Salt Applications and Alternatives for Snow and Ice Control by Local Agencies: Literature Search
July 6, 2017

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Resources searched: Transport database, web, TRB Research in Progress, MnDOT Library catalog

Summary: The results below reflect the most relevant citations for each of the topics requested in the IdeaScale proposal. The subheadings are in red. A few of the subheadings are also referenced in a previous literature search on a similar topic that is also included as a separate document. All of the results reflect a subject descriptor phrase, “Snow and Ice Control” in addition to the other subheadings mentioned. There were no least relevant results included.

Most Relevant Results

Salt Brine

Title: Salt Brine Blending to Optimize Deicing and Anti-icing Performance (Phase I)
Author: Drschel, Stephen J.
URL: https://www.lrrb.org/media/reports/201220.pdf

Title: Salt Brine Blending to Optimize Deicing and Anti-icing Performance and Cost Effectiveness (Phase II)
Author: Drschel, Stephen J.
URL: https://www.lrrb.org/media/reports/201443.pdf

Title: Estimating the Application Rate for Liquid Chloride Products based on Residual Salt Concentration on the Pavement.
URL: http://rip.trb.org/view/1439834
Abstract: The goal of this project is to determine and document the residual salt concentration on pavement after initial application of salt and salt brine during snow and ice control operations, and then recommend modified application rates for salt and salt brine for various temperatures based on the residual salt concentration on the pavement. The findings from the study will help winter maintenance agencies reduce salt usage while meeting the defined level of service (LOS). In addition, findings will contribute to environmentally sustainable policies and reduce the salt usage (snow and ice control products) into the environment.

Title: Methodology for Salt Brine Use in a Winter Services Strategic Plan.
URL: http://rip.trb.org/view/1244525
Abstract: The purpose of this project is to develop a methodology for the manufacture and storage of quality salt brine and the application of the brine in the Pennsylvania Department of Transportation’s (PennDOT’s) anti-icing and/or pre-wetting salt operations. Successfully providing winter services improvements, including levels-of-service, reduced winter maintenance costs, reduced corrosion of equipment, facilities, bridges,
pavement, etc. and lower environmental impacts is due in large part to the quality of the salt brine that is manufactured by the PennDOT’s County Maintenance Organizations.

Title: Environmental Life-Cycle Assessment of Winter Maintenance Treatments for Roadways.
Author: Fitch G Michael; Smith James A; Clarens Andres F
Citation: Journal of Transportation Engineering. 2013/2. 139(2) pp 138-146(Figs., Refs., Tabs.)
Abstract: Departments of Transportation (DOTs) rely heavily on chloride-based treatments for winter road maintenance despite the well-documented effects of these chemicals on infrastructure and the environment. Proposed alternative treatments have yet to be widely adopted because of economic and technical limitations that are largely outside of the control of the DOT. This work explores the application of winter maintenance chemicals with a life-cycle approach to understand which actions a DOT can take to reduce the negative life-cycle environmental impacts of these activities. Three representative treatments and/or best management practices are compared: conventional rock salt, calcium magnesium acetate (CMA), and preemptive treatments of roadways with a brine of salt and/or CMA. The results conclusively show that CMA, which has been widely touted as an environmentally preferable, if more expensive, alternative to chloride-based treatments, has considerably higher environmental impacts over its entire life cycle. Most of these burdens are associated with the upstream production processes required to generate the CMA. The salt-based treatments consume considerably less water, energy, and generate fewer greenhouse gases and biochemical oxygen demand in receiving waters. Applying the chloride chemicals as a brine rather than in the dry form results in important reductions in all environmental impacts over the entire life cycle. This result is consistent for a variety of climate conditions (e.g., representative of coastal, piedmont, and mountain climates) considered for this study, which used historical weather data from Virginia. Because DOTs can affect appreciable improvements in efficiency by using brines, sensitivity analysis identifies the activities specifically resulting in the most important environmental improvement on a systems basis. The DOT-controlled steps with the greatest potential for improvement include reducing the energy consumed for the salt application process and implementing practices that reduce total storm water runoff to reduce chloride loading.

Title: Potential for Natural Brine for Anti-Icing and De-Icing.
Author: Kauser J; Yusuf M
Citation: 2012/9. 216p
Abstract: This project focused on the feasibility of the use of natural brine for anti-icing and pre-wetting in Onondaga County, Syracuse, New York. A thorough literature review was conducted on the use of brine as an anti-icing and pre-wetting agent both in the United States and abroad. The review indicated that the use of brine as an anti-icing and pre-wetting agent has gained popularity in most of the Departments of Transportation (DOT) in the U.S. and abroad over the years. Studies indicate that decreased applications of anti-icing chemicals lead to significant savings in material costs, reduced use of abrasives (rock salt and sand), better road conditions, lower accident rates, better environmental protection and lower costs for winter road maintenance. Costs analyses indicated that natural brine applications costs were comparable to commercial brine applications in the Onondaga County region. Deicing materials and accident data analyses for the Village of Fayetteville, Onondaga County and the New York State DOT Onondaga East Residency office indicated that: (1) snow events are a significant contributor to winter road accidents; (2) frequency of accidents go up immediately after a heavy precipitation; and (3) number of accidents in the 2010-2011 winter season when brine was applied was less than when rock salt was applied (2009-2010 winter season) even though the precipitation was greater in the former case for I-81 and I-481.

Title: Salt Brine, Salt Brine Blends and Application Technologies During the 2008 - 2009 Winter Maintenance Season.
Author: Cloutier Jason; Newbury Gil
Citation: 2009/10. 18p(4 Phots., 2 Tabs.)
Abstract: This report documents the evaluation of Vermont's salt brine technology project. The primary objectives of this research initiative were to construct a salt brine facility, experiment with different combinations of salt brine and other ice melting additives, reduce the use of winter road sand while raising the level of service of state roads, and determine if cost savings can be attributed to the use of salt brine and/or salt brine combinations. The original scope of work included deploying three Stratos spreaders to conduct the experiment on control and experimental test sections on Interstate 89 in Northwest Maintenance Districts 5 and 8. Due to equipment complications, the experiment was modified and included different roadway sections of similar length and characteristics in both districts. Results have shown that the experimental section saved an average of 24% of material usage over the 2008-2009 winter season.

Title: Recycling of Salt-Contaminated Stormwater Runoff for Brine Production at Virginia Department of Transportation Road-Salt Storage Facilities.
Author: Fitch G Michael; Craver Vinka O; Smith James A
Citation: 2008/5. 24p(8 Figs., 2 Photos., 5 Tabs.)
Abstract: A large part of the Virginia Department of Transportation's (VDOT's) maintenance effort comprises the implementation of its snow removal and ice control program. Earlier research confirmed that VDOT captures significant volumes of salt-laden stormwater runoff at its 300+ salt storage facilities throughout the state and that the disposal options for this water are limited and costly. Although VDOT is implementing recommended management options to reduce the quantity of salt water captured, this research was undertaken to determine the possibility of recycling salt-contaminated stormwater runoff for the purpose of producing brine that can be used for pre-wetting of granular NaCl and direct application. Laboratory and field tests were conducted using bench-scale brine generation equipment. In the laboratory phase, brine was produced using tap water while hydraulic retention times and water temperatures were varied to determine how these changes would affect the quantity and quality of brine production. Stormwater runoff from a storage pond without any previous treatment was used in the field phase to allow a better estimate of the potential effects of stormwater on the quality of the brine generated. Results showed that the optimum conditions for brine production were low hydraulic retention time (high flow rates) and high temperatures. The total suspended solids present in the stormwater runoff did not diminish the quality of the brine in the field tests. Based on historic precipitation and chemical application data, VDOT appears to capture sufficient volumes of water to meet the majority of its potential brine production needs. Further, significant economic benefits can be obtained by applying this recycling strategy, with the greatest benefits resulting from generating brine for both direct application and pre-wetting. Assuming average stormwater volume collection and average total NaCl application, VDOT can save approximately $3 million each year by generating brine for pre-wetting only versus approximately $6.5 million each year by generating brine for the combination of pre-wetting and direct application.

Title: THE STATE OF THE STATES' ANTI-ICING TECHNOLOGY.
Author: Stidger R W
Citation: Better Roads. 2002/4. 72(4) p. 52-55(3 Photos.)
Abstract: This article describes various studies and applications of anti-icing technologies taking place through state departments of transportation. It relates experiences in Alaska, Colorado, Indiana, Iowa, Kansas, Kentucky, Maryland, Minnesota, Missouri, and Nebraska. Some of the challenges that are being tackled include: experimenting with ice-free roads, implementing anti-icing on a budget, preventing bond formation between the snow or frost and the pavement, and reducing salt use. Some of the solutions included: applying liquid magnesium chloride to a road prior to a storm in order to prevent ice bond from forming; creating brine-making systems using parts from local facilities; and, using zero-velocity spreaders and prewetting liquids such as salt brine in order to reduce both salt use and costs.

Title: DEICING OF ROADS IN NORWAY WITH BRINE.
Author: Stotterud R; Reitan K M
**Citation:** Transportation Research Record. 1993. (1387) p. 23-28(4 Figs., 2 Tabs.)

**Abstract:** Norway's Public Roads Administration (PRA) started a test program for deicing roads with brine in 1989. With limited access to earlier experiences with the method, the PRA wanted to evaluate the suitability of use of brine in Norway. The following was to be achieved by applying brine instead of dry or prewetted salt: (a) instant reaction, (b) increased spreading speed, (d) reduced consumption rates of salt, and (d) faster drying of deicing roads. The follow-up has shown that these objectives have been met. The effects have been judged to be very good when brine is applied in conjunction with preventive actions before expected snowfalls or icy conditions and after the formation of frost or thin layers of ice. During precipitation the effects depend on the intensity and duration of the snowfall. Brine can be used when temperatures are warmer than about -10 deg C (14 deg F).

**Alternative Chemicals** (there are a few listings that specifically mention CMA, but there are other chemical and non-chemical materials that can be researched further such as pickle juice, cheese brine/whey, molasses, vodka, sugar beets, etc.)

**Title:** Maintenance Services, Transportation Weather, and Winter Maintenance, 2015
**Citation:** TRR 2482

**Title:** Guidelines for the selection of snow and ice control materials to mitigate environmental impacts includes decision support tool software and appendices
**Citation:** CD-ROM TE220.5 .G857 2007

**Title:** Sixth International Symposium on Snow Removal and Ice Control Technology
**Citation:** June 7-9, 2004, Doubletree Spokane City Center, Spokane, Washington CIRC E-C063

**Title:** Advances and issues in snow-removal and ice-control technology
**Citation:** TRR1741

**Title:** Summary of evaluation findings for the testing of Ice Ban
**Citation:** TE220.5 .S86 1999

**Title:** Use of Chemical Admixtures to Increase the Effectiveness of Snow and Ice Removal.
**URL:** http://rip.trb.org/view/1329577

**Abstract:** Snow and ice removal can be a large expenditure during the winter months. With the increase in traffic volumes, winter weather events have a more serious impact on what is considered to be necessary and efficient movement of people and goods, reducing the costs associated with snow and ice prevention and removal would be very beneficial to the Department. There are products on the market now that boast longer working times, lower working temperatures, a less-corrosive formula and that are safer for the environment when compared to typical rock salt. Some of the Department's maintenance yards already use some sort of pre-wetting chemical for their sand/salt mixtures, but there are newer products out there that are made with sugars and are safer for the environment. Other cities and states are already using some of these products to reduce cost and be more environmentally conscious. Using a highly concentrated mixture of salt water (salt brine) has also been an option for anti-icing applications for some time. Salt brine has a benefit over rock salt because it will stick to the roadway, allowing it to work longer without being scattered by vehicles. Some of the Districts in the state have started using salt brine for anti-icing operations to keep the snow and ice from sticking to the pavement to begin with, allowing for easier removal with plows. Also, the Department's ability to view remote areas during winter weather events is limited. Adding weather monitoring systems to more remote areas of the state allows Department personnel the ability to more effectively utilize their resources. Managers will know what kind of equipment to send to these areas if they know what they are facing before leaving the maintenance yard.
Title: Investigation of Alternative Deicers for Snow and Ice Control.
URL: http://rip.trb.org/view/1428969
Abstract: The goal of this project is to identify alternative deicers to chlorides for snow and ice control operations, with a specific focus on potassium acetate and succinate. The products will be assessed to determine if they allow transportation agencies to meet their defined level of service standards, are cost competitive, and have fewer impacts to the environment and infrastructure. The project will work in conjunction with a synthesis project on this topic for Minnesota Department of Transportation (MnDOT). To support and build off this work, this project will aid in the literature review portion of the project, as well as conduct laboratory testing of selected deicing products for comparison of performance to sodium chloride based products.

Title: A New Sustainable Additive for Self-Deicing Asphalt Mixture.
URL: http://rip.trb.org/view/1436906
Abstract: Transportation agencies are increasingly relying on the use of chemical deicers for winter roadway safety and mobility. However, excessive use of such deicers (mainly chloride-based salts) poses potential risks to the natural environment, transportation infrastructure and motor vehicles. Previous research has indicated that a road wearing course paved with mixtures containing chloride based deicing additives (Cl-DIA) exhibited a higher level of self-ice melting capacity compared to conventional asphalt mixtures. However, in addition to the concerns regarding long-term effectiveness, released chlorides can still cause pollution of the surrounding environment and corrosion in steel structure of vehicles and bridges. Therefore, there is a great need to develop a more sustainable deicing additive for asphalt mixture. The primary objectives of this project are to: (1) synthesize and characterize the new formate intercalated Zn-Al-Layered double hydroxide (ZnAl-FALDH); and (2) evaluate the self-deicing performance of the new LDH based additive and its effect on functional performance of asphalt mixture.

Title: Locally Sourced Renewable Additives for Infrastructure-Friendly Snow/Ice Control Operations.
URL: http://rip.trb.org/view/1436903
Abstract: Research is needed to further optimize the “green” additives derived from Washington-sourced waste streams (apple pomace, cherry pomace, manure, etc.), with a focus on snow/ice control performance and infrastructure preservation. While our recently completed Center for Environmentally Sustainable Transportation in Cold Climates (CESTiCC) project demonstrated the feasibility of using “green” additive sourced from waste sugarbeet leaves for anti-icing, the biochemical process of deriving the “green” additive is not optimized for improving anti-icing performance. Furthermore, our preliminary laboratory study revealed that the “green” additive sourced from apple pomace exhibits better corrosion inhibition efficiency than that sourced from waste sugarbeet leaves and the two feature distinctly different chemistry and thus merit further investigation. Finally, the Washington State Department of Transportation (WSDOT) expressed interest in using such liquid formulations for pre-wetting operations. The objective of this project is to develop innovative anti-icing and pre-wetting formulations for snow and ice control on roadways, using locally-sourced agricultural wastes, fruit by-products and other bio-based additives for freezingpoint suppression, performance enhancement, and infrastructure preservation.

Title: SPR-3864: Performance of Deicing Salts and Deicing Salt Cocktails.
URL: http://rip.trb.org/view/1360244
Abstract: The focus of this study is on how the composition of different salts interact with cementitious paving binders to form deleterious reactions that can cause damage. The objective of this research is to develop guidance (a test procedure or rules of thumb) that can be used to quantify the extent of the expansive reaction that occurs. This information will be used to improve pavement binder selection that reduces the potential for joint deterioration given the salt and salt cocktails most likely to be used in Indiana. This data will also provide information on the salts in this process.
Title: Bio-based Renewable Additives for Anti-Icing Applications.
URL: http://rip.trb.org/view/1328333
Abstract: Relative to de-icing and sanding, anti-icing leads to improved level of service (LOS), reduced need for chemicals, and associated cost savings and safety and mobility benefits. Yet, the anti-icers available on the market are plagued by growing concerns over their corrosion to metals (chlorides), impact on concrete and asphalt (acetates), toxicity to the aquatic resources (agro-based products), etc. Agencies are constantly seeking for alternatives that maximize the benefits of acetates and agro-based products while minimizing their drawbacks. Meanwhile, research is needed for value-added utilization of desugared beet molasses and glycerol, which are the principal by-product of beet sugar refining and biodiesel production, respectively. The objective of this project is to develop innovative anti-icing formulations for snow and ice control on highways, using beet sugar refining by-products, glycerol, and other bio-based additives for freezing-point suppression, performance enhancement, and corrosion inhibition. This project will produce at least one paper for presentation at the Transportation Research Board (TRB) annual meeting and publication in a peer-reviewed journal. One patent application will be filed out of this project. Building on the success of this research, field operational tests will be conducted as part of a follow-up study. The team will work closely with transportation agencies to field test the new "green" anti-icers. The project fits under the Center for Environmentally Sustainable Transportation in Cold Climates (CESTiCC) research thrust of "reducing environmental impacts during construction, operations and preservation through effective design, management and preservation strategies". It also meets the United States Department of Transportation (USDOT) strategic goal in environmental sustainability as it helps "advance environmentally sustainable policies and investments that reduce harmful emissions from transportation sources". Development of alternative anti-icing products serves the public interest, as such research is expected to generate significant cost savings for the DOTs and other maintenance agencies, traveler benefits in terms of improved safety and mobility, and societal benefits in reducing the amount of chlorides into the environment. The use of alternative products will greatly reduce corrosion and environmental impacts from winter roadway operations. This work provides maintenance agencies with more options in their snow and ice control toolbox for sustainable winter road service. The exploration of bio-based renewable additives for anti-icing applications would also add value to agricultural by-products and stimulate the local economy (e.g., the $50+ million Montana beet sugar industry).

Title: EVALUATION OF AN ICE BAN (REGISTERED TRADEMARK) PRODUCT AS A PREWETTING AGENT FOR SNOW REMOVAL AND ICE CONTROL OPERATIONS.
Author: Roosevelt D S; Fitch G M
Citation: 2000/1. 25 p.(8 Figs., 2 Photos., 9 Tabs.)
Abstract: The purpose of this project was to determine if the Virginia Department of Transportation (VDOT) should use Ice Ban (registered trademark) M50 for snow and ice control. Ice Ban M50 was evaluated for its effects on snow removal and ice control operations, the environment, and the highway infrastructure. The operational component consisted of a literature review. The environmental component consisted of tests conducted on roadside vegetation, turfgrass seed, and freshwater minnows. The highway infrastructure component consisted of tests conducted on concrete and metals. The researchers concluded that the cost and operational problems associated with using Ice Ban M50 as a presetting agent exceeded those associated with using magnesium chloride (MgCl2) as a presetting agent. VDOT should consider experimentation in which Ice Ban M50 is applied directly to pavements when temperatures are below -12 deg C. Experimentation should proceed cautiously until additional research addresses concerns with product stability, mold, and other probable environmental issues.

Title: Laboratory Investigation of Performance and Impacts of Snow and Ice Control Chemicals for Winter Road Service.
Author: Fay Laura; Shi Xianming
Citation: Journal of Cold Regions Engineering. 2011/9/1. 25(3) pp 89-114(7 Figs., Refs., 5 Tabs.)
Abstract: This work evaluated the performance attributes and impacts of several alternative deicers along with traditional chloride-based deicers. Four Strategic Highway Research Program tests were conducted to evaluate the ice melting, ice penetration, and ice undercutting capabilities of the deicers of interest, and also
their impact to the freeze-thaw resistance of portland cement concrete. Three additional novel methods were utilized to assess the friction coefficient of deiced concrete surfaces, thermal properties of the deicers, and corrosion effects of deicers to metals. The laboratory data shed light on the complexity and challenges in evaluating various deicers. To facilitate scientifically sound decision-making, the writers propose a systematic approach to integrate the information available regarding various aspects of deicers, and to incorporate agency priorities, which is expected to aid agencies in selecting or formulating their snow and ice control chemicals.

**Title:** Evaluation of Alternative Anti-Icing and Deicing Compounds Using Sodium Chloride and Magnesium Chloride as Baseline Deicers - Phase I.

**Author:** Shi X; Fay Laura; Gallaway Chase; Volkening Kevin; Peterson Marijean M

**Citation:** 2009/2. 294p

**Abstract:** This project aims to evaluate potassium acetate, sodium acetate/formate-blend deicers, and potassium formate as alternative anti-icing and deicing compounds relative to sodium chloride (NaCl), salt-sand mixtures, and magnesium chloride (MgCl2) currently used by CDOT. Based on the literature review, deicers may pose detrimental effects to portland cement concrete infrastructure and asphalt pavement, cause corrosion damage to the transportation infrastructure, or have significant impacts on the environment. We conducted laboratory tests to evaluate the performance of several alternative deicers compared with traditional chloride-based deicers, including: SHRP ice melting, penetration and undercutting tests, differential scanning calorimetry test, and tribometer tests. The negative effects of deicers on metals and concrete were investigated both in the laboratory and in the field. It was estimated that even for high-quality concrete, the implications of chloride-based deicers on the service life of steel-reinforced concrete might be significant. At the three field locations, water samples were collected periodically and the data showed no immediate impact from chloride-based deicers following application adjacent to waterways. We described a deicer composite index that would allow winter maintenance managers to numerically evaluate deicers based on their agency priorities or local needs and constraints.

**Title:** CALCIUM MAGNESIUM ACETATE AT LOWER-PRODUCTION COST: PRODUCTION OF CMA DEICER FROM CHEESE WHEY.

**Author:** Yang S T; Huang Y L; Jin Z; Huang Y; ZHU H; Qin W

**Citation:** 1999/4. 120 p.(3 Apps.)

**Abstract:** Calcium magnesium acetate (CMA), a mixture of calcium acetate and magnesium acetate, is used as an environmentally benign roadway deicer. The present commercial CMA deicer made from glacial acetic acid and dolomitic lime or limestone is expensive compared with salt and other deicers. Also, a liquid potassium acetate deicer is used to replace urea and glycol in airport runway deicing. The goal of this project was to develop low-cost acetate deicers from cheap feedstocks, such as biomass and industrial wastes, via fermentation. A novel fibrous bed bioreactor was developed for fermentation to produce acetic acid from whey lactose by a co-culture of Lactococcus lactis and Clostridium formicoaceticum. The acetic acid yield from lactose in this fermentation was 90 percent, and the acetate concentration from the fed-batch fermentation was as high as 75 g/L. An energy-efficient solvent-extraction process was also developed to separate and recover acetic acid from the fermentation broth. Back-extraction or stripping with a base solution produced acetic acid salt at a high concentration, >20 percent (weight per volume)(w/v), and simultaneously regenerated the solvent. Two alternative methods to produce low-cost acetate deicers from cheese whey were studied. CMA deicers produced from cheese whey by fermentation and extraction were tested for their acetate content and deicing properties. The CMA solid sample obtained from extraction of the acetic acid present in a dilute aqueous solution and then back-extracted with dolomitic lime to form CMA had about the same acetate content (70 percent acetic acid or 90 percent CMA) as that of the commercial CMA deicer. The sample from dried whey fermentation broth contained 50 percent acetic acid or 63 percent CMA, with the remaining solids being other organics and salts present in whey. Deicing tests showed that CMA samples from fermentation and extraction had an equal or slightly better ice penetration rate than that of the commercial CMA. Cost analysis showed that CMA can be produced at a product cost of $204-$328/ton.
($224-$360/tonne), less than 30 percent of the current market price for the commercial CMA, for a plant size of 8400 tons (7640 tonnes) CMA per year. The lower CMA cost should dramatically increase CMA use in the deicing market. Scale up of these processes is feasible. Detailed process evaluation and cost analysis are given in this report.

Title: Migration of alternative de-icing chemicals in shallow aquifers.
Author: NYSTEN,T; HELLSTEN,P
Citation: 2002. (III-101f) pp4p(Refs., Refs.)
Abstract: The main harmful impacts the de-icers have on ground water quality are leaching of heavy metals from soils, corrosion of water supply systems, chemical residues, and oxygen loss in water caused by organic de-icers. The migration of organic de-icers in the shallow aquifers typical in Finland is not well known and we should find solutions to minimize the negative impacts the de-icing have on ground water quality. The objective the project MIDAS (Migration of Alternative De-icing Chemicals in Aquifers) is to find de-icers which have the least harmful impacts on groundwater quality. Migration of sodium chloride as a tracer and five alternative de-icers in aquifers are being studied. The alternative de-icers are calcium chloride, magnesium chloride, calcium-magnesium-acetate, potassium acetate and potassium formiate. The research consists of in vitro study and field research that will follow. The results will be use to choose a de-icer from existing chemicals and for the development of new less harmful de-icers. The information will be use mainly in Scandinavia and North America where the hydrogeological conditions are similar to those in Finland. (A).
For the covering abstract of the conference see ITRD E212110.

Title: SEARCH CONTINUES FOR ALTERNATIVE DEICING CHEMICALS.
Citation: Better Roads. 1985/6. 55(6) p. 44-45
Abstract: Routine use of a nonchloride deicer remains limited to a few specialized situations. Cost, rather than effectiveness, seems to be the central issue. Recent work by the Federal Highway Administration has fostered interest in calcium magnesium acetate (CMA). In many states, work is underway to produce CMA economically, to evaluate its effectiveness and to determine its corrosive effects. Basically, CMA is produced by a reaction of dolomatic lime with acetic acid. There are several ways to achieve this reaction, however, and much research is centered on cost-effective production methods.

Technology Applications and/or GIS

Title: Prototype Development of a Piezo-heating Array for Deicing Applications on Bridges.
URL: http://rip.trb.org/view/1366952
Abstract: The proof-of-concept prototype will be a scaled model of a bridge and its approach slab. The model will have a scaled version of an axle tandem loading the approach slab. On the approach slab, the team will install the prototype technology - a piezo-electric array linked (in series?) and tied to a battery. As the axle tandem rolls on the model bridge approach, electricity will be generated and stored. The prototype will serve as an example of how modern bridge approach slabs could be constructed to harness the energy produced by truck traffic to mitigate winter conditions.

The team envisions triggering a heat element to raise the temperature of the mock road-surface up to sufficient temperature to surpass the needed energy to melt an inch of snow or moderate amount of ice. The prototype will be constructed to conform to a technical memorandum documenting performance metrics for a successful competitor to deicing chemicals. National Cooperative Highway Research Program (NCHRP) Synthesis 449 offers several conditions that contribute to deicing performance:

(1) In a case study, the shift from using rock salt to brine for deicing led to roughly 50% materials savings, as the standard application rate of rock salt and salt brine was 250 pounds and 50 gallons per lane mile, respectively, and 1 ton of rock salt makes about 1,000 gallons of brine (Dave Frame, CalTrans, personal communication, Apr. 5, 2012).
"When the pavement temperature drops below \(-12.2^\circ C\) (10ºF), salt is no longer cost-effective, and agencies thus utilize other chemicals either alone or as pre-wetting agent to enhance the performance of salt (Ohio DOT 2011) or apply abrasives to provide a traction layer on pavement."

Other resources to consider in the development of this performance metric will be the following: (1) Manual of Practice for an Effective Anti-icing Program (FHWA, Ketcham 1996).

(2) NCHRP Report 577 "Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts".

(3) Burtwell, M., Transportation Research Circular Number E-C063: Deicing Trails on UK Roads: Performance of Prewetted Salt Spreading and Dry Salt Spreading, Sixth International Symposium on Snow Removal and Ice Control Technology (04-063).


Title: Carbon Fiber Heating Wire for Pavement Deicing.
Author: Wu Jianmin; Yang Fei; Liu Jianguo
Citation: Journal of Testing and Evaluation. 2015/5. 43(3) pp 574-581
Abstract: The use of electric heating technology in pavement deicing has received considerable attention because of its fast and environmentally friendly features. Carbon fiber heating wire (CFHW) buried in concrete slabs is a type of technology that belongs in this category. This study conducts indoor heating tests to analyze and determine the factors that influence the heating rate of CFHW, including depth of installation, layout interval, input current, ambient temperature, and overlying material. A finite element model is established and calibrated by simulating the indoor heating tests. The heating effect of concrete pavement in different environmental conditions is analyzed through finite element simulation. Results show that CFHW is effective for pavement deicing.

Author: Zhou Xiao min; Yang Zhaohui Joey; Chang Christiana; Song Gangbing
Citation: Journal of Cold Regions Engineering. 2012/3/1. 26(1) pp 1-15(Figs., Refs., Tabs.)
Abstract: Traditional deicing approaches such as salting pollute the environment and corrode reinforcing steel bars in concrete. Meanwhile, recently emerging carbon nanofiber material has improved electrical conductivity, a large heating capacity at low voltage, high strength, and, in particular, natural immunity to corrosion. This material offers an excellent alternative as the heating element in electrical resistive deicing systems. This paper aims to assess the effectiveness of a deicing system that has embedded carbon nanofiber paper heating elements and to evaluate the effects of several key parameters on the performance of such a deicing system. A physics-based finite-element model was built, validated by test results, and used to assess the performance of such a deicing system when applied to roadway conditions. Factors considered include air temperature, wind speed, pavement and insulation layer thicknesses, and heating input. Results show that the proposed system can be very effective for roadway deicing. Future research is needed to validate its feasibility and effectiveness in a field experiment.
Title: Delaware uses technology to combat winter storms.
Author: Livengood Chad
Citation: Transport Topics. 2011/2/14. (3933) p. 9-10(Maps.)

Author: Smithson Leland D; Burkhardt John P
Citation: TR News. 2009/11. (265) pp 17-21(Photos., 7 Refs., 2 Tabs.)
Abstract: With support from the Federal Highway Administration, a research consortium of state departments of transportation has undertaken the design and development of a highway maintenance concept vehicle (HMCV) deploying the latest technologies to improve snow and ice control operations. The consortium project was divided into three phases: prototype functions and feasibility; prototype evaluation; and field tests and evaluation. The project was followed by a second project, or Phase IV, for operations and field demonstrations. This article discusses the accomplishments of each of the four phases of the development of the HMCV.

Title: Non-Intrusive Road Weather Sensors and Their Role in ITS.
Author: Bridge Paul
Abstract: Many road authorities have invested in Road Weather Information Systems (RWIS) which provide data from locations around their road networks 24/7. Most of these systems are based on 30 year old technology, in the form of sensors embedded in the road surface to provide information about surface conditions and temperature. Along with atmospheric sensors, the majority of these road weather stations provide authorities with information to help tackle the problems of ice and snow. The 2003 American Meteorological Society (AMS) Forum on Weather and Highways noted that RWIS significantly benefit highway maintenance operations, particularly winter maintenance. The consensus of transport professionals was that there would be clear benefits from a denser network of road weather observation sites. At the same time it recognized that deployment of RWIS has been limited by their cost and the strong competition for limited funds within state DOTs. The recent introduction of non-invasive road temperature and condition sensors is providing a cost effective solution for authorities to both obtain improved road weather information and increase the density of RWIS observations. This paper explores the applications and benefits of non-intrusive road sensors with a particular focus on: winter maintenance key performance indicators, decreasing environmental impact of de-icing agents, and sensor deployment

Title: Implementation of Conductive Concrete for Deicing (Roca Bridge).
Author: Tuan Christopher Y
Citation: 2008/7/31. 153p(3 Apps., 21 Refs., 11 Tabs.)
Abstract: The search for improved deicing methods has been a research focus for quite some time. Existing technologies perform deicing by chemical, electrical or thermal energy sources. Electrically conductive concrete is produced by adding electrically conductive components to a regular concrete mix to attain stable electrical conductivity to enable conduction of electricity through the concrete. In the application for bridge deck deicing, a thin layer of conductive concrete can generate enough heat due to its electrical resistance to prevent ice formation on the pavement surface when connected to a power source. The heated deck of Roca Spur Bridge is the first implementation in the world using conductive concrete for deicing. The Roca Spur Bridge is a 150-ft long and 36-ft wide, three-span highway bridge over the Salt Creek at Lincoln, Nebraska, located near U.S. Route 77 South. This experimental bridge deck, after 5 years of evaluation, has shown that using conductive concrete has the potential to become a very cost-effective bridge deck deicing method. The technology provides an environment-friendly solution to address the looming crisis of water supply contamination by road salts, particularly on bridge decks over streams and rivers in the cold regions.
Title: Global Positioning System Controlled Salt Spreading: From Idea to Implementation.
Author: Knudsen Freddy; Sommer Bo
Abstract: Salt spreading controlled by Global Positioning System allows salt distribution on the whole road surface with automatic adjustment of spreading dosage, width, and symmetry while the driver concentrates on following the route. This technology is developed because automatic data collection from salt spreaders has shown that even skilled drivers can't adjust spreading width and symmetry in a proper way and drive the truck at the same time. In the long term the technology is essential to implement salting with different dosages based on prognoses for the salt needed along a route. Today the same dosage is used on the entire route even though we know that the salt needed won't be the same.

Title: New Technology Keeps Ice Away and Drivers Safe: Anti-icing and Anti-skid Overlay Reduces Accidents and Protects Assets.
Author: Persichetti Bob
Citation: Concrete International. 2007/2. 29(2) pp 52-55(3 Photos., 5 Refs.)
Abstract: SafeLane Surface Overlay was developed at Michigan Technological University for prevention of roadway and bridge icing and skids. Licensed to Cargill in 2003, this mixture of epoxy and aggregate acts as a rigid sponge for standard liquid anti-icing solutions applied to roadways when adverse weather is expected. The overlay automatically releases the chemicals as inclement conditions develop. It also improves surface friction for safer driving year round.

Title: SOUTHEAST MICHIGAN SNOW AND ICE MANAGEMENT (SEMSIM) - SPRING 2001.
Author: Anderson E
Citation: 2001/7. 10 p.(4 Photos.)
Abstract: The Southeast Michigan Snow and Ice Management (SEMSIM) partnership includes the Detroit Department of Public Works, the Road Commission of Macomb County, the Road Commission for Oakland County, and the Wayne County Department of Public Services. The purpose of the partnership is to develop an Automatic Vehicle Location (AVL) system that will allow the partners to fight a snowstorm in a cooperative effort. This report provides an interim status of the system prior to upgrades and additional installations that are scheduled to occur in the winter of 2001-2002. The evaluation effort consisted of (1) observations and interviews with drivers and supervisors at the operational terminals and (2) vehicle equipment inspections. The evaluation centered on determining system operational status and what system users with a year of experience would like to see in the system upgrade.

Title: SNOW AND ICE REMOVAL MONITORING AND MANAGEMENT SYSTEM.
Author: Anderson E; Metzger H; Burt W
Citation: ITS-IDEA Program Project Final Report. 2000/8. 18 p.(4 Figs.)
Abstract: This Intelligent Transportation Systems (ITS) Innovations Deserving Exploratory Analysis (IDEA) project evaluated the performance and utility of using automatic vehicle location, wireless communication technologies and geographic information systems as applied to snow and ice removal operations. Removal of snow and ice on Wayne County roads is done by snowplow trucks that are given a route and are then unsupervised for the duration of the time they are working on the assigned route. Since there may be over 100 snowplow trucks working separate routes and since each and every storm presents different conditions to the driver of the plow, it is very hard for a dispatching supervisor to have a clear idea of how the road clearing operation is progressing. The end result of this project was to put a map display showing route status in different colors on a terminal in front of the dispatcher.
Title: IMPLEMENTING NEXT GENERATION MAINTENANCE VEHICLE TECHNOLOGY.
Author: Smithson Leland D
Citation: Conference Title: Ninth AASHTO/TRB Maintenance Management Conference. Location: Juneau, Alaska. Sponsored by: American Association of State Highway and Transportation Officials; Transportation Research Board; Federal Highway Administration; Alaska Department of Transportation and Public Facilities; and Iowa Department of Transportation. Held: 20000716-20000720. 2000. 10p(3 Figs.)
Abstract: The mission of the Iowa Department of Transportation (DOT) Maintenance Division is to manage the preservation and operation of Iowa's transportation system to deliver transportation services that support the economic, environmental and social needs of its customers. This mission is particularly challenging to Snow Belt states during the perils of a winter season. Just-in-time goods deliveries, a key ingredient in any state's economic vitality, places an ever-increasing importance on reliable year-round transportation. These increasing transportation demands are coming at a time when most states are being asked to downsize their maintenance operations work force. The application of advanced snow and ice control technologies and their integration with Intelligent Transportation Systems (ITS) offer excellent potential for increasing operational efficiency and effectiveness as well as improving winter mobility and driver safety. In 1995, the Iowa, Michigan and Minnesota DOTs formed a consortium to define and develop the next-generation highway maintenance vehicle that would utilize the latest maintenance operational technologies and interface with ITS. Focus groups consisting of each DOT's internal and external customers revealed that while all maintenance operations could benefit from creating this new generation vehicle, ice and snow operations were the most complex and would benefit greatly from improvements in state of the art vehicle navigation systems, onboard computer applications, and enhanced safety systems. This advanced technology highway maintenance vehicle functions as both operational truck and a mobile data-gathering platform. Sensors mounted on the vehicle record air and roadway surface temperature, roadway surface condition, and roadway surface friction characteristics. This information is Global Positioning System (GPS) correlated and used in maintenance operational decision-making. The information will eventually be interfaced with the ITS technology in the Traffic Management and Information Service Provider Centers Subsystems of the National ITS Architecture. The advanced technology highway maintenance vehicle performs an important role in the U.S. Federal Highway Administration's "Weather Information for Surface Transportation ITS Field Operational Test" being conducted by the FORETELL consortium. The vehicle operates as a mobile environmental sensor station gathering real time pavement thermal profiles and air temperature data for input to the FORETELL micro scale models. Each of the three consortium states has built and operated an advanced technology highway maintenance vehicle in their daily maintenance operations for three years. Each vehicle and its advanced concept technologies have passed proof of concept tests. Each technology is now being evaluated to make sure what benefits have been realized and calculate their respective benefit/cost ratio. Emerging technologies are also being tested on the concept vehicle.

Title: U.S. DE-ICING TECHNOLOGY IS CATCHING UP WITH THE REST OF THE WORLD.
Author: Southerland R
Citation: American City and County Product Review. 2000/2/15. 115(3) p. 8-9(1 Phots.)
Abstract: Using information acquired on trips to Japan and Europe, the Iowa Department of Transportation (DOT) pushed for development of a snow removal vehicle that includes the latest technology along with the usual snowfighting equipment. Manufacturers saw the possibility of an enlarged market for the vehicle and set about creating a concept vehicle for the state's use. The truck premiered in the winter of 1997. In addition to a friction meter that can determine the slickness of a wintertime snow- or ice-bound road, it carried global positioning satellite (GPS) technology, infrared temperature devices for reading the temperature of the pavement and the air, monitors for measuring the proper distribution of materials, and prewetting equipment to make sure sand and salt placed on the roads stuck to the pavement and did not get blown away by wind or passing traffic. The truck also carries devices for spraying chemical agents on a roadway before the arrival of snow and ice storms that act as debonding agents, allowing the snow to be
plowed without sticking to the pavement. GPS technology was incorporated into 19 additional vehicles, allowing the central agency to determine which trucks are out, where they are located, if their plows are up or down, and whether their spreaders are on or off. The control offered by GPS inspired Virginia's DOT to equip 80 snow removal vehicles with the technology.

**Title:** WINTER MAINTENANCE GOES HIGH TECH.
**Author:** Krylowski T
**Citation:** Roads & Bridges. 1998/12. 36(12) p. 14(1 Phots.)
**Abstract:** The Iowa, Michigan, and Minnesota Departments of Transportation are using advanced winter maintenance trucks that feature everything from global positioning systems to fiber-optic lighting. The vehicles are a product of a research consortium formed by the three states in 1995. The consortium collected information on the latest snow and ice control technologies and then conducted focus groups to help determine the most desirable features for the truck. Once the design was developed, a prototype vehicle was assembled for each of the states by March 1997. The Michigan truck has a chassis-mounted material spreader and brine tank, while the Iowa and Minnesota trucks have dump boxes. All three trucks have front, wing, and underbody plows. The trucks’ features include liquid and granular spreading equipment that can dispense dry, prewetted, or liquid materials for deicing or anti-icing operations; fiber-optic lighting that provides increased visibility during storms and whiteout conditions; and a newly designed friction measuring device that measures and records the friction of the road surface. The trucks received a full tryout during the winter of 1997-1998 and performed very well. The states are working on building a second generation vehicle for use in 1999-2000.

**Title:** FROM BLACKTOP TO DESKTOP: FIVE TECHNOLOGIES CHANGING PUBLIC WORKS.
**Author:** Ward J; Shapard R; Black T
**Citation:** American City & County. 1997/9. 112(10) 17 p.(2 Figs., 4 Phots.)
**Behind virtually every element of today's infrastructure is a piece of modern technology that has shaped the way it is built or maintained by local public works agencies. This article looks at five of those technologies and their implications for the future of the business. Computer-aided design (CAD) has given the designers and builders of the nation's infrastructure a window into the hearts and minds of the citizens who will ultimately use the results of their efforts. Geographic information systems (GIS) can provide public works departments with information on landscapes, roads, and bridges that need to be built, maintained, or replaced. Using a pavement management system (PMS) was something that many local agencies were initially forced into, but now find quite useful. Although the use of reverse osmosis (RO) and other membrane processes is expanding, they are still fairly uncommon in much of the United States. Anti-icing and deicing of the nation's roads now relies heavily on the computers and pavement sensors of road weather information systems (RWIS). Sidebars highlight a microwave pothole repair technology and outline stream restoration and stabilization efforts enacted in Fairfax, Virginia, that were centered around bioengineering and stream morphology.

**Title:** Development of Road Surface Friction Monitoring System.
**Author:** Takahashi Naoto; Kiriishi Makoto; Tokunaga Roberto; Kamiyama Shigeru
**Citation:** Conference Title: 19th ITS World Congress. Location: Vienna.Sponsored by: ERTICO - ITS Europe.Held: 20121022-20121026. 2012. 8p(Figs., Maps., Phots.)
**Abstract:** In cold and snowy regions, winter weather poses a significant hazard to road transportation. Winter Road maintenance is essential to provide a safe road surface for the driving public. In Hokkaido, the northernmost major island of Japan, skidding accidents account for 90% of the winter-type traffic accidents. Therefore, measures against icy road surfaces play a very important part of winter maintenance. In order to carry out these measures appropriately, it is necessary for maintenance staff to understand the spatial changes in road surface conditions and to share that information promptly. Aimed at solving these issues, Road Surface Friction Monitoring System has been developed by taking advantage of Intelligent Transportation System (ITS) technology. The core of the system is a Continuous Friction Tester (CFT). With
the ability to measure road surface friction continuously, CFT makes it possible to understand spatial changes in road surface conditions in detail. The data obtained are transmitted in real time by using mobile devices and can be checked in offices through a web based Geographic Information System (GIS). Sharing the same information between patrol staffs and office workers improves promptness and certainty in decision-making. Also, the accumulated data are utilized to improve the appropriateness and the effectiveness of winter maintenance.

Title: OPTIMIZATION OF ANTI-ICING & SANDING OPERATIONS VIA MOBILE DATA COLLECTION IN SOUTHEAST ALASKA.
Author: Thompson G E
Citation: Date on documentation page: September 30, 2003; Date on cover: December, 2003.
Abstract: The Alaska Department of Transportation and Public Facilities (AKDOT&PF) investigated the effectiveness of remote data collection technology to optimize the deicing and anti-icing material distribution methods in the Juneau, Alaska area. Researchers customized an in-vehicle remote data collection system provided by ThomTech Design, Inc., to collect objective data on meteorological conditions and deicing and anti-icing material distribution rates. The researchers also used an evaluation module of the remote data collection system to collect subjective data on the effectiveness of the snow/ice control treatments. The study team then analyzed the data with ArcVIEW GIS software to reveal opportunities to optimize the performance and cost effectiveness of AKDOT&PF's regional snow and ice control program. The study revealed that remote data collection technology promises to be an effective tool for optimizing the cost effectiveness of snow and ice control treatments in Juneau, Alaska. Additional data collection and analysis are necessary to more clearly establish performance and cost effectiveness of various treatments in Juneau's variable winter climate.

Geothermal (see additional literature search attached).

Permeable Pavements

Title: Permeable Pavements, 2015
Citation: TE251 .P47 2015

Title: Permeable Pavements in Cold Climates: State of the Art and Cold Climate Case Studies
Citation: TE270 .P475 2015

Title: Highway Design, 2010
Citation: TRR2195

Title: Highway Facility Design, 2007
Citation: TRR 2025

Title: Drainable Pavement Systems: Participant Notebook
Citation: TE215 .D73 1992

Title: Winter Effluent Quality from Partial-Infiltration Permeable Pavement Systems.
Author: Drake Jennifer; Bradford Andrea; Van Seters Tim
Citation: Journal of Environmental Engineering. 2014/11. 140(11) Content ID 04014036(Refs.)
Abstract: This study, conducted between 2010 and 2012, compares the winter quality of storm water outflows from one pervious concrete and two permeable interlocking concrete pavement systems with runoff from an asphalt control pavement. The permeable pavement systems were designed for partial infiltration with underdrains. During the winter, the pavements were plowed and, occasionally, salted. Analyses are based on samples of permeable pavement effluent and asphalt runoff collected for 19 events over two winter seasons.
The permeable pavement systems performed similarly and provided excellent storm water treatment during winter months by reducing event mean concentrations (EMC) and total pollutant loadings for petroleum hydrocarbons, total suspended solids, metals (copper, iron, manganese, and zinc), and nutrients (total-nitrogen and total-phosphorus). The permeable pavements were also shown to provide temporary storage and create opportunities for the dilution of sodium and chloride in outflows. Road salt was identified as a pollutant source for numerous pollutants beyond sodium and chloride. Freezing conditions did not inhibit the functionality of the permeable pavement systems for storm water treatment.

**Adaptive Management**

**Title:** Adaptive Management for De-icing in Minnesota  
**URL:** [https://www.wrc.umn.edu/adaptive-management-de-icing-minnesota](https://www.wrc.umn.edu/adaptive-management-de-icing-minnesota)

**Title:** City of Bloomington Snow and Ice Control  
**URL:** [http://www3.apwa.net/library/meetings/pwx/10409.pdf](http://www3.apwa.net/library/meetings/pwx/10409.pdf)

**Title:** Minnesota Stormwater Manual: Chloride Management Plan combined  
**URL:** [https://stormwater.pca.state.mn.us/index.php?title=Chloride_Management_Plan_combined](https://stormwater.pca.state.mn.us/index.php?title=Chloride_Management_Plan_combined)

**Title:** Twin Cities Metropolitan Chloride Management Plan  
**URL:** [https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf](https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf)

**Title:** Adaptive Management to Improve Deicing Operations.  
**URL:** [http://rip.trb.org/view/1471866](http://rip.trb.org/view/1471866)

**Abstract:** The goal of this project is to find ways to further reduce the use of deicing salts by linking automatically collected data from salting trucks to automatically collected water quality data. The outcomes will take adaptive management (AM) for deicing operations to a new level that would achieve both traffic mobility goals and water quality goals (lower chloride, Cl). The University will communicate this information throughout the state with a web-based AM tool (e.g., a simple spreadsheet tool) and documentation, an online video presentation, and presentation of findings at several professional conferences. This research may lead to multiple benefits: material cost savings; labor savings; user savings; construction savings; reduced life cycle costs; reduced environmental damage; reduced risk; user benefits.

**Vegetation / Living Snow Fences**

**Title:** Establishment, Protection, and Reestablishment of Urban Roadside Vegetation Against Salt and Ice  
**Author:** Johnson, Ann M.  
**URL:** [https://www.lrrb.org/pdf/200033.pdf](https://www.lrrb.org/pdf/200033.pdf)

**Title:** Using Living Snow Fence to Improve Snow and Ice Control and Vegetation along Highways.  
**URL:** [http://rip.trb.org/view/1228597](http://rip.trb.org/view/1228597)

**Abstract:** The project will develop research and training materials so Department staff can design and install living snow fences. It will also evaluate the factors for living snow fence success in New York State and calculate the benefit cost of living snow fence installations. As part of the project, the researcher is likely to use actual living snow fence installation as a training and evaluation device. Desired Outcome: A greater understanding of how living snow fences work and their benefits, Department staff who are trained to design and install living snow fence and distribution of the research experience within the Department and to other transportation agencies.

**Title:** Designing, Developing, and Implementing a Living Snow Fence Program for New York State.  
**URL:** [http://rip.trb.org/view/1343183](http://rip.trb.org/view/1343183)
Abstract: This project is designed to further our understanding of the design and installation of living snow fences in NY and the region and transfer this knowledge to practitioners. A review of the literature on living snow fences and lessons learned from living snow fence programs in other states will be conducted and used to develop guidelines for design, installation, and maintenance of living snow fences. These guidelines will be used to prepare training documents and presentations, which will be presented to NYSDOT staff through a series of eight interactive and hands-on workshops, the last two of which will be run by NYSDOT staff. Protocols will be developed, based on review of the literature and field experience, for site assessment prior to design and installation. A second set of protocols will be developed for field assessment of operationally-mature living snow fences. A network of living snow fences installed in the past few years in NY will be used to evaluate protocols. Data collected on established and prospective sites will also be used to develop a cost-benefit model for living snow fences in NY. Throughout the duration of the project, these protocols, as well as training materials will be tested, updated, and revised using an adaptive management approach to further our understanding of how these systems work and how best to transfer this knowledge to practitioners.

Title: Unconventional Application of Snow Fence.
URL: http://rip.trb.org/view/1400940
Abstract: Region 3 maintenance forces were noticing that they were going out to plow certain sections of road after a storm when the sun was shining because of drifting snow. Some snow fence was placed on the right-of-way line which is contrary to the design recommendations. It has reduced the need for the plows to go back after storms because of drifting snow in the areas of the snow fence. However, the adjacent sections of road still have the drifting. A study is proposed to look into the non-conventional application of snow fence on Utah Department of Transportation (UDOT) roads to document the effectiveness of the existing locations and determine the conditions in which more snow fence would be successful.

Title: Design of Living Barriers to Reduce the Impacts of Snow Drifts on Illinois Freeways.
URL: http://rip.trb.org/view/1399387
Abstract: An emerging alternative to a structural snow fence is a living snow fence (LSF), which provides a longer-lasting, low-maintenance and cost-effective solution to snowdrifting. It is desirable to improve the use of living barriers as a passive yet sustainable snow/ice control measure for Illinois freeways. Existing design protocols are based on semi-empirical assumptions about snow transport and deposition around structural barriers, which fail to represent the diverse scenarios around LSFs or guide their proper siting and design. The objective of this project is to “develop recommendations on design and placement of living snow fences to minimize the snow drift”.

Title: Economic and Environmental Costs and Benefits of Living Snow Fences: Safety, Mobility, and Transportation Authority Benefits, Farmer Costs, and Carbon Impacts.
Author: Wyatt Gary; Zamora Diomy; Smith David; Schroder Sierra; Paudel Dinesh; Knight Joe; Kilberg Don; Taff Steve; Current Dean; Gullickson Dan
Citation: 2012/2. 174p
Abstract: Blowing and drifting snow on Minnesota's roadways is a transportation efficiency and safety concern. Establishing standing corn rows and living snow fences improves driver visibility, road surface conditions, and has the potential to lower costs of road maintenance as well as accidents attributed to blowing and drifting snow. It also has the potential to sequester carbon and avoid the carbon emissions of snow removal operations. In recent years the Minnesota Department of Transportation (MnDOT) has paid farmers to leave standing corn rows to protect identified snow problem roadways. They have paid farmers $1.50 per bushel above market price. With increasing demand for corn to fuel the ethanol industry, paying $1.50 per bushel above market price may not be sufficient incentive for leaving standing corn rows. Also, with MnDOT's memorandum of understanding with USDA to plant living snow fences through the Conservation Reserve Program (CRP), now is an opportune time to review MnDOT's annual payment structure to farmers and prepare a new one. This project has: 1) developed a calculator to estimate payments for farmers that includes consideration of safety and snow removal cost savings; 2) estimated potential income from carbon payments;
3) worked closely with MnDOT engineers and plow operators, estimated the safety and snow removal costs and carbon emissions avoided by MnDOT through establishing living snow fences; and 4) evaluated farmers’ willingness to establish living snow fences and identified farmers/landowners' constraints to adoption. Data is provided to MnDOT to assist staff in its decision making related to their Living Snow Fence Program.

Title: Living Snow Fences.
Author: Nixon Wilfrid A; Davison Megan; Kochumman George
Citation: 2006/11. 36p(2 Tabs.)
Abstract: Blowing snow can cause significant problems for mobility and safety during winter weather in three distinct ways. It may drift onto the road, thus requiring almost continuous plowing while the wind is blowing (which may occur when a given winter storm is over). Snow may drift onto wet pavements (perhaps caused by ice control chemicals) and dilute out the chemicals on the road, creating ice on the road. And sufficient blowing snow can cause a major deterioration in visibility on the road, a factor which has been shown to be significant in winter crashes. The problem of blowing snow can be very effectively addressed by creating a snow storage device upwind of the road that requires protection from snow drifting. Typically, these storage devices are fences. Extensive design guidance exists for the required height and placement of such fences for a given annual snowfall and given local topography. However, the design information on the placement of living snow fences is less complete. The purpose of this report is to present the results of three seasons of study on using standing corn as snow fences. In addition, the experience of using switch grass as a snow storage medium is also presented. On the basis of these experimental data, a design guide has been developed that makes use of the somewhat unique snow storage characteristics of standing corn snow fences. The results of the field tests on using standing corn showed that multiple rows of standing corn store snow rather differently than a traditional wooden snow fence. Specifically, while a traditional fence stores most of the snow downwind from the fence (and thus must be placed a significant distance upwind of the road to be protected, specifically at least 35 times the snow fence height) rows of standing corn store the majority of the snow within the rows. Results from the three winters of testing show that the standing corn snow fences can store as much snow within the rows of standing corn as a traditional fence of typical height for operation in Iowa (4 to 6 feet) can store. This finding is significant because it means that the snow fences can be placed at the edge of the farmer's field closest to the road, and still be effective. This is typically much more convenient for the farmer and thus may mean that more farmers would be willing to participate in a program that uses standing corn than in traditional programs. On the basis of the experimental data, design guidance for the use of standing corn as a snow storage device in Iowa is given in the report.

Title: DEICING SALT COMPATIBILITY WITH VEGETATION.
Author: Priebe L V
Citation: Public Works. 1990/4. 121(4) p. 48-49(2 Tabs.)
Abstract: When it is handled properly, salt can be completely compatible with the natural environment. It is important that officials with ice and snow removal responsibilities be thoroughly familiar with the proper storage, handling, and use of deicing road salt. When they are, they can take advantage of its economical and efficient characteristics, and at the same time avoid problems with vegetation and corrosion that are associated with excessive salt use. The degree of harm to vegetation depends on four characteristics: the amount of salt, type of soil, total precipitation, and plant species. Many trees resist effects of salt well. These include oaks, locusts, Scotch elm, Russian olive, hawthorne, and silver and gray poplars. Tables are provided with this article showing salt tolerance (low, moderate, or good) of trees and ornamentals, and salt sensitivity of grasses and forage legumes. For additional information, interested persons are referred to two sources: the National Roadside Vegetation Management Association, 309 Center Hill Road, Centerville, Delaware 19807, and the Salt Institute, 700 North Fairfax Street, Fairfax Plaza, Suite 600, Fairfax, Virginia 22314-2040.
Title: SNOW AND ICE CONTROL: ROAD SALT USE IN MINNESOTA. WORKSHOP PROCEEDINGS, HELD AT ST. PAUL, MINNESOTA ON SEPTEMBER 13, 1977.

Citation: 1977/9/13. 164 p.

Abstract: The Snow and Ice Control Workshop was held in response to a Proposal that the Committees on Transportation and Environment and Natural Resources establish a special subcommittee to examine the feasibility of salt use by the Department of Transportation and other road authorities throughout the state of Minnesota for the purpose of snow and ice control on roads and streets. It was also proposed that the subcommittee undertake a study with the objective of finding substitute deicing materials that would reduce the negative effects of salt on vehicles and the environment. This publication includes the presentations of each of the speakers who participated in the workshop. Section one contains the three papers dealing with the current use of road salt in Minnesota. Section two follows with papers concerning corrosion and its structural consequences. Section three deals with environmental problems. The final section deals with alternative snow and ice control methods.

Least Relevant Results