TREATMENT OF BLACK ICE ON A MAJOR FREEWAY


ABSTRACT

The Calder Highway between Melbourne and Bendigo is being upgraded to provide a high standard highway or freeway and to date, approximately 110 km of the 150 km project has been completed. The highway crosses the Great Dividing Range between Gisborne and Kyneton at an altitude of approximately 610 metres. The old highway was generally four lane undivided and was regularly subject to black ice as well as frost and snow. Black ice in this region is often extreme in winter and causes a large number of accidents. Winter conditions present dangerous and icy conditions for motorists. The Black Forest Section is particularly prone to the formation of ‘black ice’.

Black ice may be defined as a thin, clear layer of ice on a pavement. The fact that the ice is clear means that the ice is largely invisible. Black ice can form when the air, dew point and pavement are at or near freezing. Fog adds to the problem, as the air is warm and full of moisture, compared to the frozen ground surface.

VicRoads engaged CSIRO to carry out thermal imaging of the highway during extreme conditions. The study highlighted various areas that were subject to black ice and in conjunction with local knowledge was used to determine possible treatments. The study confirmed that in extreme conditions, bridge decks are colder than adjacent road pavements and also highlighted that areas subjected to shade, such as where trees were overhanging or sections of road in deep cutting, were also far more susceptible. The study also confirmed that where pavements had good surface drainage, the formation of ice was less likely.

Following detailed consideration of alternative treatments, it was agreed to electrically heat various bridges along the route where black ice was known to be a problem. A system of sensors measuring both atmospheric and surface temperature conditions is used to predict when ice is likely to form. These sensors automatically switch on the bridge deck heating maintaining their surface temperature above 0°C. In addition to the deck heating system an integrated ice warning system has been installed. This system incorporates signs with flashing messages and lights, which are again turned on automatically to warn motorists of the likely presence of ice on the road pavements. Other measures also undertaken to minimise black ice on the freeway were developed to ensure good surface drainage, minimise the area of pavement in shade and to trial a length of open graded friction course asphalt to determine its effectiveness in reducing surface moisture.

The system has proven to be very successful, and at the time of writing, no accidents related to black ice have occurred since the opening of these sections of freeway.
INTRODUCTION

This paper describes the measures taken to mitigate the effects of black ice, frost and snow on a section of the Calder Freeway between Gisborne and Kyneton.

VicRoads primary objective in mitigating the effects of black ice was to reduce the number of accidents attributed to the formation of ice on the road surface.

A number of possible measures were considered during the planning process for the freeway upgrade in response to the existing highway’s winter accident record. The primary measure adopted was the design and implementation of a fully automated bridge deck heating and ice warning system however attention was also paid to minimising shade and surface water on the new freeway as further means of reducing the accident risk.

BACKGROUND

The formation of black ice on road surfaces is a worldwide traffic safety problem including Australia. In Victoria, black ice occurs regularly on only a few major highways and only when certain weather conditions prevail.

The Calder Freeway between Melbourne and Bendigo crosses the Great Dividing Range near Woodend at an altitude of approximately 610 metres. The road is regularly subject to black ice as well as frost and snow. Black ice in this region is often extreme in winter and causes a large number of accidents. (See Photo 1)

Black ice may be defined as a thin, clear layer of ice on a pavement. Black ice can form when the air, dew point and pavement are at or near freezing. Fog adds to the problem, as the air is warm and full of moisture, compared to the frozen ground surface. The fact that the ice is clear means that the ice is largely invisible.

The Calder Freeway between Gisborne and Kyneton is being delivered in 3 sections

<table>
<thead>
<tr>
<th>Section</th>
<th>Length</th>
<th>Cost</th>
<th>Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Forest Section</td>
<td>6.8 km</td>
<td>$46.0M</td>
<td>3/2000</td>
</tr>
<tr>
<td>Woodend Bypass</td>
<td>13.0 km</td>
<td>$85.0M</td>
<td>12/2001</td>
</tr>
<tr>
<td>Carlsruhe Section</td>
<td>6.2 km</td>
<td>$46.0M</td>
<td>12/2003 (Expected)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>26.0 km</td>
<td>$177.0M</td>
<td></td>
</tr>
</tbody>
</table>

Work commenced on the Black Forest Section in December 1997 and it is expected that the Carlsruhe Section will be completed during December 2003.

It should be noted that the Black Forest Section and the Woodend Bypass were construct only contracts with the design undertaken by VicRoads design, whilst the Carlsruhe Section is a design and construct contract.

In 1993, VicRoads commissioned the Bureau of Meteorology to carry out a Meteorological Study during the planning study for the Woodend Bypass. The report noted the following:

- Radiation inversions are more likely to occur in valleys. Inversions minimise the wind, which in turn allows a faster rate of cooling and therefore lower temperatures.
- Since creeks often run in valleys there is usually ample moisture for the formation of fog and/or ice.
- Frost occurs wherever the ground temperatures drop below 0°C. Consequently, the valleys may be susceptible to frost, particularly when there is insufficient moisture for the formation of fog.
- Higher elevations also cool very rapidly and experience sub zero ground temperatures readily. These areas are also often subject to frost.
Elevated road surfaces, such as bridges and overpasses, radiate heat more rapidly and effectively than road surfaces at ground level because they can radiate heat in all directions. Air passing beneath bridges can also remove heat via conduction. As such, bridge structures may experience black ice development at lower altitudes than roads in general because they lose heat more rapidly and therefore reach lower temperatures.

Anecdotal evidence obtained from local emergency service coordinators suggested that in their experience, they had witnessed the formation of ice and precipitation as snow more frequently at or above the 580m contours.

The Bureau of Meteorology Study recommended that VicRoads carry out thermal mapping to more accurately determine “cold spots” along the freeway routes.

VicRoads commissioned CSIRO to carry out thermal mapping of the Calder Corridor to determine which areas were more frost prone. The study was conducted in 1995 and reached a number of conclusions as follows:

- Black ice formation requires persistent temperatures below 0°C and the presence of moisture (e.g. freezing rain, snow, dew, or water)
- Black ice formation is most prevalent in the extreme/wet condition (typically a clear night following the passing of a cold front)
- The formation of ice is affected by the road surface, proximity of trees and the presence of moisture
- Bridge decks were generally up to 1.5°C colder than the adjacent roadway

Due to the accident record associated with extreme weather conditions including ice, and taking into account the above findings, VicRoads undertook to do the following on these sections of Freeway:

- Ensure good surface drainage to prevent the retention of surface water, which may freeze.
- Ensure that landscaping was carried out to minimise tree overhang thus minimising variable pavement temperatures.
- Install a length of open graded friction course asphalt to determine its benefit in reducing surface moisture and therefore the potential for ice formation.
- Install a bridge deck heating system on all freeway bridges and certain overpasses to ensure that these bridges remained above 0°C and therefore frost-free.
- Install a network of Ice Warning Signs to warn motorists of the likely presence of ice on the adjacent road pavements.

**DESIGN ISSUES**

VicRoads carried out the detailed design for the first two sections of freeway. Each of the above undertakings presented certain design issues. These are described as follows:

**Surface Drainage**

Freeways are built to a higher standard than other classes of road. Consideration was given to altering the standards relating to super elevation to facilitate surface drainage, however it was found that the standard 3% minimum cross fall was sufficient to ensure that water drained effectively from the road surface. Further consideration was also given to the location of super elevation transitions. This project has not altered any standards relating to this but has taken care to minimise flat spots by ensuring that these transitions where possible did not combine with other geometrical elements such as vertical curves and cross fall to produce flat spots. VicRoads also placed strict tolerances on surface level and rideability, which ensured that the final road surface was as free from surface water as practicable. An area of further research may be to investigate the benefits obtained from shortening super transition lengths or steepening crossfall to further facilitate surface drainage.
Landscaping

The existing section of the Calder Highway through the Black Forest had many trees close to the road, which placed large sections of the pavement in shade until later in the day. This prevented the sun from heating the pavement thus increasing the length of time that ice was present when the conditions were right for the formation of ice. In its design of the freeway sections, VicRoads took care to ensure that trees were not planted close to the road pavement. VicRoads policy is to plant no trees within 9m of the travel path for safety reasons. In this instance trees were kept even further back to ensure that the amount of pavement in shadow was minimised. Whilst it can be argued that trees do provide some level of insulation to the road surface, it was felt that due to the climate in this area, frost would still form under the trees, particularly on very cold nights. It was therefore concluded that the presence of the trees adjacent to the roadway would not only be a safety hazard themselves but the shade would prevent the pavement from warming therefore creating hidden patches of ice which would create even further risk of accident.

Open Graded Friction Course Asphalt Trial

VicRoads were required to place extensive amounts of open graded friction course asphalt (OGFC) to ensure compliance with its noise policy. The placement of this asphalt has allowed the further study of the effectiveness of this form of asphalt as a means of reducing surface moisture and therefore ice. The open graded nature of the asphalt mix allows water to run off beneath the surface of the asphalt further reducing surface moisture. Whilst no detailed investigation of this asphalt has taken place, visual observation of this section to date indicates that this type of asphalt assists in reducing surface moisture, which in turn reduces vehicle spray and the likelihood of ice on this section of pavement.

It is known that over time the pores within OGFC asphalt tend to clog, reducing both its effectiveness as a noise reducing measure as well as its ability to remove moisture from the surface. It is possible that as the pores begin to clog, moisture will begin to be trapped within the asphalt. Further consideration and possible further research should be done into the effects that freezing and thawing have on this type of asphalt and its long-term viability and cost-effectiveness.

The OGFC on the Black Forest Section of the Calder Freeway has now been in place for 3 years and continues to be effective.

Freeze thawing of the pavement itself should not be an issue provided that water is prevented from entering the pavement. In this instance the surface of the road beneath the asphalt, was sealed to prevent water from penetrating. Furthermore, it is standard practice in Victoria to construct flexible pavements using a boxed pavement where the sides and base of the pavement are further prevented from moisture ingress through the use of impervious type a fill.

Bridge Deck Heating System

As described above, bridges are more prone to freezing due to their greater surface area and lack of thermal mass. A variety of means of preventing the formation of ice were considered. These included:

- Electrical heating
- Gas heating
- Groundwater circulation through bridge decks,
- Spraying water and/or anti freezing agents onto the bridge deck surface
- Solar heating
- Thermal insulation

Thermal insulation would be of value on existing bridges and was considered on this section of freeway. It was not used however, as the benefit when combined with more active prevention
measures, was considered to be minimal and not cost effective. Insulation of the underside of
the bridge will only go part way to removing the problem and thermal modelling is
recommended to ascertain the benefits of such a treatment. Of the remaining options, the
electrical heating option was considered to be the best option in terms of costs and local
expertise to install and maintain the system. As such it was decided to install electrical heating
elements in each of the freeway bridge decks that could be turned on in cold conditions to
maintain the road surface temperature on the structure above 0°C. The following is a brief
description of the system. (See Figure 1)

Deck heating elements

- A series of three (3) electric heating cables were installed at 100mm centres in a grid
  fashion above the top deck reinforcement in the specified bridge decks. These cables
  combine to heat the deck by providing up to 190 watts of electricity per m² of deck area.
  A duplicate cable is provided for each of these three circuits. The duplicate cable is not
  connected and is purely for back up in the event of a cable failure that cannot be
  repaired. (See Photo 2)
- The deck heating cables terminate in the bridge parapets where they are connected to
  “cold tails”. Cold tails are non-heating electrical cables and as such do not require
  100mm spacing. These cables then run through conduits back to the main deck heating
  control box.
- Due to voltage losses, each circuit has a maximum length of approximately 100m. As
  such most bridges were divided into sections with their own circuits. These were
designed to coincide with the deck pour sequence.

Weather sensors

- Each deck heating location has the following sensors.
  - Air temperature,
  - Wind Speed
  - Dew Point Calculator – measures and/or calculates dew point, wet bulb
    temperature, air temperature and relative humidity
  - Bridge deck surface temperature

Note: -
- The dew point is the temperature to which the air must be cooled, for the water
  vapour it contains to condense in the form of dew. If the dew point is below the
  freezing temperature of water, water vapour turns directly into ice. This is
  known as frost.
- Wet-bulb temperature is the temperature that would be measured by an ordinary
  liquid-in-glass thermometer with (1) water on its liquid-reservoir "bulb" (the
  "wet bulb"); and (2) air blowing steadily past it. It is the lowest temperature
  achievable solely by evaporating water into the air.

- It is planned during Summer 2002/03 to also install road surface temperature sensors to
  further assist in the prediction of ice on the adjacent freeway pavements
- With the exception of the bridge and road surface sensors, the atmospheric sensors are
  located within the deck heating control box.

Control Software & Switching

- The deck heating control box contains an industrial computer and modem with back up
  power supply. Each location is connected to mains power supply and the telephone
  network. The back up power supply is sufficient to run the computer and modem for up
  to 20 minutes, which would be sufficient to ensure that the Traffic control room
  receives the required power fail signal. Back up power supply for the deck heating was
  considered far too impractical and costly
- Each computer is loaded with custom written software, which interprets the weather
  sensor information and predicts the likelihood of ice being present on the road and/or
  the bridge decks.
The control software performs all communications, switching and data logging and is able to be remotely accessed to download data logs or to view current conditions.

All data from the temperature sensors is logged on the hour, every hour and is stored in a structured text file for easy importation into a spreadsheet for further analysis and graphing. A second log file records all activity i.e.: all communications and events such as frost detect or deck heating = On.

The control software is able to be remotely accessed to download data logs or to view current conditions.

The logs have sufficient memory to store approximately 4 months data.

The current algorithms for the prediction of ice formation are as follows:

- If $T_w < 2.0^\circ C$ and $T_{dp} < 1.5^\circ C$ then set Frost Alert = On
- If Frost Alert = On and $T_{bridge} < 3.0^\circ C$ then set Deck Heating = On
- With the addition of a road temperature sensor these algorithms will be altered and will continue to be fine tuned under operating conditions to ensure a good match between predicted and observed road conditions.

The settings for turning elements off are currently set as follows:

- If $T_w > 2.5^\circ C$ and $T_{dp} > 2.0^\circ C$ then set Frost Alert = Off
- If Frost Alert = Off and $T_{bridge} > 4.0^\circ C$ then Set Deck heating = Off

The following symbols apply to the above formulae:

- $T_w$ = Wet Bulb temperature
- $T_{dp}$ = Dew Point Temperature
- $T_{bridge}$ = Bridge Surface Temperature

When the above formulae returns a value of Deck heating = On, the system automatically turns on the deck heating cables for that bridge site. The bridge deck heating will remain on until the flag Deck heating returns to Off mode. Each bridge deck operates independently and is only operational when the above formulae are true, based on the conditions at that site. (See Photo 3)

Communications

VicRoads Central Traffic Control & Communications Centre (TCCC) is notified via the modem of the following:

- Frost Alert = On (This condition, indicates that ice is likely to be present)
- Frost Alert = Off (This condition, indicates that ice is not likely to be present)
- Deck Heating = On
- Deck Heating = Off
- Power Failure
- Communications Failure

All of the above messages appear on the control room operator’s computer screen. The operator then advises the relevant authorities and media.

TCCC computers regularly check each station to ensure that communication lines are operational.

All messages received by TCCC are logged for audit purposes

Ice Warning Signs

Ice warning signs are located along the freeway at regular intervals. The purpose of these signs is to alert drivers to the possibility of ice being present based on the conditions recorded at each of the weather and road surface monitoring stations. These signs operate independently from the bridge deck heating and aim to warn motorists about ice forming on the roads and not necessarily the bridges as these are heated to prevent ice formation. These signs operate on mains power and do not have back up power supply due to the cost involved. It should be noted
however that in the event of a power failure, the computers, which do have a back up power supply, would notify TCCC. TCCC would then be able to mobilise repair crews and/or notify the relevant media if it was considered that there was a risk of ice being present. Static signs are also available to be placed at each sign location warning the motorists that the ice warning signs are not operational.

**Sign layout & Message**

The Ice warning signs are mounted on frangible pole assemblies, are yellow and black and have both a static and variable message component as follows:

- 2x240W amber flashing lights. These lights alternate such that one light is visible at all times.
- Slippery symbol with the words “WHEN ICY” beneath.
- Beneath this, is a message board, which alternately flashes the preset messages “USE LEFT LANE” and “40km/h” when operational. ([See Photo 4](#))

**Operation**

- Upon receipt of Frost Alert = On – the relevant ice warning signs are automatically contacted and turned on.
- If the flag Frost Alert = On, then VicRoads Traffic Control & Communications Centre (TCCC) is notified via the modem. TCCC computers then automatically dial the ice warning signs and turn them on.
- The ice warning signs are grouped together in zones such that when a control station within that zone detects Frost Alert = On, all ice signs within that zone will turn on. These signs will remain on until all frost alert flags have been cleared from all sites within that zone.
- Staff have the ability to manually override the signs regardless of the flag status to turn the signs off or on as required.

**Communications**

- VicRoads Central Traffic Control & Communications Centre (TCCC) is notified via the modem of the following: -
  - Sign = On
  - Sign = Off
  - Power Failure
  - Communications Failure

- All of the above messages appear on the control room operator’s computer screen. The operator then advises the relevant authorities and media.
- TCCC computers regularly check each sign to ensure that communication lines are operational.
- All messages received by TCCC are logged for audit purposes

**CONSTRUCTION ASPECTS**

During the installation of the Ice Warning and Deck Heating System, a number of issues arose which were dealt with as follows:

**Power Supply**

The deck heating component of this system has the potential to consume large amounts of electricity. As such, dedicated transformers were installed as close as possible to each site. From the transformer the power cables lead into a distribution cabinet, which contained the relevant power supply meters. Careful planning and liaising with the local electricity supplier was required to ensure that the right size transformers were provided, and that sufficient conduits were placed during construction.
It was a requirement that all meters be located in safely accessible locations. This precluded using the deck heating control boxes located in the median at each bridge site.

**Telecommunications**

Each deck heating control site required a unique phone line, as did each of the Ice Warning Sign locations. Careful planning with Telstra was required to ensure that sufficient capacity was available in the phone network and that sufficient conduits were placed during construction to provide telecommunications to all of the required points.

**Conduits in the Bridge Structure**

The size and number of cables required for each bridge meant that for certain bridges additional conduits were required to be placed within the structure. This was a particular issue for the longer bridges. Due to restrictions on the maximum length of any one circuit, the number of cables needing to be returned back to the controller to complete circuits became quite large.

**Placement of Sensors**

**Sensors in Controller Cabinet**

As described previously, most sensors are placed inside the controller cabinet. This location was chosen for security reasons. It was discovered later, that sensors needed to be located well away from any electrical cable such that the heat that these cables emit would not affect them. As such all sensors are now located in the very top of these cabinets with the electrical cables being located primarily towards the bottom. Independent checks of these relocated sensors show that they now operate correctly when the deck heating is operational.

**Sensors in Bridge Decks**

The deck heating sensors were placed inside a conduit located beneath the top reinforcement. Experience has shown that this location does not give a true reflection of the actual surface temperature. These sensors are currently being reinstalled within the top 30mm of asphalt surfacing.

**Operation in low temperatures**

Industrial PC’s and modems, capable of operating in sub zero temperatures have been used. In addition to this, low voltage condensators, which provide a low level of heating, have been installed adjacent to the PC’s in each of the cabinets to ensure their continued operation in extreme conditions.

**Installation of Heating Cable**

Two cables should not be placed closer than 100mm from each other, otherwise a hot spot and potential malfunction may develop. Furthermore, to ensure the heat is evenly distributed throughout the deck, cables should not be placed further apart than 100mm from each other. To assist in ensuring that the 100mm spacing was adhered to, the Contractor placed a 100mm fine mesh on top of the top deck reinforcement to tie the cables to. This mesh also provided additional support to the cables during the deck pour but did not add significantly to the thickness of the deck. (See Photo 2)

During the deck pour, the resistivity of all circuits was continuously checked to ensure that no breakages occurred. (See Photo 2)

**OPERATION**

The Black Forest Section has now been in operation for two full winters with the Woodend Bypass having had one full winter in operation. The Carlsruhe Section is yet to be completed.
Testing of System Capabilities

Over the last two winters there have been sufficient cold nights to fully test the system. During the winter period, the data logs were regularly checked and compared against independent weather data obtained from a portable weather station. These checks were carried out to verify the accuracy of the installed sensors. Surface temperature readings were also taken during extreme weather conditions using an infrared thermometer. The surface temperature checks verified the CSIRO conclusions that bridge decks were up to 1.5°C cooler than the adjacent road surface.

The system has been running satisfactorily with most “bugs” now removed from the software. Fine-tuning of the ice prediction formulae has occurred with further modifications and sensor upgrades to be carried out prior to winter 2003.

ACCIDENT HISTORY

The following table shows the relevant accident histories for each of the three sections of freeway.

**Calder Highway Accident Statistics 1987 - 2002**

<table>
<thead>
<tr>
<th>Road Section</th>
<th>Total # of Accidents</th>
<th>Total Casualty Accidents</th>
<th>Icy Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Serious</td>
<td>Other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fatal</td>
<td>Injury</td>
</tr>
<tr>
<td>Black Forest Section</td>
<td>11</td>
<td>49</td>
<td>86</td>
</tr>
<tr>
<td>Woodend</td>
<td>3</td>
<td>28</td>
<td>80</td>
</tr>
<tr>
<td>Carlsruhe</td>
<td>5</td>
<td>23</td>
<td>47</td>
</tr>
<tr>
<td><strong>Subtotal - Old Road</strong></td>
<td><strong>19</strong></td>
<td><strong>100</strong></td>
<td><strong>213</strong></td>
</tr>
<tr>
<td>BF &amp; Woodend Fwy</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Road Section</th>
<th>Total # of Casualties</th>
<th>Total Casualties</th>
<th>Icy Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>Serious</td>
<td>Other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fatal</td>
<td>Injury</td>
</tr>
<tr>
<td>Black Forest Section</td>
<td>13</td>
<td>84</td>
<td>174</td>
</tr>
<tr>
<td>Woodend</td>
<td>3</td>
<td>35</td>
<td>128</td>
</tr>
<tr>
<td>Carlsruhe</td>
<td>7</td>
<td>43</td>
<td>93</td>
</tr>
<tr>
<td><strong>Subtotal - Old Road</strong></td>
<td><strong>23</strong></td>
<td><strong>162</strong></td>
<td><strong>395</strong></td>
</tr>
<tr>
<td>BF &amp; Woodend Fwy</td>
<td>1</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

As can be seen in the above table, since the opening of the Black Forest Section in March 2000 and the Woodend Bypass in December 2001, there have been no ice related accidents on either of these two sections of freeway.

COSTS

The following table provides a summary of costs of the deck heating and ice warning systems for each of these sections:

<table>
<thead>
<tr>
<th>Freeway Section</th>
<th>System Installation Costs</th>
<th>Electrical Infrastructure Costs</th>
<th>Estimated Annual Running Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Forest Section</td>
<td>$783,000</td>
<td>$346,000</td>
<td>$27,400</td>
</tr>
<tr>
<td>Woodend Bypass</td>
<td>$1,322,000</td>
<td>$628,000</td>
<td>$50,300</td>
</tr>
<tr>
<td>Carlsruhe Section</td>
<td>$771,000</td>
<td>$151,000</td>
<td>$28,600</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$2,876,000</strong></td>
<td><strong>$1,125,000</strong></td>
<td><strong>$106,300</strong></td>
</tr>
</tbody>
</table>
System Installation costs
Supply and installation of cables, conduits, signs, deck heating controller boxes, software, sensors, commissioning and testing

Electrical Infrastructure costs
Provision of telecommunications, electricity supply and distribution boxes

Annual Running costs
Anticipated electricity charges. These have been calculated based on thermal modelling using a worst-case scenario of historical climate data for the area. Actual costs for the Black Forest and Woodend Sections have come in at a fraction of these costs over the last two years

BENEFIT COST RATIO
Thoreson (1998) provides the following estimates of the costs of accidents in rural Victoria.

Rural Victorian Unit Accident Costs (30 June 1998 prices)

<table>
<thead>
<tr>
<th>Accident Severity</th>
<th>Unit Accident Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatality</td>
<td>$1,064,000</td>
</tr>
<tr>
<td>Serious Injury</td>
<td>$292,000</td>
</tr>
<tr>
<td>Other Injury</td>
<td>$20,200</td>
</tr>
</tbody>
</table>

Using the above accident rates as a basis and the Rural Victorian Unit Accident Costs provided by Thoreson the system will have a return on investment period of 15 years and over a period of 20 years will have a BCR of 1.22 provided that ice related accidents on the new sections of freeway, continue to remain low.

CONCLUSION
Ice has been successfully minimised on the Calder Freeway by using a bridge deck heating and ice warning sign system, which provides a high quality interactive warning and prevention system for the treatment of black ice on a major freeway. This system has now been operational in parts for over 2 years and to date there have been no ice related accidents on these sections of freeway. Although expensive to install, over the last two years this system has provided a low cost preventative measure for ice related accidents. If, as expected, the number of ice related accidents continues to be far less than before, the system will return its investment costs within 15 years.

REFERENCES


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- Mr A. Williams, A.J. Williams Electrical Contractors

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AUTHOR BIOGRAPHIES

Andrew White obtained his Bachelor of Civil Engineering from the University of Melbourne in 1988. He has recently completed a Graduate Diploma of Business Management from Deakin University. Since 1989, Andrew has been employed by VicRoads on a variety of construction projects in both urban and rural areas of Victoria where his duties have ranged from financial and project monitoring to the management of road and bridgeworks in both construct only and design and construct contracts. Andrew has also spent two years working with local government in Massachusetts, USA. He is currently the Team Leader – Construction on the Calder Corridor Project responsible for the upgrade of the Calder Highway linking Melbourne and Bendigo in the state’s North West.

Richard Warwick obtained his bachelor of Civil Engineering from the Swinburne Institute of Technology. He has also completed a Master of Business Administration from Deakin University. Since 1974, Richard has been employed by VicRoads on the design and construction of a wide range of roadworks projects. Apart from four years in the design area, he has spent the rest of his career on the construction and maintenance of roads and bridges in both urban and rural areas, including several major projects in the metropolitan area of Melbourne. He was until recently the Project Manager on the Calder Corridor Project and is currently the Project Manager of the Eastern Freeway Project in Melbourne’s eastern suburbs.

John Baldock obtained his Diploma of Engineering from the School of Mines and Industries, Ballarat. Since 1970, John has been employed by VicRoads on the design and construction of a wide range of roadworks projects. Apart from a number of years in the bridge design area, he has spent the rest of his career on the construction and maintenance of roads and bridges in rural areas, including several major projects on the Hume and Calder Freeways. He is currently the Acting Project Manager on the Calder Corridor Project responsible for the upgrade of the Calder Highway linking Melbourne and Bendigo in the state’s North West.
Figure 1
Photo 4

When icy

Use left lane