Spring 2018

Winter Maintenance of Akron Roadways

Kayla Hillegass
kah172@zips.uakron.edu

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Current practices and a comparison to other communities

Kayla Hillegass

Department of Civil Engineering

University of Akron

Abstract

The city of Akron experiences several hundred crashes each winter season due to winter road and weather conditions. The winter maintenance practices of the city follow a guide by the Salt Institute that uses a combination of plowing and salting to clear the roads. This paper provides an understanding of winter maintenance from its beginnings to present day and will discuss how certain practices came to be. Looking at three other cities across the United States with similar characteristics in size or snowfall amount show many similarities with a few new concepts that Akron can consider (e.g., better communication via app with citizens and private contractors) and see if they are applicable to their situation. How citizens can be better equipped to handle the changing road conditions and the rules/practices behind studded tire use in Ohio will be addressed. Research being done on different chemicals placed on the roads as well as different types and mixes of road material will provide ideas and concepts for the city to consider and possibly incorporate into the future practices of the city of Akron.

Introduction

The city of Akron is located in Summit County in the Northeast Ohio area. Akron winters have on average 43 inches of snowfall each year (*Climate*). Winter weather brings about difficult driving conditions with snow and ice accumulation on the roadways. With snowfall occurring in the Akron area in general between October and April, drivers have to deal with these conditions over a majority of the year. Many advancements have occurred to improve the ability to safely traverse roads during these months, from both the vehicle perspective and the roadway perspective. Cities like Akron, which is home to approximately 190,000 people and houses many businesses, schools, and universities, bring in many drivers from throughout the region, so roads need to be accessible. Being able to combat the winter weather of Northeast Ohio in the most efficient way is a challenge that the city faces and a comparison to the practices of other cities will be an indicator if there are other winter maintenance practices to put into effect in the city of Akron.

History

Winter weather has created issues for people since the early settlers and indigenous people. These harsh weather conditions made gathering supplies to keep warm and walking/horse riding difficult especially as towns grew and routes between towns became more established. Changes were made to the ways people moved about and dealt with the snowy weather, from stockpiling supplies to adapting the horse carriages to function better on snowy roads. Everything was done by trial and error for the growing populations in these snowy areas to learn to predict snow conditions and remove the snow from the roadways as this was critical to get supplies into cities. Many travellers and townspeople packed down the snow and switched out wheels for ski-like runners to travel. These “snow wardens” were people employed by the towns to flatten snow with these giant rollers and pack it onto the road (Soniak). This caused issues as some roads or bridges needed snow added to them to match the “ski slope like roadways” and the melting of the snows brought about issues with uneven surfaces. Most initial snow removal in the 1800’s was by the citizens with shovels if they wanted to have people visit them or to be able to move themselves. The patents for the first snowplow were issued in the 1840s but the first snowplow was recorded in use in the 1860s (Cheshire). These were pulled by a team of horses and grew in popularity along with intercity trains attaching plows to their front to clear streets as well. The invention of the snowplow allowed cities to recover quicker after a snow event but brought about issues as well, some of which still occur to this day. Though plows clear the roads, it creates uneven surfaces on the road and can effectively block side roads, storefronts, and sidewalks with large piles of snow left from the plowing effort. Some cities started to use salt on the roads during the late 1800s but many citizens protested its use because it ruined clothing and the streets for sleighing (Laura Cheshire). After horrible blizzards in the 1880s, many cities started to organize snow removal and start snow removal in the early stages of the storms instead of after the storm ended. Assigning multiple plow drivers to different areas and beginning to create better infrastructure (bury lines, build subways) to deal with the winter storms helped advance cities going into the turn of the century.

Snow Removal in New York City (Cheshire)

With the advent of motorized vehicles, many cities abandoned the horse-drawn carts for trucks/tractors with snow plows. As many cities still had to remove the snow offsite, trucks and other haulers were used to transport the snow to dumping sites. In the 1920s in Chicago, a snow loader was developed: as the snow was plowed it forced the snow up and was caught by a conveyor belt which brought the snow into a chute and was dropped into a dump truck underneath the contraption (Cheshire). The use of snow fences and the continual advance of snow removal technology was increasingly important for air travel and as cities grew during the early 1900s, especially with the development of motorcars.

Safe, dry roads became in demand with increases in the use of motor vehicles as the winter snowfall creates hazardous conditions. As the road conditions worsen, the adhesive properties change between the tire and the roadway as other elements come between them: mainly ice, black ice, and snow. The friction coefficients between ice and snow roadways vary with temperature but occurs between 0.05 to 0.2, which is less than the 0.7 for dry roadways (Walus and Olszewski). Compact snow can increase traction but not to the extent of dry roads, which is why drivers want dry road conditions to drive in. Accident levels rose as the plows left behind layers of ice on the roads when removing the snow, which increased the usage of salt and motorized salt spreaders as cities used that to combat the ice along with using cinders and sand to increase traction. Different types of vehicles and plows were developed throughout the years with the main vehicles being trucks, motor graders, and loaders. Trucks are smaller vehicles that can have plows or spreaders, motor graders are vehicles which can be equipped with plows, work at slower speeds, and dig-in to roadways less than truck mounted plows, and loaders are vehicles which are used to load material into spreaders or can have a plow attached (*Winter Maintenance Equipment and Technologies*). Some large highways use tandem trailers attached to plow trucks to increase their plow width. Plows come in a large variety as well depending on the use, vehicle type, and cost including future maintenance. Using the right plow for the right roadway with the correct adjustments and shoes/castors will lessen the impact on road wear and damage to road objects such as catch basins. Other communities need to remove the snow from the roads which involve either some type of conveyor system as previously described, some type of snow melting machines, or even snow blowers to clear the snow away from the roadways. The plowing vehicles are equipped with spreaders which distribute product onto the roadway, usually salt or some similar solution of it.

A Marquette University study noted that use of road salt reduced crashes by 88%, injuries by 85%, and accident costs by 85% (*Safe winter roads protect lives*). Since salt is only effective to a certain temperature and does not work in deep snow conditions, the roadways still need to be plowed quickly and efficiently to be driveable. At a temperature of 30 degrees Fahrenheit, 1 lb of salt melts 46.3 lbs of ice while at a temperature of 15 degrees Fahrenheit, 1 lb of salt melts only 6.3 lbs of ice (*Safe and Sustainable Snowfighting*). In the 1960s environmentalists studied the effects of salting roads, which brought about protests for salt usage once again as salt damaged vehicles, killed roadside plant life, and polluted water sources. Some cities use different chemical mixtures instead of a regular salt solution to melt the ice at lower temperatures or to help salt adhere to the ice. The use of wet material instead of just placing dry allows the material to spread quickly in more accurate dosages along with helping defrost roads quicker and saving on total road salt usage (*Winter Road Maintenance*). Though sodium chloride is the most commonly used salt, many places use other materials such as calcium chloride and magnesium chloride as they melt at lower temperatures and stick to the roads longer (*Winter Road Maintenance*). Having a wet material on the road allows the salt to start working quicker as salt needs moisture to be effective, which makes some other materials better as they stay in this wet state longer than normal rock salt. The timing of plowing operations need to be coordinated with salt application so as to not waste material as it can greatly impact the community's outlook if material seems to just pile on the roads and is dumped into the water. Initial treatment of the roads needs to be effective in preventing ice from forming on wet pavement during the initial storm as the pavement temperature, especially the material the road sits on, affects the temperature of the road as well as the air temperature which is why bridges freeze quicker than roads as both sides of the bridge are exposed (*Safe and Sustainable Snowfighting*). The variety of materials used in the melting of ice and the pretreatment of roads lead communities to need to research the best material needed to treat in their climate while keeping costs low.

The cost of combating the snowy roads is less than the cost of the closure of roads transporting goods and the cost of accidents that occur on snowy roads (up to $700 million total per day lost); especially since deicing the roads pays for itself about 25 minutes after salt is spread according to studies of the cost-benefit analysis of snow maintenance (*Safe winter roads protect lives*). This very visible department of a community can easily endanger their citizens, emergency personal, and businesses if the clean up during and after a storm event is not handled quickly. It is reported that in snow belt communities winter maintenance can account for 20% of their total budget (*Safe and Sustainable Snowfighting*). Since around 70 percent of the roads and 70 percent of the population live in areas that receive a minimum of five inches of snow a year, this cost quickly adds up but it is a rising cost for cities everywhere so the best practices are to find the balance between the most efficient and the least expensive.

Crash Data

The GCAT Tool is an online program through the Ohio Department of Transportation's (ODOT) website which uses OH-1 crash reports provided by police. The lists of crash data information from this online database were processed in a CAM Tool Excel file to procure this information about crashes within the city of Akron limits as reported by the police. Three winter periods (October-April) were looked at to give the best average of winter crash rates when dealing with a large variable that is inconsistent winter weather. In the city of Akron between October 2014 thru April 2015 there were over 4200 crashes with about 17% of those crashes (~700) being in a snow/ice road condition. Between October 2015 thru April 2016 there were over 4100 crashes with about 6% of those crashes (~250) being in a snow/ice road condition and between October 2016 thru April 2017 there were over 4200 crashes with about 10% of those crashes (~400) being in a snow/ice road condition. Most crashes were property damage only crashes with injury crashes accounting for approximately 13-15% of crashes for each season. There was only one fatality on snow conditions which occurred during 2017. Most crashes related to the road conditions deal with unsafe driving due to high rates of speed, following too closely, or oversteering the vehicle.

WEATHER_CONDITION	Number	%
Clear	1683	39.4%
Cloudy	1480	34.7%
Snow	490	11.5%
Rain	488	11.4%
Other/Unknown	88	2.1%
Sleet, Hail	29	0.7%
Fog, Smog, Smoke	7	0.2%
Blowing Sand, Soil, Dirt, Snow	4	0.1%
Severe Crosswinds	1	0.0%
Grand Total	**4270**	**100.0%**

ROAD_CONDITION	Number	%
Dry	2329	54.5%
Wet	1105	25.9%
Snow	547	12.8%
Ice	191	4.5%
Unknown	73	1.7%
Slush	23	0.5%
Other	2	0.0%
Grand Total	**4270**	**100.0%**

October 2014 – April 2015 Crash Data via CAM Tool

WEATHER_CONDITION	Number	%
Clear	1790	43.4%
Cloudy	1346	32.6%
Rain	574	13.9%
Snow	274	6.6%
Other/Unknown	124	3.0%
Fog, Smog, Smoke	8	0.2%
Sleet, Hail	8	0.2%
Blowing Sand, Soil, Dirt, Snow	3	0.1%
Severe Crosswinds	1	0.0%
Grand Total	**4128**	**100.0%**

ROAD_CONDITION	Number	%
Dry	2716	65.8%
Wet	1049	25.4%
Snow	201	4.9%
Unknown	101	2.4%
Ice	46	1.1%
Slush	6	0.1%
Other	6	0.1%
Sand, Mud, Dirt, Oil, Gravel	2	0.0%
Water (Standing, Moving)	1	0.0%
Grand Total	**4128**	**100.0%**

October 2015 – April 2016 Crash Data via CAM Tool

WEATHER_CONDITION	Number	%
Clear	1824	42.8%
Cloudy	1394	32.7%
Rain	517	12.1%
Snow	376	8.8%
Other/Unknown	111	2.6%
Sleet, Hail	23	0.5%
Fog, Smog, Smoke	8	0.2%
Severe Crosswinds	5	0.1%
Blowing Sand, Soil, Dirt, Snow	3	0.1%
Grand Total	**4261**	**100.0%**

ROAD_CONDITION	Number	%
Dry	2722	63.9%
Wet	1040	24.4%
Snow	280	6.6%
Ice	118	2.8%
Unknown	88	2.1%
Slush	10	0.2%
Other	2	0.0%
Sand, Mud, Dirt, Oil, Gravel	1	0.0%
Grand Total	**4261**	**100.0%**

October 2016 – April 2017 Crash Data via CAM Tool

Nationally there are over 500,000 crashes annually with 136,000 injuries and 1,800 fatalities due to snowy and icy roads based on data between 2005 through 2014 (*Icy Road Accident Statistics*). For the state of Ohio there were 22,400 crashes per year on snowy/icy roads between 2012-2017 with over 6000 injuries and 34 deaths on average. Other resources put Ohio as the deadliest for winter car crashes with an average of 86 deaths per year with data from 2011 to 2015 (Doyle Rice). Further analysis of this data looks to the amount of experience a driver has in snow, out of state drivers, and road conditions as well as major causes of these crashes. The Auto Insurance Center compiled data from 2015 fatal accidents and noted that nationally around 90% of the crashes happened on snow- or ice-covered roads with the two major causes of the crashes being control/traction loss and driving off the road. Though most crashes throughout the United States happen on dry roads, with wet roads being a close second, these weather conditions happen more frequently and are more common compared to snowy conditions. This makes the accident-per-hour based on the type of weather condition rate for snow conditions a lot higher than in wet or dry conditions as these occur more frequently (*Icy Road Accident Statistics*). Crashes created by snowy conditions can lead to large numbers of vehicles being involved, such as a 81 vehicle pile up in March of 2018 on Interstate 71 in central Ohio (Associated Press). The difference in numbers between sources is most likely due to chosen data parameters, yet that number is very high and with the city of Akron having several hundred crashes a winter season there comes a question as to what the city of Akron does to take care of the roads during the winter season.

Current Winter Maintenance Practices of Akron

Winter maintenance of all roads and interstates within the city limits is done by the city itself. The city of Akron's fleet includes 43 city trucks and 8 tandem trucks for interstate work totalling 51 trucks that cover 220 centerline miles of interstate, 850 centerline miles of primary routes, 160 centerline miles of secondary routes, 370 centerline miles of residential routes with some overlap of each route as the city has only 900 miles of roads. The large network of roads in the city limits requires a hierarchy of roads which the Publics Work Manager Jim Hall says is broken down into 4 different levels of service. The first level is 11 trucks going on the primary routes and bridges as they freeze before the roadways. The second level has 21 trucks in service and the third level has 28 trucks hitting primary and secondary routes as needed. The fourth level has all 51 trucks going out to plow the primary and secondary routes. The residential routes are plowed by a resident request to their 311 service on a first come first serve basis when trucks are available unless there are multiple large storm events occuring (5" or more) which would incite a city wide parking ban and a clearing of all roads. The staff rotate on three different shifts to man the roadways and respond to changing road conditions and weather conditions through the city's personal meteorologist through Accuweather (Hall). When clearing the roads curb to curb, the trucks communicate with snow call centers and other drivers during storm events and after. The snow centers use the driver information along with ODOT sensors/cameras and city cameras to monitor road conditions (Hall). An automatic vehicle locator system on the trucks can track the routes the truck takes and replay the old storm paths so if a similar storm happens again the information can be recalled to learn from. This information can also help the city improve on its practices and use its resources effectively.

The city of Akron uses the *Safe and Sustainable Snowfighting* Handbook when taking care of the roads. A brine (a salty liquid mixture) is placed down to pretreat the roadways and help prevent snow from adhering to the roadway. The trucks are equipped with salt spreaders which are calibrated to 9 different settings before the winter season starts to maximize an efficient usage of salt supplies. The solution used is a 23.3% salt solution to combat the ice until it hits too low of a temperature to be effective in which case other chemicals are used until the temperature rises. A community group through the University of Akron gathers over 40 local communities together as they bid and negotiate salt prices/needs based on predictions for the upcoming winter season. The city will get the minimum 80% of its bid amount and up to 120% of the amount if needed due to a harsh winter at a set cost. The cost will be renegotiated if the amount of salt needed is 120% over the estimated amount (Hall). The communities deal with a limited source of salt and must work together with their limited funds and salt rations.

Safe and Sustainable Snowfighting Handbook cover.

Cargill Salt Mine provides the salt used in the city of Akron and in many surrounding communities around the Great Lakes area. The mine produces over 4 million tons of rock salt on an average year (approximately 15 tons a day/5 days a week) which is transported all along the Great Lakes region and is transported by train or trucks to other locations as far away as Massachusetts (Johnston). While this resource is close to Akron, it is estimated that in 50 years the cost to get the salt from the mine will be too great which will increase the price of salt dramatically. This means that other practices need to be put into use and better ways to use the salt are needed unless a drastic change happens to the weather patterns in this region.

Current Winter Maintenance Practices of Three Other Cities

In comparison to other cities with similar amounts of snowfall, ways that they handle winter maintenance include practices similar to the city of Akron and some differences. By comparing to other cities it can be seen if there are some practices that Akron can implement to reduce cost and be more effective in snow maintenance.

The city of Saint Paul, Minnesota with a population of around 300,000 people has an average snowfall of 51 inches a year (*Climate*). Public Works monitors the weather and informs the crews when to begin treatment and what type. There are 8 plow routes with 1,870 lane miles within the city and there are street hierarchy with the arterial streets needing to be passable before the residential areas are taken care of (*Plow Operation FAQs*). In storm events with 6" or less of snowfall it is estimated to take 20 hours to plow the entire city once with larger events taking more time. The city center, with its large amount of on street parking, has different regulations compared to the suburban area of Saint Paul as those crews regulate the parking ordinances of their jurisdiction while the downtown cannot restrict parking unless they call a snow emergency. Saint Paul has two phases of plowing (day/night) with certain roads designated as night plowing operation (such as the downtown area) while others are plowed during the day. Once the primary roads are cleared curb to curb, the intersections and residential roads are tended to, and the operation now goes based on call-ins by residents to tend to areas noted as a "replow" where vehicles were not moved when the plow came before or the snow piles are very high. Vehicles can be ticketed and towed during a snow emergency as it prevents snow clean up from occurring and vehicles parked on the road are able to be ticketed within 96 hours after a snow emergency has taken effect (which is by 9pm for night routes or 8am for day routes). This clean up can take several days especially since sidewalks and alleyways are to be taken care of by the residents. The city uses a brine solution to activate the salt in which it uses sodium chloride above 15 degrees Fahrenheit, magnesium/sodium chloride for temperatures down to -10 degrees and sand for traction below -10 degrees (*Plow Operation FAQs*). The large metropolitan area has many parking and other ordinances along with an active snow emergency update system to keep citizens informed and can get updates on an app about parking. Having certain routes and night/day routes is different from the city of Akron as well as enforcing ticketing/towing of vehicles in snow emergencies which is needed in a city as large as Saint Paul.

The city of Salt Lake City in Utah, with a similar size population of 190,000 people, has an average of 62 inches of snowfall each year (*Climate*). The Snow and Ice Control Program of the city states that they resolve any snow and ice events within 36 hours after the event ends. Over 90 people are broken down into two shifts to be on call 24/7 to respond to a storm as Utah is a large skiing destination and prone to large storm events. Around 1,850 lane miles of roadway the Snow program salts and plows and works with the Utah Department of Transportation to clear state roads. The Streets Response Team is a crew that deals with after hour weather and does immediate snow plowing of high priority routes, emergency routes, and highly travelled routes (*Snow Removal in Salt Lake City*). There are three levels of priority routes with a similar set up to the city of Akron as residential is the lowest priority, collector streets being secondary, and major routes being the primary. The city on estimate uses around 20,000 tons of salt a year with a fleet of 45 large plow and salt spreader trucks according to their website. The city also takes care of bike routes and sidewalks within the city limits. The Utah Department of Transportation seems to follow a similar pattern of wetting salt and plowing the roads with efficient usage of salt and wing plows along with having a website to locate a plow being accessible to citizens during the clean up process of a storm event (*2015 Strategic Direction*). The state and city uses brine and other methods similar to the city of Akron.

The city of Aurora, Illinois has an average of 28 inches of snowfall each year (*Climate*). Being a similar sized city to Akron with a population of 200,000 people, this city cares for 1360 lane miles of roads with 700 being primary routes which are treated first and during a snow event with the other 660 miles being residential and treated after the storm stops (*Public Properties - Snow Plowing*). The city has 35 snow routes with manpower broken up to the different departments and even some by private contractors which during heavy snow events the city will call upon private contractors to help in residential areas. This is different from Akron as the city has only the public works department working on the road maintenance while Aurora has some routes managed by different departments and private contractors. The city of Aurora has three shifts on weekdays as it tries to handle accumulated snow and ice conditions in an attempt to clear the roads within 12 hours after a storm event of 3 inches or less with heavier snows taking longer to clear. The city takes care of the roads as soon as ice starts to form so the use of salt and other materials is also important in fighting the icy roads once they form. Sidewalks are taken care of by the owner/resident. The Illinois Department of Transportation uses the *Snowfighting Handbook* as well so with Aurora being located right outside of Chicago many of these practices done on the state roads occur in the city as well though at a smaller scale.

Comparison of Winter Maintenance Practices

The city of Akron, in following the *Snowfighters Handbook*, follows much of the same practices as other cities do across the country. Roads are pretreated before a storm event and then treated with a salt combination to combat ice from plowing efforts until the roads are clear. The time of road clearing and the amount of lane miles each city covers is different due to fleet size and other resources. With Saint Paul having a night route and day route plow system, it would not work well if storm events hit hard during certain hours and that route is not plowed clear until 12 hours later. In Akron, this would really affect the traffic flows as Saint Paul is more of a grid design of roadways comparative to Akron. The strict parking bans and their replow system that sounds similar to Akron's 311 call in would be additional things that Akron can look into as parking bans are usually not very effective for the city even though the Akron Revised Code bans street parking with snow accumulation of 2 inches or more. Having an app or text messaging system to push out alerts about parking bans and have citizens report areas that need maintenance would be a an idea to consider as technology moves forward. One thing to consider is a sidewalk/bike path plowing service for the city of Akron. Property owners are to maintain the sidewalks in Akron but there seem to always be issues with maintaining the walks in a timely manner, so having a service that the owner partially pays for could help keep the sidewalks clear. In places like Salt Lake City where the city cares for all the sidewalks, it would be good to provide that service to major sidewalk paths within Akron or to have a team to take care of sidewalks specifically. With Akron trying to be a more pedestrian friendly city care is to be put into these bike paths and sidewalks as much as the roads, so the costs of having a team to specially care for sidewalks (even as a private contractor) might be negligible. With Aurora having some private contractors it would be interesting to see if that would be a possibility in dealing with extreme snow events or for city owned sidewalks/bike paths to have a separate crew. Cities with smaller vehicle fleets use local private plowing services to help during snow events so there is no need have a large number of vehicles or have to store them and pay for their maintenance. However, private contractors tend to be more expensive hourly so the balance of not having the equipment cost might or might not outweigh the contractor cost. Yet to be able to relocate resources elsewhere in the city and have a more rapid snow recovery and reaction time which would lessen the amount of crashes if private contracting was to be done on roads. From further research, there are many opportunities in study or practice that can help the city of Akron or residents combat snowy weather conditions.

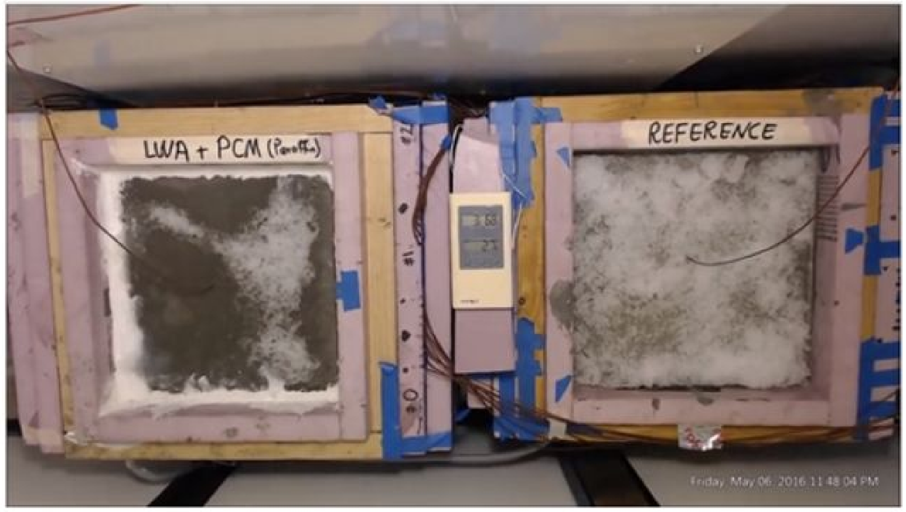
Current and Future Advancements Related to Winter Maintenance

Autonomous vehicles and other vehicular advancements lead to better driver reaction time and can in the future accommodate for difficult road conditions with communication between vehicles and with road sensors. The timing for smart vehicles and smart cities is on the horizon but this system will not be full perfected for many decades to come. Some simple advancements that can be used currently include using snow tires or studded tires and having them easily accessible to the motoring public as these tires can improve traction and create less skidding environments as long as a driver slows down in bad road conditions and is aware of their surroundings. The state of Ohio allows these “studded tires” to be used between November 1st and April 15th on all roads and tire chains to be used on snow and ice roads only per the Ohio Revised Code Section 5589.081. The Code also discusses retractable studded tires to as a option with the studs being only allowed to be deployed during the same days. Since excessive speed is a known cause of many crashes, some locations have tested variable speed limits on highways to see if that can warn drivers to slow down to a safer speed for road conditions. That is being tested in parts of Northeast Ohio right now which can give feedback on if it is an effective way to slow down drivers and reduce winter weather crashes. Driver negligence in these winter road conditions is a main contributing factor to all the crashes that occur as one should adapt to the weather conditions; however, it is the duty of the government to clean these roads for their citizens sake and for the commerce that needs to travel on the roads.

One major factor in snow removal on the roads is the types of chemicals used. As previously discussed, the chlorides are the most common option as a deicer as they tend to be less expensive and less harmful to the environment compared to other deicers despite the chlorides corrosive ability for steel (*Chloride Free Snow and Ice Control Material*). Most rock salt is combined with a corrosion-resisting product to lessen the corrosive nature of the chloride as well as improve the effectiveness of the salt, though this produces more expensive treated salt as compared to traditional rock salt (*Snow & Ice Practices*). Jim Hall noted that a common misconception is that beet juice can melt the ice but when this product is sprayed it helps the salt stick to the ice better to melt it. The beet juice along with other organic products are additives that are used with deicing material to improve anti-corrosive or anti-caking along with some naturally having salts in the residual product (*Chloride Free Snow and Ice Control Material*). Extensive research has looked at how different chemicals react with the environment as the biggest issue is the material polluting drinking water and stream life. Many chemical deicers, such as acetates, formates, and urea among other non-chloride deicers, use up dissolved oxygen in the waterways as they break down which takes away oxygen from the aquatic life and sometimes leaves behind even worse compounds as the chemicals breakdown (*Chloride Free Snow and Ice Control Material*). This study notes that there are no perfect solutions right now as all chemicals used create some type of harm to the environment. Some abrasives such as sand, cinders, crushed limestone, and slag are still used today to improve traction on roads and as fillers to reduce the amount of salt spread on the roads. However, these can clog drainage structures, can reduce traction in some instances as too large of amounts accumulate on the roadways, and can be costly to sweep up once the snow has cleared which limits some communities from using too many abrasive materials (*Snow & Ice Practices*). Further research is needed to find better ways to remove the ice chemically.

The roads themselves are also part of the equation when dealing with snow maintenance. It has been noted that concrete, with its higher thermal mass and lighter color, heats and cools at slower rates than asphalt, along with being a less impervious road surface (*Pavement and Salt Management*). There are porous concrete pavements but they are used more to recharge groundwater, which could increase salt infiltration especially as concretes tend to shed brine very quickly. Asphalt is more porous of a material depending on its construction and the level of wear it endures. Some porous material has been tested in winter use in various parts of the country and in Europe with mixed results as salt material can get trapped and damage the roads as well as require an increase in material usage. Some locations in New Hampshire showed that some parking lots with porous asphalt drained the melting snow well and did not refreeze as bad or that the pores of the road surface clogged (*Chloride Free Snow and Ice Control Material*). However, pervious roads need to be cleaned and swept for debris to extend the life of the road by keeping the pores clear and the cost of installation and maintenance is more expensive than normal roads. With the mixed testing results (most likely based on differing road material composition) it is important to see if these would be a good fit for the city based on soil structure, material resources, and maintenance as further testing is done in different parts of the country.

Another possible option is to look at the composition of the roads. A research team at Drexel University (along with Purdue and Oregon State), with support from the Federal Aviation Administration, conducted multiple tests on adding a phase change material (PCM) to concrete as either a lightweight aggregate or in pipes embedded in the concrete to see if the thermal reaction of the PCM (in this case paraffin wax) changing from a liquid state to a solid state would heat up the concrete to melt the snow. The tests resulted in the concrete being heated due to the phase change of the material and it was a success as it melted the snow in 25 hours which was quicker than the untreated concrete, even in a case where the air around the concrete was cooled before the snow was added to the concrete test piece (Britt Faulstick). With the concrete itself being a source to heat the road, it should reduce the amount of deicer needed or even eliminate it which would save money. Further testing is needed to see how long the road lasts, how it handles vehicle traffic, and how it would handle a large range of temperatures in areas such as Akron with hot summers and freeze/thaw winters. It will take time for contractors as well to feel comfortable using a PCM as a part of the concrete as it is a newer concept and does not have history of use so the liability of this product working will keep contractors nervous until further research and proof is done. Another type of concrete called Verglimit has tiny capsules of calcium chloride coated in linseed oil and caustic soda which react with moisture in the air and prevents ice and snow from sticking to the roads (*Current Deicing Practices and Alternative Deicing Materials*). As the road surface wears away and exposes these capsules, moisture is absorbed from the air and spills over to dampen the surface which makes it difficult for the ice and snow to adhere to the road. Since the calcium chloride only comes to the surface when the pavement is wet, it comes out very diluted but will save on road salt as it is less corrosive than it. However testing has shown that the roads need to be highly travelled for it to be effective as a deicer and it is very expensive compared to regular asphalt. To make this a viable option for road composition, the cost of the material in the concrete would have to be less than the cost of the road salt used and be able to withstand varying weather and road conditions.



Screenshot of lab test video between PCM concrete and reference concrete with "snow" melting. (Faulstick)

These new practices and research should be on the radar of the city of Akron to become better equipped to battle the winter weather with newer technology and different practices to become an efficient machine and save money and lives in the process.

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