INVESTIGATION OF USING ICEPHOBIC COATINGS ON A CABLE STAYED BRIDGE

Ahmed Abdelaal, Clinton Mirto, Douglas Nims, Tsun-Ming Ng - University of Toledo – University Transportation Center
Kathleen Jones and Charles Ryerson – US Army Cold Regions Research and Engineering Laboratory
Victor Hunt and Art Helmicki, University of Cincinnati – Infrastructure Institute
Outline

• Icing problem
• Veterans’ Glass City Skyway Bridge and Icing
• Anti/de-icing technologies and selection
• University of Toledo testing facilities
• Coating testing indoor and outdoor
• Other Anti-/de-icing Techniques
• Real time monitoring system(Dashboard) and sensor development
• Conclusions
Icing problem

Ice accumulation on the east side of VGCS

Ice accumulation pattern on VGCS stays

Ice shed from the stays
Icing problem

Cable stayed bridges in the United States and lower tier of Canada and map of footprints of damaging ice storms (1946-2014)

Legend
- Red = Open to Traffic
- Yellow = Under Construction
- Orange = Proposed

Cable stayed bridges in the United States and lower tier of Canada and map of footprints of damaging ice storms (1946-2014)
Veterans’ Glass City Skyway Bridge

• Veterans’ Glass City Skyway (VGCS) is a large single pylon cable stayed bridge in Toledo, Ohio, USA with a main span of 375m

• Stay sheaths are brushed stainless steel

• Three lanes of traffic in each direction with average daily traffic count of 50,000

• Owned and operated by the Ohio Department of Transportation (ODOT) and opened to traffic in 2007
Veterans’ Glass City Skyway Bridge

Veterans’ Glass City Skyway

Veterans’ Glass City Skyway’s illuminated glass pylon
Veterans’ Glass City Skyway Bridge and icing

<table>
<thead>
<tr>
<th>Ice Event</th>
<th>Ice Accretion</th>
<th>Ice Shedding Trigger</th>
<th>Ice Persistence (Days)</th>
<th>No. of Lanes Closed</th>
<th>Damaged Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec 2007</td>
<td>Freezing rain, fog</td>
<td>Rain with temperature above freezing</td>
<td>2</td>
<td>2</td>
<td>Yes</td>
</tr>
<tr>
<td>Mar 2008</td>
<td>Snow, rain, fog</td>
<td>Sun with temperature above freezing</td>
<td>1</td>
<td>2</td>
<td>Yes</td>
</tr>
<tr>
<td>Dec 2008</td>
<td>Snow, fog; freezing rain, fog</td>
<td>Rain, gusty winds and temperatures above freezing</td>
<td>7</td>
<td>2</td>
<td>No</td>
</tr>
<tr>
<td>Jan 2009</td>
<td>Freezing rain, fog</td>
<td>Gusty winds, temperature above freezing</td>
<td>10</td>
<td>1</td>
<td>No</td>
</tr>
<tr>
<td>Feb 2011</td>
<td>Freezing rain, clear</td>
<td>Light wind, overcast, and temperature above freezing</td>
<td>4</td>
<td>All</td>
<td>No</td>
</tr>
<tr>
<td>Jan 2015</td>
<td>Freezing rain, snow</td>
<td>Gusty winds and overcast, remaining ice sublimated/melted following day when air temperature was above freezing</td>
<td>4</td>
<td>All</td>
<td>No</td>
</tr>
</tbody>
</table>
Anti/de-icing technologies

• Broad investigation was conducted to review all the identified anti/de-icing technologies

• Selection of the tested technologies was based on efficiency, cost, and environmental friendliness of each technique

• Three technologies selected
  • icephobic coatings
  • chemicals
  • internal heating

• This study focuses on testing several icephobic coatings
University of Toledo testing facilities

- Cooling Unit
- Freezing Room
- Test Section
- Tunnel System

UT Icing Tunnel
University of Toledo testing facilities

**UT Icing Experiment Station**

UT Icing experiment station

UT Icing station

Three specimens with different orientations
Indoor coating testing

• Three icephobic coatings were tested:
  (1) Aliphatic petroleum distillates with proprietary additives
  (2) Epoxy polymers, silicate mesh with new melt-point-depressants
  (3) Fluorocarbon polymer and aliphatic, moisture-cure, three-part polyurethane

• Air speed was 8.8 m/s and the temperature was -5.5°C

• Misting system to simulate freezing rain

• Three nozzle sizes (40, 42, and 50 microns) to simulate different rain drop sizes

• Test also done for uncoated specimen at the same conditions
Indoor coating testing

Uncoated

Aliphatic petroleum distillates with proprietary additives

Epoxy polymers, silicate mesh with new melt-point-depressants

Fluorocarbon polymer and aliphatic, moisture-cure, three-part polyurethane
### Indoor coating testing

Ice thickness comparison of ice-phobic coatings and droplet sizes

<table>
<thead>
<tr>
<th>Drop size</th>
<th>Coating</th>
<th>Aliphatic petroleum distillates with proprietary additives</th>
<th>Epoxy polymers, silicate mesh with new melt-point-depressants</th>
<th>Fluorocarbon polymer and aliphatic, moisture-cure, three-part polyurethane</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 micron</td>
<td>None</td>
<td>6.5 mm</td>
<td>10.0 mm</td>
<td>8.0 mm</td>
</tr>
<tr>
<td>42 micron</td>
<td>None</td>
<td>5.5 mm</td>
<td>6.5 mm</td>
<td>9.5 mm</td>
</tr>
<tr>
<td>50 micron</td>
<td>None</td>
<td>5.0 mm</td>
<td>6.5 mm</td>
<td>9.5 mm</td>
</tr>
</tbody>
</table>
Outdoor coating testing

Aliphatic petroleum distillates with proprietary additives was selected

Aliphatic petroleum distillates with proprietary additives sprayed on half of the specimen

Water droplets due to icephobic coating
Other anti/de-icing techniques

*Thermal de-icing/anti-icing (internal heating)*

- VGCS stays are hollow with the structural elements occupying 50% of the internal volume
- Internal heating experiments were conducted with 70,000 BTU forced air as a heat source
- Tried as de-icing and as anti-icing technique
Other anti/de-icing techniques

**Thermal de-icing/anti-icing (internal heating)**

- De-icing pattern in thermal test
- Accumulated ice in anti-icing thermal test
Other anti/de-icing techniques

**Fluid Chemical De-icer**

- Material used was an organic-based fluid made of refined molasses carbohydrate: NaCl, CaCl₂, KCl, and MgCl₂
- De-icing and anti-icing experiments were conducted
- Did not prevent the ice from accumulating or remove existing ice
Real time monitoring system (Dashboard)

• Automated real time monitoring system built to observe the conditions on the bridge

• Dashboard shows data from the sensors on the bridge (stay temperature, ice accumulation, precipitation, solar radiation) and from local airports and Road Weather Information System (RWIS) stations

• Developed algorithm based on the weather data on the bridge that identifies ice accumulation, ice shedding, and clear conditions
Real time monitoring system (Dashboard)

Screenshot of dashboard tab of the monitoring system
Sensor development

• Two new sensors developed: ice presence and state sensor and ice thickness sensor

• *Ice presence and state sensor*: resistance based sensor used in conjunction with a thermocouple to detect whether water is present on the stay and if it is liquid or ice

• *Optical ice thickness sensor*: measures thickness of the ice on the stay with a laser and camera

• These sensors have been tested successfully in the lab and field and will be deployed on the VGCS in winter 2015
Conclusions

• None of the anti-/de-icing techniques were appropriate on the bridge
  • did not prevent icing
  • high cost
  • altered aesthetic features of the stays
  • environmental concerns

• Developed automated real-time monitoring system to obtain the current condition of the stays

• Developed new sensors for ice accumulation and thickness
  • ice presence and state sensor
  • ice thickness sensor
Thank You
Questions?

Ice Accumulating 2/20/2011

Ice shedding on closed bridge 2/24/2011
References


