Freezing of Anti-Icing Solutions on Road Surfaces

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• Freezing process
• Composite ice-brine mixture
• Consequences to winter maintenance
• Mobile measurements
Ice Fraction = $\frac{b}{a+b}$

Brine Fraction = $\frac{a}{a+b}$
Research on Freezing Solutions

  - adequate friction even with low brine fraction
  - pressure dependence of safe brine fraction

  - safe brine fraction is independent of salt type
Salt Concentration and Slipperiness

![Graph showing the relationship between concentration and temperature, with different lines and markers indicating slipperiness and ice formation](image-url)

- **Slippery**
- **Not Slippery**
- **Sea ice 0.60 MPa**
- **Sea Ice 0.40 MPa**
- **Sea Ice 0.20 MPa**
- **Brine Fraction 0.255**
- **Liquidus**
Salt Concentration and Slipperiness

The graph depicts the relationship between temperature and concentration of NaCl for assessing slipperiness in anti-icing solutions. The data points indicate that as the concentration increases, the temperature at which the solution remains liquid decreases, potentially leading to slipperiness. The graph includes lines for different sea ice pressures and brine fractions, showing how these factors influence the slipperiness of the solutions.

Legend:
- Red circles: Slippery
- Blue circles: Not Slippery
- Dashed line: Sea ice 0.60 MPa
- Dashed-dotted line: Sea ice 0.40 MPa
- Dash-dotted line: Sea ice 0.20 MPa
- Dashed-dotted-dotted line: Brine Fraction 0.255
- Dash-dotted line: Brine Fraction 0.40
- Solid line: Liquidus
Minimum Safe Brine Fraction

- Sea Ice 0.60 MPa
- Sea Ice 0.40 MPa
- Sea Ice 0.20 MPa
- Klein-Paste and Wahlin
- Timco and O'Brien

Flexural Strength (MPa) vs. Minimum Safe Brine Fraction
Consequences to Winter Maintenance

1. Fairly low salt concentrations keep friction at tolerable levels, even at low temperatures

\[ 0.25 \text{ mm} \times 1 \% = 2.5 \text{ g/m}^2 \text{ NaCl} \]

or

\[ 0.01'' \times 1 \% = 30 \text{ lbs per lane mile} \]
Consequences to Winter Maintenance

2. Let surface partially freeze
   • reduce liquid spray at low temperatures
   • safety factor, clear windshield
Consequences to Winter Maintenance

3. Liquid anti-icers work well
   • low brine fraction required – small amount of added water
   • sticks well to the road surface, lasts longer, easy to spray evenly
Consequences to Winter Maintenance

4. Potential for **saving salt** and anti-icers
   - measure
     - friction
     - water layer
     - add weather forecast
     - calculate required salt amount

   – Mobile Winter Road Condition Monitoring
Road Condition Monitor

- road surface condition
  - dry,
  - moist,
  - wet,
  - icy,
  - snowy,
  - slushy
- water layer thickness
- modeled friction
- surface temperature
Road Condition Monitor

- user interfaces
  - cell phone application in the vehicle
  - Mobile Road Condition Map in the internet (AVL)
Map Interface for Friction...
Summary ...

• Low brine fractions increase friction
  – partly frozen surfaces can be safe
  – save salt

• Mobile Road Condition Monitoring
  – measure friction, obtain brine fraction
  – optimize salt usage