STUDY OF WINTER HIGHWAY MAINTENANCE IN CONNECTICUT

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THE DIFFERENCE BETWEEN "DE-ICING" AND "ANTI-ICING"

As used in the CASE report, "de-icing" is the use of salt and sand or mechanical means to remove snow and provide traction on roads. "Anti-icing" is the use of pre-wetted salt on roads before snow accumulates.

ISSUE

This report summarizes certain findings and recommendations of a study of winter highway maintenance operations in Connecticut required by PA 14-199.

It discusses findings about the state Department of Transportation's (DOT) winter road maintenance strategy and its impact on highway safety; the amount of road salt used by DOT, municipalities, and private entities; the salt's corrosive effects and impacts on infrastructure, motor vehicles, and the environment; de-icing alternatives; and recommendations for preventing or reducing corrosion.

PA 14-199 (§ 6) required DOT to analyze the corrosive effects of chemical road treatments on (1) snow and ice equipment vehicles; (2) bridges, highways, and other infrastructure; and (3) the environment. The act called for (1) determining the cost of corrosion caused by the road treatments; (2) evaluating alternative techniques and products, such as rust inhibitors; and (3) comparing their cost and effectiveness.

The Connecticut Academy of Science and Engineering (CASE), a private nonprofit corporation that advises the state on science and technology matters, conducted the study for DOT.

SUMMARY

DOT increased its reliance on salts beginning in 2006, when it switched from a reactive strategy ("de-icing") of applying a mix of sand and solid road salt (sodium chloride) to a proactive strategy ("anti-icing") that relies on pre-wetting road salt with solutions of liquid salts (principally magnesium chloride).

According to the CASE report, the new strategy helped improve road safety. The strategy has also nearly eliminated DOT's use of sand, providing both financial and environmental benefits. But increased salt use means vehicles, roads, and bridges are more frequently exposed to salt's corrosive effects.

All chloride-based de-icers (sodium chloride, magnesium chloride, and calcium chloride) hasten corrosion. Although a number of tests have shown that sodium chloride appears less corrosive to concrete than the other two chloride de-icers, it is difficult to pinpoint which of the three is the least damaging because of the characteristics of each chloride and the many variables involved (e.g., temperature, length of exposure, road or bridge type).

Regardless, the chloride de-icers' availability, relatively low price, proven effectiveness, and ease of storage and use have made them the most extensively used de-icers nationwide. The report found that alternative de-icers are either too expensive, limited in availability, not widely used in the U.S., or pose environmental problems. It assumes that chloride-based de-icers will be the primary de-icers for winter highway maintenance for the foreseeable future.

The report notes that the amount of salt DOT applies may represent only a small fraction of the total amount used each winter in Connecticut. DOT annually applies less than one half the amount of salt municipalities apply, and the study was unable to determine how much salt private firms apply on parking lots, shopping centers, and sidewalks.

Consequently, the report maintains that winter maintenance, including appropriate use of de-icing chemicals, is a shared responsibility of DOT, municipalities, and private entities.

The CASE report makes a number of recommendations on how DOT, motorists, and the trucking industry can reduce corrosion, such as by frequently washing vehicles exposed to road salt. It also calls on car washes to disclose whether they use recycled water, the percentage of recycled water they use, and when in the car washing process they use it.

DOT'S SWITCH FROM A "DE-ICING" TO AN "ANTI-ICING" STRATEGY

DOT's increased reliance on calcium chloride and, more recently, magnesium chloride, stems from its 2006 switch from a strategy of treating roads with a mix of sand and road salt ("de-icing") to one relying on pre-wetting of road salt (sodium chloride) and almost completely eliminating the use of sand ("anti-icing").

De-Icing Strategy

Under the de-icing strategy, DOT spread a mixture of sand and road salt on snow and ice to melt the snow and provide traction.

According to the CASE report, the approach was generally effective, but often resulted in snow and ice that bonded to the road (snow pack). Snow pack could often last for many hours or days after a storm. Removing it involved significant labor, large quantities of salt, and the use of equipment. Furthermore, the report noted, the improved traction the sand provided was short-lived, because the sand was rapidly dispersed by the flow of traffic.

Anti-Icing Approach

In 2006, DOT switched to an "anti-icing" strategy. This involves spreading road salt that is pre-wetted with a chloride-based liquid de-icer early in a storm to prevent snow and ice from sticking. According to CASE, this clears the roads much more quickly and reduces the chance that ice will form beneath a layer of snow.

DOT uses a small amount of liquid magnesium chloride to pre-wet road salt. The report said that studies have shown that pre-wetting helps keep salt crystals from bouncing and scattering when they strike pavement, triggers faster de-icing, and can reduce the amount of salt needed by between 10% and 20%.

According to the report, DOT first used calcium chloride to pre-wet road salt, but switched to magnesium chloride in 2009 because it was less expensive and more effective, especially at lower temperatures.

By the winter of 2011-2012, DOT's switch to the anti-icing policy meant it had almost completely stopped using sand. This reduction, the report says, should reduce DOT's purchasing, application, storage, and clean-up costs and decrease the amount of sand in drain pipes or accumulating in streams and ponds.

Anti-Icing and Highway Safety

According to the CASE report, DOT's anti-icing policy has helped reduce the number of winter accidents that result in injuries, although it does not give credit for safer roads to that policy alone.

CASE analyzed the number of crashes in which injuries occurred and found that, on average, there were fewer crashes on state-maintained highways covered with snow, slush, or ice when DOT employed the anti-icing approach than in the years in which DOT applied a salt and sand mixture.

The report cautions that while it is hard to distinguish the impact on highway safety of improvements in vehicle technology (e.g., traction control, anti-lock brakes) from the effects of the anti-icing strategy, it is likely that anti-icing policies are responsible for a portion of the decline in winter crashes.

USE OF SAND AND ROAD SALT BY DOT, MUNICIPALITIES, AND PRIVATE ENTITIES

DOT's move from de-icing to anti-icing has significantly affected the amount of sand and salt it uses.

In 2005-06, the last winter of its de-icing strategy, DOT used 198,301 tons of sand and 107,930 tons of road salt. In 2013-14, the report notes, DOT used less than 10 tons of sand.

Since switching to the anti-icing policy, the amount of road salt DOT uses has ranged from a low of 63,113 tons in the winter of 2011-12, in which there were six storms, to a high of 227,511 tons in the winter of 2013-14, in which there were 17 storms.

And, despite concern over the increased use of magnesium chloride, the report points out that this chemical compound accounts for only about 1% of the salt DOT uses annually. In the winter of 2013-14, for example, DOT used 225,170 tons of sodium chloride and 2,341 tons of magnesium chloride.

But DOT's use of salt represents only a portion of the total amount applied in the state. The report notes that DOT maintains about one-quarter of the state's public roads, or about 10,800 lane miles, while municipalities maintain 35,231 lane miles, more than three times as much as DOT. (A lane mile is a highway's length multiplied by the number of its lanes.)

In 2013-14, DOT applied 227,511 tons of salt and municipalities applied an estimated 483,000 tons, for an estimated total of 710,511 tons. Over the past five years, the report found, DOT applied an annual average of 153,000 tons of salt. Municipalities applied an annual average of 350,000 tons during that time, more than twice the amount DOT applied.

This total does not include the amount of salt private firms apply on shopping centers, parking lots, and sidewalks. CASE said it could not obtain these figures, but estimated that private applications for these purposes could be substantial, and that DOT's use of de-icers may account for as little as 9% of the total statewide chloride application per season.

Because of these findings, the report maintains that winter maintenance, including appropriate de-icing chemical use, is something that the state, municipalities, and private entities, must share responsibility for.

SALT AND ITS CORROSIVE EFFECTS

DOT's Use of Chlorides Compared to Other Northeastern States

The report cautions that it is difficult to compare salt usage patterns among states because of differences in climate, chloride blends, and winter road maintenance levels.

Nevertheless, it found that (1) the total amount of salt DOT uses is lower per lane-mile than all but two northeastern states (Maine and Vermont), but that (2) DOT's use of 87 gallons of liquid de-icers per lane-mile to pre-wet road salt places it second only to New Jersey for the amount of liquid de-icer per lane mile used by northeastern states.

Effectiveness and Cost

According to the report, CASE found that the ready availability, reasonable price, proven effectiveness, and ease of storage and use of sodium chloride, calcium chloride, and magnesium chloride helped make them the most extensively used de-icers nationally. Alternative de-icers are either too expensive, limited in availability, not widely used in the U.S., or pose environmental problems. Thus, the report states, chloride-based de-icers will continue to be the primary de-icers for winter highway maintenance.

Corrosiveness

All chloride-based de-icers hasten corrosion. Although tests have shown that sodium chloride appears less corrosive to concrete than calcium chloride or magnesium chloride, it is difficult to pinpoint which is the least damaging overall because of the characteristics of each and the other variables involved (e.g., temperature, chloride mixture, road or bridge surface).

Further, the report says it is "virtually impossible" to determine exactly how much chlorides contribute to corrosion, because other factors, such as humidity levels, also play a role. "Even without exposure to de-icing chemicals, corrosion would eventually occur by natural processes," the report said.

USEFULNESS OF CORROSION INHIBITORS

CASE also evaluated corrosion inhibitors, which can be added to chloride de-icers to reduce chloride's corrosive effect. Corrosion inhibitors, many of which are organic in nature, reduce corrosion by consuming oxygen before it reacts with iron to form rust. DOT initially used an inhibitor in its calcium chloride solution, but discontinued this in 2007, because, among other things, the inhibitor was depleting oxygen levels in state streams, posing a threat to aquatic life.

According to the report, there is too little evidence of the effectiveness of corrosion inhibitors to recommend their use. The report said that while laboratory tests have indicated that inhibitors are effective, field tests have not. It instead recommended that DOT continue to monitor the findings of other agencies and studies on the effectiveness of corrosion inhibitors.

IMPACT OF CHLORIDE DE-ICERS ON WATER QUALITY

According to the report, there is little question that chloride de-icers affect water quality.

Groundwater and Drinking Supplies

De-icing salts are a primary source of chloride in groundwater. According to the report, since the early 1900s average statewide well water chloride concentrations have increased tenfold, "and this increase has been spatially correlated with major roadways."

High sodium levels may adversely affect people on low sodium diets because of kidney or heart disease or high blood pressure. According to the Department of Public Health (DPH) high levels of chloride often occur with elevated sodium levels. Responding to DPH concerns about elevated sodium levels, DOT in the early 1990s changed its de-icing material to a special mixture of calcium chloride and sodium chloride. Since then, it has also implemented new best practices, such as calibrating spreaders, pre-wetting, and better controlling application rates.

Still, the report said, in at least 1,700 water samples collected in Connecticut since 2002, sodium levels in public drinking water wells or reservoirs exceeded the level (28 milligrams per liter) at which DPH requires public water supplies to notify their customers. (DPH regulations specifically limit the use of salt on roads, driveways, or parking areas where sodium levels in drinking water supplies exceed 15 milligrams per liter (Conn. Agency Regs. § 19-13-B32 (h))).

The report recommends that instances of elevated sodium concentrations should be monitored and appropriate action taken if necessary.

Surface Water

According to the report, there are currently no surface water bodies in the state which are impaired because of high chloride levels. It says that chloride impacts on these water bodies can be managed by reducing the amount of chloride de-icers, using alternative de-icers, re-routing surface water runoff, or dilution. The goal, the report says, should be to limit application rates and prevent high concentrations of sodium and chloride through best management practices.

ALTERNATIVE DE-ICERS

The CASE report found that alternatives to chloride de-icers have drawbacks. Many of the alternatives were more costly than the chloride options. Some are not as effective, do not work well at low temperatures, or have harmful environmental effects. We discuss acetate, organic byproduct, and proprietary product alternatives below.

Acetates

CASE found that calcium magnesium acetate was not as effective as the chlorides, had harmful environmental impacts, and cost much more than road salt (about $1,800 per ton, compared to between $67 and $80 per ton for road salt in 2014).

CASE also looked at sodium acetate, currently used on Bradley Airport runways. It found that while sodium acetate is generally not corrosive to vehicles, bridges, and utilities, it can irritate the skin or eyes, and costs more than $1,900 per ton.

Organic Byproducts

Some states, including Missouri and New York, have experimented with organic byproducts, such as beet juice, on their roads.

According to the report, these products are expensive and often mixed with other de-icers to lower their cost. It found that these products can enhance a de-icer's performance and help road salt stick to the road. Their drawbacks include cost ($1.12 or $1.60 per gallon for beet juice, compared to 69 cents to 76 cents per gallon for magnesium chloride in 2013) and a stickiness that may cause the salts with which they are mixed to adhere longer, causing more damage to metals. Organic products may also temporarily deplete oxygen levels in surface waters.

Proprietary De-Icers

CASE also examined proprietary de-icers (commercially available de-icing products, many of which include a chloride de-icer, water, and additives that make the product easier to spread, stickier, or less corrosive). Although DOT does not use such products, they have been used by about 100 Connecticut municipalities and school systems. CASE found that these products work well at low temperatures and are less corrosive to steel. The products' disadvantages include detrimental environmental effects.

RECOMMENDATIONS

The report says the state must balance the de-icers' harmful effects "with the improved roadway safety and positive economic impacts that result from effective and prompt winter highway maintenance practices in response to winter weather events."

It makes several recommendations for DOT, municipalities, the trucking industry, and the general public. We highlight a few of these below.

General Recommendations for DOT

The report calls on DOT to stay current with, and annually review, state-of-the-art winter road maintenance practices to ensure it maintains highway safety while balancing impacts on vehicles, roads, bridges, and the environment.

It also recommends that DOT:

- Continue its anti-icing policy;
- Continue to participate in organizations, such as the Clear Roads Consortium, that research best practices for snow and ice control;

- Continue to use sodium chloride as its primary de-icer because it is the most economical inorganic chemical and an effective de-icer in most conditions above 20°F;
- Continue to use (1) sodium chloride as the primary pre-wetting agent at the beginning and end of the winter season and (2) magnesium chloride as the pre-wetting agent in the coldest months;
- Monitor studies on the effectiveness of corrosion inhibitors;
- Continue with plans to increase, from 13 to 36, the number of Road Weather Information Stations, which provide current location-specific weather data, and share this information with towns;
- Create a voluntary certification program for private contractors that apply de-icing chemicals; and
- Consider developing a "road condition index" to provide information directly to the public.

Recommendations for DOT Regarding Bridges

The report recommends that DOT take a proactive approach to (1) minimize chloride damage on existing bridges before it becomes significant and (2) incorporate corrosion mitigation when designing new bridges. It calls for implementing a life-cycle cost analysis that includes maintenance and preservation costs in addition to construction costs.

According to the report, bridge components that are more likely to retain moisture could benefit from periodic cleaning and retrofitting with corrosion resistant materials. The report recommends that DOT:

- Protect roads and bridge structures by using materials that reduce or prohibit chloride penetration into concrete and steel, including reestablishing a bridge painting program for steel structures and using sealer on new bridge decks;
- Develop a long-term bridge rinsing and cleaning program to remove a majority of chlorides in the spring; and
- Use (1) best management practices to maintain bridges and (2) anti-corrosion materials when designing new bridges.

Vehicle Maintenance Recommendations

All Vehicles. The report points out that while it is commonly accepted that the rate of vehicle corrosion began increasing about 10 years ago, when states began using magnesium chloride, little peer-reviewed research is available on this topic. Other factors may have played a part in accelerating the rate of corrosion, including a phase-out of vehicle manufacturers' use of hexavalent chromium, a toxic metal that had been effectively used to coat brake lines and electrical systems.

The report recommends that residents periodically wash their vehicles, particularly their undercarriages, as soon as possible after exposure to road salt to minimize corrosion. It also asserted a need for regular voluntary undercarriage inspections, possibly during routine oil changes or standard vehicle maintenance.

Commercial Car Washes. According to the report, commercial car washes should be encouraged to disclose whether they use recycled or clean water, and, if they use recycled water, to disclose the percentage of water that is recycled, when it is used, and the use of any additives.

The report recommends that the legislature and departments of Consumer Protection and Energy and Environmental Protection consider adopting regulations requiring this disclosure and the posting of information on the use of recycled water.

It also (1) said car washes should use fresh water during the final rinse and (2) called for research on the acceptable concentration of salt that could be allowed in recycled water so as not to damage vehicles.

Trucks. The report calls on (1) truck manufacturers to use corrosion resistant practices, material, and technology and (2) trucking firms to regularly wash truck undercarriages to reduce the corrosive effects of road salts. It also calls for the establishment of additional commercial truck washing stations.

ADDITIONAL INFORMATION

More information on DOT's use of magnesium chloride can be found in OLR Report 2014-R-0001.

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