Deicer Effect on Concrete Bridge Decks: Practitioners' Perspective and a Method of Developing Exposure Maps

Jiang Huang  
Western Transportation Institute-Montana State University  
P O Box 174250, Bozeman, MT 59717  
Phone: (406) 994-6486; Fax: (406) 994-1697  
Email: jiang.huang@coe.montana.edu

Shaowei Wang, PE  
ITSNODE LLC  
4520 Glenwood Dr,  
Bozeman, MT 59718  
Phone: (406) 624-9558  
Email: swang@itsnode.com

Jaydeep Chaudhari, AICPT  
Western Transportation Institute  
Montana State University  
P.O. Box 174250  
Phone: (406) 994-2322  
Email: Jaydeep.chaudhari@coe.montana.edu

Steve Soltesz  
Oregon Department of Transportation  
Research Unit  
200 Hawthorne SE, Suite B-240  
Salem, Oregon 97301-5192  
Phone: (503) 986-2851. Fax: (503) 986-2844  
Email: Steven.M.SOLTESZ@odot.state.or.us

* Xianming Shi, Ph.D., P.E.  
Western Transportation Institute- Montana State University  
P O Box 174250, Bozeman, MT 59717  
Phone: (406) 994-6486; Fax: (406) 994-1697  
Email: xianming_s@coe.montana.edu

* Corresponding Author

Word Count: 4967+ 8*250 = 6967
Abstract:
This work illustrates a method of developing exposure maps that can be used to better understand the potential effects that deicers and other relevant variables may impart on an agency’s concrete infrastructure. To capture the practitioners’ perspective on the subject, two surveys were conducted with participants from ODOT winter maintenance and bridge management practitioners. Subsequently, the method was established using the Oregon Department of Transportation (ODOT) as a case study and the study involved the collection of relevant data for developing exposure maps for select 12 representative ODOT concrete bridge decks. Through the ODOT case study, issues with data availability and quality were identified and it is recommended that deicer type and application rate, traffic volume, weather condition (air temperature, precipitation, etc.), and bridge mix design data should be documented into an integrated bridge preservation program; or should be added to the existing bridge management systems, for any agency planning to investigate the role of such variables in the durability of its concrete bridge decks.

1. Introduction
There are multiple dimensions to the highway winter maintenance operations, particularly when it comes to the use of chloride-based chemicals for snow and ice control. Such chemicals are important tools used by maintenance agencies to maintain a reasonably high level of service during wintery weather, as there are substantial implications in highway safety, reliability, and mobility. Yet, there have been growing concerns over the potential negative effects of such chemicals. The United States spends approximately $2.3 billion annually to keep highways free of snow and ice, and the associated corrosion and environmental impacts add at least $5 billion to that cost (FHWA, 2005). Currently, approximately 20 million tons of sodium chloride is applied on roadways each year in the U.S. for snow and ice control. The corrosive effect of chlorides (sodium chloride, magnesium chloride and calcium chloride) on embedded steel reinforcement is well-known. Existing research also suggest that chloride deicers may have detrimental effects on concrete infrastructure through their reactions with cement paste and/or aggregates and thus reduce concrete integrity and strength. This, in turn, may foster the ingress of moisture, oxygen and other aggressive agents onto the rebar surface and promote rebar corrosion in concrete.

Prior to this study, there is little research in the published domain on how the durability of concrete bridge decks in cold-climate regions are affected by their exposure to chloride deicers. This is likely due to the fact that the deterioration of concrete structures in such service environments are likely a combined result of many different factors, with both physical and chemical processes at play. In order to isolate the effect of a single factor (e.g., deicer exposure), groundwork research is needed to establish a framework under which the relevant data can be identified, collected, integrated, and made ready for subsequent analyses.

In this context, a study was proposed to and approved by the Oregon Department of Transportation (ODOT). While the overall goal of the study was to understand and mitigate the effect of chloride deicers on ODOT concrete bridge decks, the very first task was to develop exposure maps for select ODOT decks as such maps are essential to facilitate the subsequent tasks. The following sections report on the key findings from this very task. Note that this paper will focus on illustrating the elements and challenges of developing exposure maps, whereas the findings of other tasks under the study (e.g., analyzing cores taken from select bridge decks) will be reported elsewhere. A GIS-based map showing the estimated amount of chloride deicers used on select ODOT concrete bridge decks was developed. In addition, information regarding the concrete bridge decks was obtained from the DOT bridge management systems.
and the exposure map also included information such as bridge configuration, concrete mix design, and historical data related to the traffic and climatic conditions.

2. Methodology

This methodology is developed to generate a deicer exposure map showing the deicer exposure of concrete bridge decks maintained by the ODOT along selected highway sections.

1) Conduct surveys

A winter maintenance practice survey and a bridge management survey were conducted with participants from both winter maintenance and bridge management managers to obtain a high-level understanding of the current and past practices of ODOT practitioners in managing their winter roads and concrete bridge decks.

2) Select bridge sites

The bridge decks that have been exposed to a representative traffic volume and environmental conditions in the ODOT were identified. The selection considers the age of the bridge deck, the level of traffic volume and the level of deicer usage. The deck selection avoided the coastal districts where chloride from marine environment may have compromised this study. Decks without nearby weather station and decks that have been rehabbed with a polymer sealer or microsilica overlay were avoided.

3) Gather relevant data and develop exposure map for the selected bridge decks.

To correctly assess the deicer exposure at a specific selected bridge deck, these data are required: most recent Average Daily Traffic (ADT) data with truck percent, air temperature/freeze-thaw cycle data from nearby weather station, bridge mix design data, and annual deicer usage data. In the end, a deicer exposure map was created for ODOT, illustrating the history of deicer exposure on the selected concrete bridge decks.

2.1 Bridge Selection Process

To describe how a specific bridge site was selected for deicer exposure map, a guideline along with a flowchart (Figure 1) is provided in this section.

By using the ARCGIS or any other Geographic Information System (GIS) software, a bridge geodatabase has been created to include: DOT districts shape files, highway functional classification shape files, concrete bridge shape files, and road weather information system (RWIS)/MesoWest Shape files with required attributes available. Then the selection of concrete bridge procedure was initiated with the following 4 steps:

1) District Selection based on Geolocation and Winter Severity:

(a) Geolocation (coastal/non-coastal): Eliminated districts that are on the coastal areas to avoid a marine environment effect. (b) Grouped districts by their Winter Severity (low/high). Winter severity is determined by historical annual deicer usage data of each district. Therefore two concrete bridge lists of high winter severity districts and low winter severity districts were generated.

2) Bridge Age Sub-grouping Within Low/High Winter Severity District Groups:

For a low winter severity district concrete bridge list, the bridges were categorized according to its built Year: 1996-2011, 1981-1995, before 1980. Three table lists and the associated files/shape files have been generated. The same categorization was applied to the high winter severity districts concrete bridge list. Therefore, a total of six table lists/shape files were generated.
3) Average Daily Traffic (ADT) Sub-Grouping within Age Sub-groups:

The bridges within the generated six lists were then categorized based on its most recent ADT value. The cutoff level is set to 10,000. In the end, a total of 12 table lists/shape files were generated.

4) RWIS/ MESOWEST stations: In each category of the above selection, bridges which are within 10 mile radius of RWIS/ MESOWEST stations were selected.

5) Bridges that have been overlaid with microsilica or polymers were eliminated, and then only one bridge in each category was selected. 12 concrete bridges with each representing one category were selected.

2.2 Data Collection and Deicer Exposure Map Developing

For developing ODOT deicer exposure map to fully illustrate the key factors in the ODOT case study, the following data elements were collected for each specific bridge site: bridge mix design data, traffic volume data, deicer usage data, annual precipitation total and freeze-thaw cycle data. In the end, deicer exposure GIS map was developed based on all of the data we collected.

The bridge mix design data, traffic volume data, and deicer usage data had been obtained from the ODOT maintenance management system and bridge management system. According to a literature results, the surface temperature of bridge decks usually tracks air temperature more closely than do the adjacent roadway pavements (Roosevelt, 2004). Freeze-thaw cycle data were calculated using the following approach: hourly/sub hourly historical air temperature data from nearby weather stations were used to calculate yearly bridge deck freeze-thaw cycle. For a given nearby weather station with the air temperature data, one freeze-thaw cycle had been computed if the observation air temperature record indicated a cross (either rise over or drop below) of the freezing point (32°F).
Bridge Selection Procedure

Project: Understanding and Mitigating Effects of Chloride Deicer Exposure on Concrete

Figure 1. Bridge Selection Procedure Flowchart
3. Results and Discussion:

3.1 Key Survey Results

3.1.1 Perspective of Winter Maintenance Practitioners

The winter highway maintenance practice survey was designed to understand ODOT current/past winter anti-icing, deicing and pre-wetting practices in managing their winter roads (e.g., type of deicing, anti-icing or pre-wetting products used and their respective application rates, rules of practice, winter severity and road weather scenarios, annual deicer usage, and the possible negative effects of chloride deicers to winter roadways, etc.). The ODOT is presently divided into 5 geographic regions with 16 maintenance districts. The various maintenance districts have developed their own strategies to address the needed level of service for their roadways. 8 out of 16 districts had responded to this survey, which resulted in a 50% response rate. Figure 2 shows where the survey responses came from by district (as highlighted in purple). All the participating districts are using deicing chemicals with the three types of snow and ice control strategies: anti-icing, deicing and pre-wetting. With the exception of one district (D2B), 7 out of 8 districts have used anti-icing for over 10 years. Again with the exception of one district (D2B), 7 out of 8 districts have used deicing technique for over 10 years, district 2B have used for less than 10 years. Only one district (D10) used pre-wetting for less than 10 years; while the other 7 districts don’t use pre-wetting at all. The primary chemical used in all these eight districts is MgCl₂. 6 districts have reported a change of type of deicing chemical in the past years. Calcium Magnesium Acetate (CMA) was used in some districts a couple of years ago, they switched to MgCl₂ over the past 5-10 years and it was successful. D10 used CMA both in liquid and solid from 1998 to 2001; however, it didn't work well with their colder climate and they switched to MgCl₂ in 2002. Some districts started to experiment on other MgCl₂ based deicers. When asked if there is any change in usage of the deicer chemicals during the past ten years, they all observed an increased usage of chemicals and attribute this change to the following facts: better understanding of advantages of the chemicals over sanding, higher level of service expectations, higher traffic volumes and the colder weather. Table 1 provides a comparison of winter maintenance practices of four selected districts based on the survey results.
Table 1. Winter Maintenance Practices of Selected Four ODOT Districts from 2011 Survey Results

<table>
<thead>
<tr>
<th>Region/District</th>
<th>Primary Deicer Products</th>
<th>Maintained Lane miles /Application Rates</th>
<th>Application Rates for anti-icing, deicing, pre-wetting</th>
<th>Typical Winter Maintenance Season</th>
<th>Estimated Annual Deicer Usage/Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>R5/D12</td>
<td>MgCl₂</td>
<td>1785miles /NA</td>
<td>Pretreat: 15-60 Gal/Ln-mi Deicing: 15-60 Gal/Ln-mi</td>
<td>November-April 15ᵗʰ</td>
<td>500,000-750,000Gal/ $750,000</td>
</tr>
<tr>
<td>R1/D2B</td>
<td>MgCl₂</td>
<td>1000miles /8-30 Gal/Ln-mi</td>
<td>Deicing: 20-40 Gal/Ln-mi Pre-wetting: 20-40 Gal/Ln-mi</td>
<td>November-March</td>
<td>300,000Gal/ NA</td>
</tr>
<tr>
<td>R5/D13</td>
<td>MgCl₂</td>
<td>1250miles /NA</td>
<td>Pretreat: 15-60 Gal/Ln-mi Deicing: 15-60 Gal/Ln-mi</td>
<td>November-April</td>
<td>300,000Gal/ $420,000</td>
</tr>
</tbody>
</table>

When asked about the possible negative effects of chloride deicers, most districts (7 out of 8) disagree that deicer poses a significant risk. However, district 2B thinks that the deicer poses significant risk to the durability of concrete bridge decks with no comments. Little negative effect of deicing chemicals on the asphalt, concrete and bridge deck pavements had been observed for most districts. One district (D2B) reported moderately negative effect observed for concrete pavement and bridge decks. District 8 commented that ice control chemicals used correctly can provide safety and mobility for the travelling public and it is wonderful in the tool box.

Anti-icing has been widely used by ODOT districts and was believed to be very successful as indicated by participating respondents. Chemical-based deicer use has generally been increasing through the past ten years due to colder weather, higher traffic volumes and higher level of service. The significant negative deterioration effect on the concrete and bridge deck hasn’t been observed by most of the winter maintenance district respondents (7 out of 8). More efficient chemicals are under experimenting stage; however, efforts along these lines have not been particularly successful to date. The survey results did not indicate when the surveyed districts started using MgCl₂, except for one district (D10 started in 2002 by switching from CMA to MgCl₂).

3.1.2 Perspective of Bridge Management Practitioners

Bridge managers at ODOT oversee the design, construction, operation, and maintenance of the bridges located in Oregon and uses a centralized system known as Bridge Management System. The bridge managers regularly conduct inspections, assessment of condition and strength, repairs, and rehabilitation; therefore, the bridge managers/engineers of ODOT headquarter, Region 3, Region 4, Region 5 have been approached to understand the bridge management practices to shed light on the durability of concrete bridge decks and the potential effects of deicers, freeze-thaw cycling on bridges decks, and its severity. There are total of 5 regions in Oregon State. Regions 1 and 2 have not responded to the survey because the climate there is mild and there is little need for deicer.
The bridge managers were asked about which external factors influence the premature deterioration (including cracking, spalling, delamination or other forms of deterioration related to the concrete itself and/or rebar corrosion) of concrete bridge decks in Oregon. A majority of bridge managers believed that freeze-thaw damage and chloride deicers influence on deterioration of bridge decks; however, their opinions differed on the level of influence. For chloride deicer, two opinions were that the level of influence was high as compared to one opinion for low level of influence.

Cracking caused by traffic loading, excessive rain, natural calamities (earth quack, fire, storm surge, flood), spalling, and tire studs were also considered as external impacting factors on bridge deck premature deterioration by the bridge managers. The managers had also started considering chloride contamination as a factor in influencing the decision making for bridge deck maintenance, repair, and rehabilitation.

In addition, inquiry had been made to ask whether the ODOT headquarter or regions changed the mix design or construction/maintenance/rehabilitation practices for concrete decks for preventing premature deterioration. The respondents listed that the ODOT often makes necessary changes in the concrete design. In the recent past, the following changes had been made:

1. Increased curing effort, time requirement for covering wet concrete and extended for total cure time to 14 days;
2. Adopted high performance concrete mix with silica fume for decks; and
3. Increased use of thin bonded overlays and deck sealers.

These changes have been updated in the ODOT guidelines for concrete design to prevent premature deterioration, which are followed by the other regions.

The results from both surveys showed a discrepancy in opinions on whether the deicer chemicals have a significant negative effect on the premature deterioration of ODOT concrete bridge decks. The significant effect of chemical deicers on the premature deterioration of concrete bridge decks hasn’t been observed by most of the winter maintenance district respondents (7 out of 8). However, 2 out of 3 of the regional bridge managers/engineers reported that the use of deicer chemicals does pose a high level risk on premature deterioration of concrete bridge decks. To better understand the deterioration effects of chemical deicers on concrete bridge decks of ODOT, a deicer exposure map was then created based on the related data.

### 3.2 A Method of Developing Deicer Exposure Map: ODOT Case Study

#### 3.2.1 Bridge Selection

A total of 12 categories were identified through the bridge selection procedure as described in the methodology section. Then 12 representative highway bridge decks from each identified category were selected to showcase the methodology of developing deicer exposure maps. Table 2 lists characteristics of 12 selected bridges ordered by category with the nearby MesoWest station names.

<table>
<thead>
<tr>
<th>Category</th>
<th>Bridge</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Elevation</th>
<th>District</th>
<th>Year_Built</th>
<th>ADT_2008</th>
<th>MesoStation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19268</td>
<td>42.06269</td>
<td>-123.707</td>
<td>1700</td>
<td>2B</td>
<td>2005</td>
<td>003100</td>
<td>ODT25</td>
</tr>
<tr>
<td>2</td>
<td>19681</td>
<td>45.34397</td>
<td>-118.122</td>
<td>2900</td>
<td>13</td>
<td>2003</td>
<td>005454</td>
<td>ODT18</td>
</tr>
<tr>
<td>3</td>
<td>18940</td>
<td>45.61778</td>
<td>-122.807</td>
<td>100</td>
<td>2B</td>
<td>2002</td>
<td>020600</td>
<td>ODT06</td>
</tr>
<tr>
<td>4</td>
<td>18525</td>
<td>42.34202</td>
<td>-122.889</td>
<td>1360</td>
<td>8</td>
<td>2002</td>
<td>013500</td>
<td>ODT26</td>
</tr>
<tr>
<td>5</td>
<td>16534</td>
<td>45.54495</td>
<td>-122.678</td>
<td>270</td>
<td>2B</td>
<td>1985</td>
<td>009793</td>
<td>ODT10</td>
</tr>
<tr>
<td>6</td>
<td>16440</td>
<td>45.92242</td>
<td>-119.324</td>
<td>190</td>
<td>12</td>
<td>1985</td>
<td>008332</td>
<td>MWQUM</td>
</tr>
</tbody>
</table>
3.2.2 Bridge Mix Design Data and ADT data

The mix design of concrete plays a crucial role in their performance and durability in the service environment. As such, this is an important data set for investigating the deicer exposure and premature deterioration of concrete bridge decks. An example of an ODOT deck concrete mix design is shown in Figure 3, which provides information on concrete proportioning (type and amount of cement and mineral admixtures; gradation, absorption and amount of fine and coarse aggregates; water-to-cement ratio) and properties of fresh concrete (slump and air content) and hardened concrete (density and compressive strength).

![Figure 3. Example of ODOT deck concrete mix design](image)

In addition, the most recent annual average daily traffic data were obtained from ODOT bridge management system and were shown in table 2. Also the truck traffic volume data (percentage of ADT that is truck traffic, no vans, pickup trucks and other light delivery trucks are included) were collected, since the heavy truck traffic volume is a more significant variable than ADT that impact the deicer exposure of concrete bridge deck.

3.2.3 Bridge Deicer Use Data

Proper deicer application rates will vary depending on the temperature and type/volume of precipitation. The level of service and traffic would also be considered. Complete records of chemical deicer applications were necessary to assess deicer exposure and possible negative effects on the concrete bridge decks. In this case study, manually recorded daily deicer rate data along with the relevant air temperature data were collected, quality controlled to calculate the annual deicer application rate total for each bridge site. The ODOT deicer usage data are only available in daily records and in paper form. Assumptions are made to address missing data for specific bridge decks.

**Data Collection**

The winter maintenance management system was approached to collect the deicer usage data for each bridge site. However, the deicer records for specific bridges were not in the ODOT Maintenance Management System. It was kept on paper form instead, (on daily handwritten deicer record logs), and
was maintained in the specific maintenance section offices. The log had application date/time, application rate (gallons/lane mile), road conditions, and air temperature by the time of application recorded. The information regarding the type of deicer applied was missing. The deicer most commonly used by ODOT was shown to be magnesium chloride and it is still used exclusively statewide from 2006. Therefore, it was believed that the deicer log data during FY2005-FY2011 are for MgCl₂/liquid only.

Quality of the Data
Application rates are determined by the current road conditions and the anticipated weather and road conditions” as stated in a paper from ODOT report. (Martinez, 2006). Winter anti-icing/deicing liquids application rates typically range from 15 gallons/lane mile to 50 gallons/lane mile. A preliminary range check was made to identify the extreme values for further revision. Less than 1% of the data has been found problematic and was revised accordingly. Suspect values are identified manually, and several approaches were used to attempt to verify the values. The very large value for application rate with 50-60 gallons/lane mile might occur before a large snow event or freezing rain. When temperatures are not too cold or close to 32°F, there is often wet snow, sleet, freezing rain or a mix of all as the worst icing conditions, the value for daily application rate may go up. When the air temperature gets very cold (<19°F), the ice/snow is less slick and traction is better, hence require lower rates. The quality controlled application rate data were then accumulated to get the yearly rate total. A large number of missing values occurred for the accumulated yearly rates total for some bridge sites. 4 bridges have 6 out of 8 years’ deicer total data missing. Under the assumption that all bridges were treated with MgCl₂/liquid since FY2006, incompleteness of the data would be a major barrier to get a complete picture of deicer use for all these bridges over the past eight years.

Quality Control and Missing Data Infilling
To assist in estimating the large part of missing yearly deicer use data at some bridge sites, ODOT maintenance management system provided the district deicer usage data of fiscal year from FY2000 to FY2011. The districts of concern are Districts 2B, 8, 12, and 13. These data have been useful in determining trends of MgCl₂ use by ODOT Maintenance Districts.

Figure 4. Yearly Deicer Usage Data for ODOT District 13, 12, 8 and 2B
Figure 4 shows that the deicer usage in each district has uniformly been increasing over the past 10 years. The change was gradual during the first 5 fiscal years (FY2000 to FY2005). Starting from FY2006 there is a dramatic increase among all the 4 districts. The deicer usage of district 13, 12 and 8 (high winter severity districts) generally increased faster than district 2B (low winter severity district). The district level deicer usage data were used to estimate the yearly deicer rate total for bridge sites based on the district deicer change rate. Assumptions were then made to address missing deicer usage data for specific bridge decks.
Note that, the application rates of deicer chemicals are site specific and depend on a variety of factors including type of deicer used, air and pavement temperature, amount of snow on the ground, and steepness of the roadway (Fischel, 2001). Thus, estimator is quite rough and could come with a high variability for a bridge site. Therefore, the district deicer usage data collected from ODOT maintenance management system should be considered as correlated information and not a statistical representation for the bridge site deicer usage. It is highly recommended that the bridge deicer usage data be documented and integrated into either maintenance management system or bridge management system database to assess the deicer exposure severity of existing concrete bridge decks.

3.2.4 Freeze-thaw cycle Data

Another influential factor is the freeze-thaw cycling that bridge decks are exposed to. The freeze-thaw cycling can pose a significant risk to the durability of concrete bridge decks as such cycling can lead to the physical deterioration of the concrete microstructure (Shi, 2009). The presence of deicers can aggravate the physical attack of concrete by freeze-thaw cycling while chemically attacking the cement paste and aggregate phases as well. The severity of freeze-thaw exposure varies with different areas of Oregon. Local weather records can help determine the severity of exposure. In this study, the number of freeze-thaw cycles was determined by the bridge surface temperature which can be estimated by ambient air temperature as discussed in the methodology section. In total nine MESOWest weather stations that are close enough to the 12 selected bridge sites were selected. Over 11 years, more than 2.5 million records of historical air temperature data were collected from University of Utah MESOWEST. The reporting frequencies for these air temperature sensors were about every 10, 15 or 20 minutes. The overall percentage of missing data for all these selected weather stations is less than 5%. For a missing winter season, the missing data could be infilled by the values that calculated from a similar winter.

Table 3 presents the summary of freeze-thaw cycle data of all 12 bridges for fiscal year 2005-2011. The average freeze-thaw cycles were also mapped on top of elevation map (Figure 5). Note that to align with other ODOT data, the freeze-thaw cycles have been accumulated for each fiscal year. Based on the results, the freeze-thaw cycles tend to increase dramatically for area with higher elevation (>1000 feet), it raises the interest for collecting more data and conducting further research to examine the general relationship between the freeze-thaw cycling and the bridge geolocation (latitude, longitude, elevation).

Table 3. Summary of Freeze-thaw Cycles for Fiscal Year 2005 – 2011

<table>
<thead>
<tr>
<th>Bridge No.</th>
<th>Elev(ft)</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>00576</td>
<td>1290</td>
<td>NA</td>
<td>NA</td>
<td>114</td>
<td>142</td>
<td>56</td>
<td>64</td>
<td>96</td>
</tr>
<tr>
<td>08958F</td>
<td>270</td>
<td>8</td>
<td>36</td>
<td>26</td>
<td>34</td>
<td>28</td>
<td>18</td>
<td>26</td>
</tr>
<tr>
<td>08682</td>
<td>1491</td>
<td>78</td>
<td>74</td>
<td>98</td>
<td>158</td>
<td>152</td>
<td>108</td>
<td>110</td>
</tr>
<tr>
<td>09268S</td>
<td>270</td>
<td>8</td>
<td>36</td>
<td>26</td>
<td>34</td>
<td>28</td>
<td>18</td>
<td>26</td>
</tr>
<tr>
<td>16844</td>
<td>915</td>
<td>NA</td>
<td>NA</td>
<td>104</td>
<td>120</td>
<td>82</td>
<td>44</td>
<td>98</td>
</tr>
<tr>
<td>16358</td>
<td>270</td>
<td>8</td>
<td>36</td>
<td>26</td>
<td>34</td>
<td>28</td>
<td>18</td>
<td>26</td>
</tr>
<tr>
<td>16440</td>
<td>190</td>
<td>165</td>
<td>170</td>
<td>170</td>
<td>202</td>
<td>170</td>
<td>162</td>
<td>142</td>
</tr>
<tr>
<td>16534</td>
<td>270</td>
<td>8</td>
<td>36</td>
<td>26</td>
<td>34</td>
<td>28</td>
<td>18</td>
<td>26</td>
</tr>
<tr>
<td>18525</td>
<td>1360</td>
<td>76</td>
<td>120</td>
<td>98</td>
<td>132</td>
<td>140</td>
<td>94</td>
<td>46</td>
</tr>
<tr>
<td>18940</td>
<td>100</td>
<td>30</td>
<td>66</td>
<td>58</td>
<td>44</td>
<td>40</td>
<td>26</td>
<td>38</td>
</tr>
<tr>
<td>19268</td>
<td>1700</td>
<td>130</td>
<td>138</td>
<td>148</td>
<td>192</td>
<td>178</td>
<td>94</td>
<td>143</td>
</tr>
<tr>
<td>19681</td>
<td>2900</td>
<td>286</td>
<td>246</td>
<td>242</td>
<td>310</td>
<td>250</td>
<td>200</td>
<td>234</td>
</tr>
</tbody>
</table>
3.2.5 Bridge Deicer Exposure Map

The deicer exposure map 2011 (Figure 5) was developed for showing the estimated amount of MgCl₂ deicer exposure in fiscal year 2011 on selected 12 concrete bridge decks maintained by the ODOT. Data structure is composed of bridge geolocation (latitude, longitude, and elevation), built year, category, ADT with truck traffic, calculated annual deicer usage in gallons per lane mile, and calculated freeze-thaw cycle data of FY2011 and annual precipitation total.

![Figure 5. ODOT Deicer Exposure Map with 12 Selected Bridge Sites (2011)](image)

3.3 Conclusion Remarks

Anti-icing strategy with MgCl₂ liquid has been widely used by ODOT districts and is believed to be very successful by participating winter maintenance survey respondents. Usage of chemical deicers has generally been increasing during the past ten years due to colder weather, higher traffic volumes and higher level of service. This trend seems to be continuing and has raised concerns regarding its negative effects on existing highway infrastructure. Nonetheless, the vast majority of the participating ODOT winter maintenance managers do not think that there has been any significant deteriorating effect of MgCl₂ on the ODOT concrete bridge decks. In contrast, a majority of bridge managers believed that freeze-thaw damage and chloride deicers both contributed to the deterioration of bridge decks, even though they disagreed on the level of influence. Some ODOT bridge management practitioners considered the use of deicer chemicals to pose a high level of risk on premature deterioration of concrete bridge decks. To address this risk, a few changes have been made by ODOT in the concrete mix design and in the construction, maintenance, or rehabilitation practices for concrete decks.

This study, while focusing on examining the relevant data from Oregon, has demonstrated the general approach that other agencies could implement or adopt in developing exposure maps. In order to investigate the root cause of premature deterioration of concrete bridge decks in cold-climate region, it is important to develop their exposure maps over time. Nonetheless, this study has revealed that currently agencies may not have complete and well-defined records of the relevant data. For instance, the deicer type and application rates on specific bridge decks are generally not available in either Maintenance Management System or Bridge Management System. It is highly recommended that deicer type and application rate, traffic volume/truck traffic volume, road weather data (deck temperature, air
temperature, precipitation, etc.), concrete mix design, and deck maintenance records be archived into an integrated bridge preservation program. Alternatively, such data should be added to the existing bridge management systems. The inventory of such data would then enable agencies to investigate the role of such variables in the durability of their concrete bridge decks.

This work unravels great challenges in data collection. Significant amount of historical air or deck temperature data are required to calculate the number of freeze-thaw cycles. Ideally more detailed records on precipitation and traffic would also facilitate the understanding of how weather, deicer, traffic, etc. contribute to the premature deterioration of concrete bridge decks.

4. Acknowledgements

This study is supported by the Oregon DOT and the USDOT RITA (via Alaska UTC and Western Transportation Institute). The authors thank the professionals who responded to our surveys and the ODOT engineers (Rick Poecker, Bert Hartman, Erick Cain, Adam Bradford, Susan Mead, Gretchen Harvey, Chad Crockett), as well as the other members of the technical panel for all of their support.

5. References

2. Fischel Marion, Evaluation of Selected Deicers Based on a Review of the Literature. Colorado DOT 2001