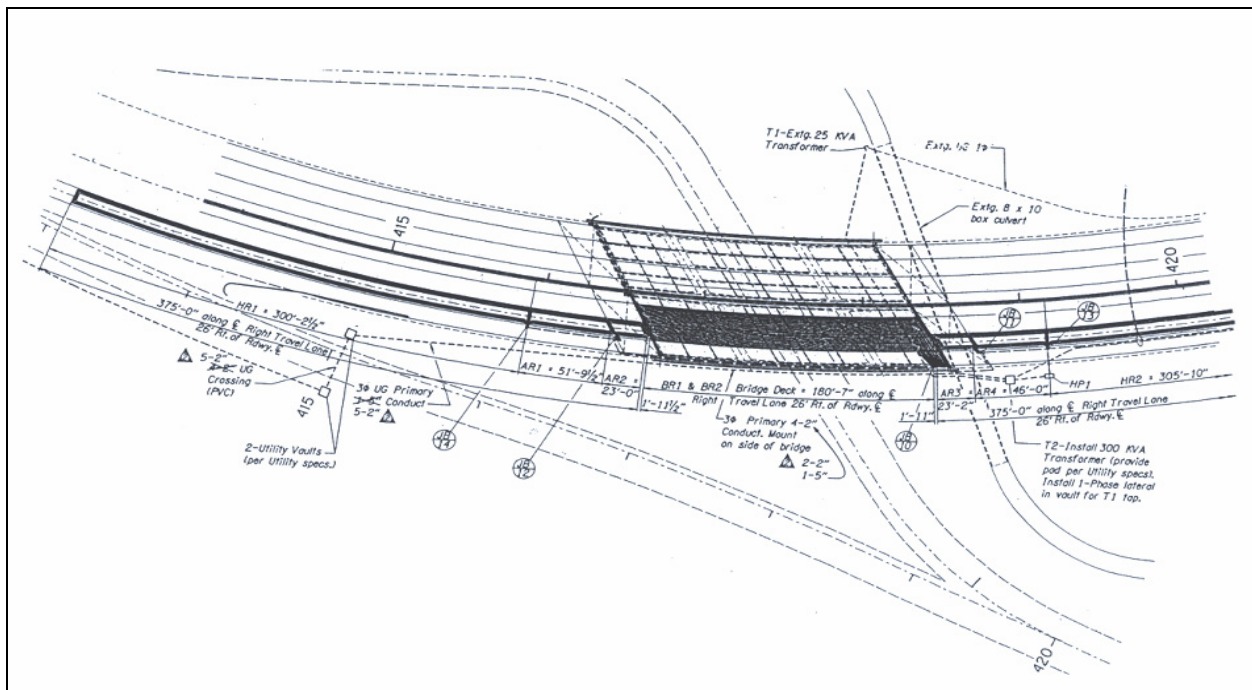


Figure 2.1: Bridge and eastbound approach

Electric thermal cables were laid-out on the bridge deck in non-overlapping rectangular serpentine loops on 9 in (22.9 cm) centers across both eastbound travel lanes. A 1.75 in (4.45 cm) microsilica overlay was placed on top.

For 300 ft (91.4 m) leading up to the bridge, thermal cables were placed into grooves cut into the concrete surface within each wheel track and sealed in place with loop detector sealant (Figure 2.2). This same cabling technique continued for 7,700 ft (2,347 m) beyond the bridge. The project originally called for use of keyway grout to hold the cables in place, but the grout was difficult to work with on the grade, and testing showed that this material was inadequate in completely encapsulating the cable.

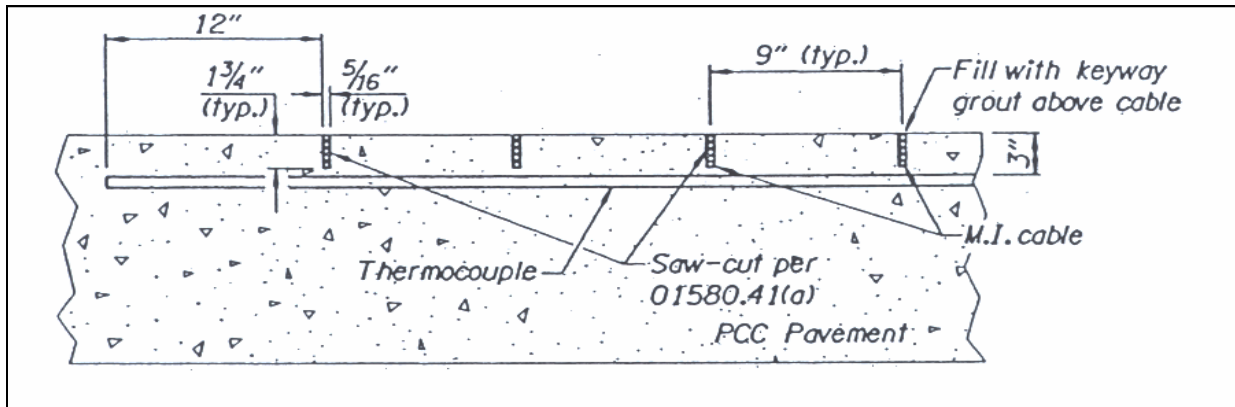


Figure 2.2: Cross-section of roadbed showing saw cuts for cable inlay

Control of the system is automated. A Roadway Weather Information System (RWIS) monitors the pavement temperature by roadway surface sensor 'pucks' located in the pavement and the bridge overlay. These transmit temperature information to the weather activated control system via cable. The RWIS is a programmable processor that enables the entire system to be turned on and off as one unit when specific temperature and moisture conditions exist at the roadway surface. To improve efficiency, local thermocouples are installed in each independent heat cable section and wired to a control in each electric power cabinet to regulate the concrete temperature.

The life of the heating system is estimated at 10 years. Corrosion of hardware is the expected eventual cause of failure due to anti-icing chemicals. Should the roadbed require replacement, a geothermal source heating system will be considered to reduce operating costs. The costs of adding such a system to an existing roadbed are prohibitive.

3.0 CONSTRUCTION

The construction contract was awarded to J. L. Brandt Electric, Inc. on December 22, 2004, with a notice to proceed on January 12, 2005. The Contract Administration/Contract Engineering (CA/CE) was outsourced to W&H Pacific, and Anderson Perry provided the inspection services.

The deck preparation went well, although there were some loose areas of PCC, and some rebar ends had to be removed before the microsilica was placed. Some areas of the existing deck showed delamination, particularly along the edge of the pour. Figures 3.1 and 3.2 show the placement of the electric heating cables.



Figure 3.1: Electric heating cables on bridge deck



Figure 3.2: Electric heating cables in tire paths

The contractor was concerned that there was not enough capacity in the original low voltage design for the middle section of the cables stretching 7,700 ft (2,347 m) up the hill after the bridge. To provide equal power to all heat cables, an additional 3,000 ft (914 m) of underground 3-phase power was proposed and accepted.

As stated in Section 2, the original plans called for the use of Keyway Grout to seal the cables in place. Testing of several grout products, however, determined that they were impractical for this application. Thus 220°F (104°C) melting point Craftco Loop Detector Sealant 271 was selected as a practical product to encapsulate the cables. Cable installation was completed in a month.

The original contract amount was \$1,106,849. A series of 15 construction change orders totaling \$247,159 increased the completed contract amount to \$1,354,008.

4.0 SYSTEM PROBLEMS

There have been minor problems that are, for the most part, due to underlying roadway issues and not related to the installation of the cables.

- Junction boxes have proved difficult to seal and require frequent inspection. Placement of the junction boxes has proven to be problematic, but this is in part a function of the topology of the installation site.
- Two of the four heating cables in the short section north of the bridge are currently non-functional because of traffic damage to the replacement concrete where heat cables enter the junction box (Figure 4.1).
- One of the junction boxes in the roadway was steaming and the heat cable circuit breaker was open. The suspected cause was water permeation of an electrical connection. This junction box will be repaired this summer.
- Thermocouple sensors in the pavement have proven to be difficult to calibrate and are unreliable. The master roadway information system is being used to turn the entire system on and off, resulting in wasted energy.



Figure 4.1: Damaged heating cables

5.0 OPERATION AND PLANNED CHANGES

The system is set to turn on at a pavement temperature of 31.5°F (-0.28°C) and to turn off when the pavement temperature falls below 19°F (-7.22°C). Heating after the temperature drops below 19°F (-7.22°C) is believed to provide no benefit, because the anti-icing chemicals do not function below that temperature.

Figure 5.1 shows the system in operation. The system currently has no data logging capability, so the times and lengths of operation are not known. A data recorder is planned for next season. The cost of electricity for operation during the winter months averages slightly over \$5,000 per month with a peak electric bill of about \$9,000.



Figure 5.1: Melted snow on tire paths due to heating cables

There are some problems associated with pre-existing roadbed conditions and the specific topology of the installation site. There is a microsilica pavement delamination at the south end of the bridge and a pavement failure at the north end of the bridge that is related to a full-depth crack in the panel. The location and waterproofing of junction boxes has proven to be problematic as well.

Future plans call for additional road surface sensors to allow individual sections of the system to be controlled separately by the RWIS. The FP2000 sensor ‘pucks’ have proven to be more useful than the thermocouples for zone control. A proposal for future modification to the system has it operating in three zones, each controlled by the RWIS roadway surface sensor ‘pucks’ that would relay pavement information back to the central controller.

There is currently no local indication when the system is active. Highway maintenance personnel have requested a method by which they can determine when the system is running to

better manage application of anti-icer and other winter maintenance options. A small, inconspicuous light visible from the roadway is planned. Also planned is a hardware upgrade to allow internet monitoring of the system with full data logging.

The system has not yet been exposed to summer heat. There is some concern that high heat may soften the loop sealant and allow the heat cables to 'float' to the surface of the roadway. The 'loop sealant' is not designed for this application, but it is hoped that the material will prove adequate. If the loop sealant proves to be a problem, an asphalt overlay could be used to protect the cable system.

6.0 CONCLUSION

The system is working and keeping the problem roadway section safe; there were no road closures in the area during the 2005-2006 winter season despite the severe weather that occurred in this region. There were no system failures serious enough to impact the function of the system in keeping the structure and road safe. The typical 5-road-closures-per-year due to accidents caused by climate conditions did not occur.

The system has met its goal of improving the safety of the roadway at a reasonable cost. With improvements to the control system, the use of electric heating cables over a long stretch of problematic roadway appears to be a viable tool.

7.0 CONTACTS

For more information on the Ladd Canyon Electric Heating project, contact the following people:

ODOT Bridge Section

Curt Cryer

Project Designer

355 Capitol Street NE
Room 301
Salem, OR 97301
(503) 986-3333

ODOT Maintenance

Michael Barry

District Operations Coordinator

3014 Island Avenue
La Grande OR 97850
(541) 963-8406

ODOT Research Unit

Mark Joerger

Senior Transportation Researcher

200 Hawthorne Ave. SE
Suite B-240
Salem, OR 97301
(503) 986-3464

Felix C. Martinez

Research Coordinator

200 Hawthorne Ave. SE
Suite B-240
Salem OR 97301
(503) 986-2848

