Deicing Technology and the Effects of Deicers on Infrastructure and Equipment

Prepared for Iowa Freight Advisory Council

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• Roadway deicer use is estimated to reduce crashes by 75-90% & prevent significant economic losses due to closures.
• Deicing accounted for 44% of the 42,000,000 metric tons of salt produced in US.
• This has led to concerns about damage to transportation infrastructure, the natural environment, and motor vehicles.
  – Recent literature suggest estimated costs of road salt damage range from $803 to $3,341/ton to vehicles, bridges, and the environment.
Iron Corrosion Chemistry

Voltaic Cell

Anodic area

Cathodic area
Iron Corrosion Chemistry

Voltaic Cell

Anodic area
“pitting”

Cathodic area
Iron Corrosion Chemistry

At the anode:
- $\text{Fe}^0_{(s)} \rightarrow + \text{Fe}^{2+}_{(aq)} + 2e^-$

At the cathode:
- $\text{O}_2(g) + 2\text{H}_2\text{O}_{(l)} + 4e^- \rightarrow 4\text{OH}^-_{(aq)}$
- $\text{Fe}^{2+}_{(aq)} + 2\text{OH}^-_{(aq)} \rightarrow \text{Fe(OH)}_{2(s)}$
- $4\text{Fe(OH)}_{2(s)} + \text{O}_2(g) \rightarrow 2\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}_{(s)} + 2\text{H}_2\text{O}_{(l)}$
- ...and other oxides

Voltaic Cell

① Fe$^0$ loses electrons (oxidation) and becomes Fe$^{2+}$

② Electrons migrate through the metal to the cathode where they combine with H$_2$O & O$_2$ (reduction) to form OH$^-$

③ Fe$^{2+}$ migrates through the droplet and reacts with OH$^-$ to form Iron oxides (rust)

The technical bit just in case you were interested...
Iron Corrosion Chemistry

Rust has three requirements:

- Iron
- Oxygen
- Moisture

All you really need to know...
What makes corrosion worse?

- Corrosion is exacerbated by:
  - Sometimes by dissimilar metals in contact in an aquatic solution (galvanic corrosion)
  - Higher temperatures
  - Acidic conditions
  - Persistent wetness
  - Presence of Cl⁻
What protects against corrosion?

- **Corrosion is lessened by:**
  - Sometimes by dissimilar metals in contact in aq. solution (galvanizing)
  - Passivation (formation of a protective oxide layer)
    - Oxide insulates & impedes oxygen diffusion
  - Painting/coating metal surfaces prevents O₂ and H₂O from contact
  - Removing as much deicer as possible from vehicles
    - Pay special attention to crevices and areas where salt can get trapped
  - Periodic application of corrosion inhibitor
What effect does road salt have?

- Salt increases electrical conductivity, prevents formation of protective oxide films (passivation) & catalyzes corrosion.

In the “pit”: \( \text{FeCl}_2 + 2\text{H}_2\text{O} = \text{Fe(OH)}_2 + 2\text{HCl} \)
What effect does a chloride salt have?

...Rate of corrosion then increases exponentially
• What effects do deicers have on pavement?
  – Concrete damage from spalling from freeze/thaw cycles
  – Deicers are hygroscopic (i.e., attract moisture).
Salt in the environment

• Growing environmental concerns about increasing chloride concentrations in lakes, rivers, reservoirs, wells
  – Chloride salts are not biodegradable; salinity is accumulative
  – EPA is concerned that rising salinity can cause problems both in human health (drinking water) and fish toxicity.
  – Trend toward more local restrictions on chloride salt use
Deicing Options

- Mechanical Removal
- Sand
- Sodium Chloride (solid or brine)
- Calcium Chloride (solid or brine)
- Magnesium Chloride (solid)
- CMA (solid)
- Sodium Acetate (solid)
- Potassium Acetate (liquid)
- Formates (similar to acetates)
- Urea
- Alternative Products: Beet Juice, Cheese Whey, etc.
Trends for Winter Maintenance

- **Tool box approach**
  - Use of better technology (weather forecasting, RWIS, pavement temperature sensors, etc.)
  - Sharing on best management practices (pre-wetting, proactive anti-icing, training, monitoring, calibration, etc.)
  - Targeted use of non-chloride deicers