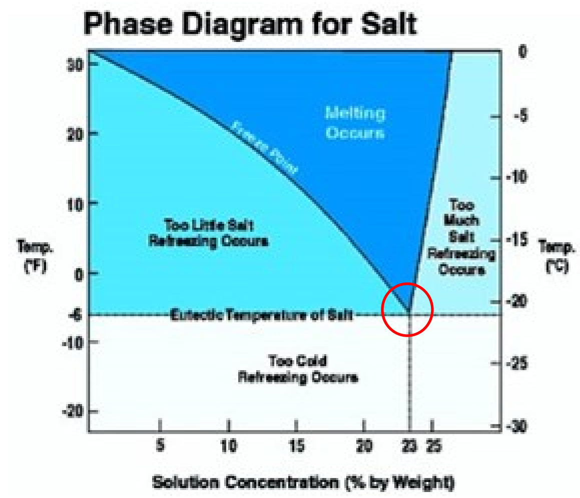
The Science of Salt

Deicing chemicals are the most common form of ice control and are necessary to prevent accidents and improve traction. Most of the time these chemicals are used without any thought toward the effect they have on the structure, surface, or roadway. Concrete in particular, can be significantly damaged by these chemicals. Most of the time too much deicer is used too frequently. The tendency is to add deicer until all the snow/ice is melted. Deicing chemicals work by lowering the freezing temperature of water. All deicer compounds have a phase diagram similar to the one shown at right, which graphs the relationship of salt content and temperature. The minimum freezing temperature (known as the eutectic temperature) is reached at a certain concentration of deicer. If more deicer is used, the freezing temperature will actually increase and re-freeze the melted snow/ice. Also, if the outside temperature falls below the eutectic, no amount of deicer will thaw the ice and snow.



The Problem

The basic problem with deicers is that they corrode cement and steel reinforcing. The most common types of commercial deicers contain chloride. Chloride is an aggressive ion that readily corrodes steel. Embedded reinforcing is ordinarily passivated by the surrounding alkaline cement. When chloride solutions penetrate into concrete and reach the rebar, they destroy the passive layer and initiate corrosion. Chloride-based chemicals dissolved into concrete can also precipitate back into crystalline solids when the moisture dries, or re-combine with other ions to form secondary minerals. The formation of these salt crystals inside a concrete can generate expansion pressure that exceeds the tensile strength of concrete causing surface scaling and other defects.

Freeze/thaw (or frost) attack is the typical cause of damage to a concrete surface. It occurs when water-saturated concrete repeatedly freezes and thaws. Concrete exposed to freezing is protected from F/T Attack by the entrained air system. Deicers like MgCl and CaCl can exacerbate F/T Attack by causing secondary mineralization of oxychloride crystals and other reactions in the concrete. For this reason, many ready-mix producers now restrict the use of deicers in their product warranty; typically for 1 and sometimes 2 years after placement. As concrete ages, porosity becomes sealed by growth of the cement crystals. Alternately, a liquid sealer or membrane can be applied to achieve a similar result.

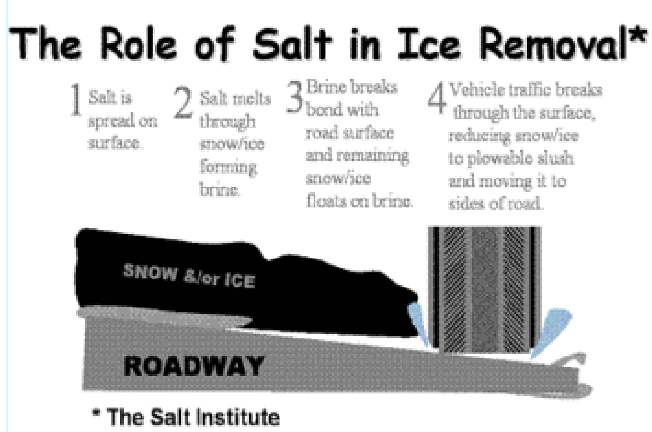
Types of Deicers

Material	Chemical Formula	Forms Used	Effective Min. Temp. °F [°C]	Median Cost per Ton
Sodium Chloride	$NaCl$	Primarily solid, but increasing use of liquid	14 [-10]	$36
Calcium Chloride	$CaCl_2$	Mostly liquid brine; some solid flake	-24 [-31.1]	$120
Magnesium Chloride	$MgCl_2$	Mostly liquid brine; some solid flake	5 [-15]	$95
Calcium Magnesium Acetate	$[Ca\,Mg_2\,(C_2H_3O_2)_2]_6$	Mostly liquid and some solid	23 to 27 [-5 to -2.8]	$1,280
Potassium Acetate	$KC_2H_3O_2$	Liquid only	-76 to -22 [-60 to -30]	n/a
Glycols	$C_3H_8O_2$, $C_2H_6O_2$	Liquid only		n/a
Urea	$(NH_2)_2CO$	Mostly solid	19 to 25 [-7.2 to -3.9]	n/a

A variety of chemicals have deicing and anti-icing properties. They generally break down into two groups: inorganic salts and organic compounds. Organic compounds such as acetates, glycols, and urea are commonly used on airfield pavements and aircraft because they are less corrosive to metal aircraft parts. However, many (such as CMA) are very expensive and some (such as urea) do not work at temperatures below about 19°F making them infeasible or ineffective in most commercial applications. The most common deicers are of the inorganic salt variety: sodium, calcium and magnesium chlorides. In transportation these are typically applied as liquid brine whereas in commercial and residential applications solid pellets are most common. Some blends also include an organic enhancing compound. While some brands market themselves as "safe" for concrete, there is no truly safe product. Any chemical that contains chloride can cause corrosion of steel and scaling of the cement surface. Sulfate-based chemicals can cause secondary mineralization such as ettringite attack, which also causes cracking and scaling. Other products, including acetates, are safer in terms of damage to concrete, but can destroy nearby vegetation.

The Solution

State DOT's have performed most of the research into the use of deicers and developed the common practices to remove ice/snow from roadways. Because of the behavior of deicing chemicals and the damage that can result, the common practice is to use deicer to break the bond between the snow/ice and the road surface and plow the roadway clean. The method is described at right. This method requires low quantities of deicer since there is no intent to thaw all snow/ice. By removing the melted slush, much of the deicing chemical is also removed from the roadway, so damage is limited. The same practice is used regardless of the type of deicer. Deicers are chosen primarily based on cost and the eutectic temperature needed.



How then are building owners and operators supposed to use deicers to avoid damaging their structures? The table below is a guide to the proper use of deicers depending on the type of deicer and the type of structure. Most importantly realize that a deicer is a harmful product and must be kept from penetrating into the concrete as much as possible.

Presence of Steel	Example	Waiting Period	Chloride-based	Non-chloride based
exposed steel	uncoated handrails, steel-framed stair treads, pan deck	1 year	never	sparingly and remove*
embedded rebar	typical decks, patios, stoops	1 year	sparingly and remove*	as needed and remove*
unreinforced flatwork	sidewalks, driveways	1 to 2 years	as needed	as needed
silane/siloxane sealed concrete**	driveways, patios	none	as needed	as needed
membrane-coated concrete***	parking garage decks, apartment terraces	none	as needed	as needed
none	asphaltic pavement	none	as needed	as needed

*remove by shoveling or other means and sweep or squeegee water when melted.
**silane and siloxane sealers penetrate and seal the upper surface of the concrete; these must be reapplied every 3 to 5 years to be effective.
***membranes require maintenance to be effective; most last roughly 10 years depending on traffic, exposure and other factors.

Resources

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