Effect of Deicing and Anti-Icing Chemicals on HMA Airfield Runways


2010 P3 Symposium
Introduction: Deicing vs. Anti-icing

- Deicing is the removal of existing ice and/or snow from the runway.
- Anti-icing is application of chemicals to prevent buildup of ice and/or snow on the runway.
- Anti-icing is also performed on airplanes in specific locations, using similar chemicals.
Introduction: Chemicals

- For aircraft deicing, ethylene and propylene glycol most commonly used.
- Potassium acetate most commonly used in airfield pavement DIAIC.
- Other chemicals used include sodium acetate, potassium formate, and sodium formate.
- Recent shift away from glycols and urea.
Introduction: Problems

- In the 1990s airfields in Norway and Sweden switched from urea to potassium acetate and potassium formate.
- Problems later observed in HMA runways: softening, stripping, degradation, disintegration.
Approach in AAPTP 5-3

- Develop laboratory test and evaluate DIAIC-related damage (if any) in the laboratory
- Perform airfield site visits, evaluate possible DIAIC-related damage, take specimens for testing in laboratory
- Develop recommendations
Lab Testing: Aggregates

- Virginia diabase, 9.5-mm
- Virginia Limestone, 9.5-mm
- Mississippi chert/gravel, 12.5-mm
- Virginia siliceous gravel, 12.5-mm
- Pennsylvania greywacke sandstone, 9.5-mm
Lab Testing: Binders

- PG 58-28
- Two PG 64-22s
- One PG 76-22, polymer modified
Lab Testing: DIAICs

- Propylene glycol
- Sodium formate
- Sodium acetate
- Potassium acetate
- All as 2% solutions in water
Immersion/Tension (IT) Test

- Similar to AASHTO T 283
- Gyratory specimens/cores
- No vacuum saturation
- 4 days in 2% DIAIC solution at 60 C
- Control: 4 days water at 60 C
- Tensile strength ratio
Four Experiments with IT Test

- Aggregate effects
  - Five aggregates
  - Single PG 64-22 binder

- Binder effects
  - Three aggregates
  - Four different binders

- Air Voids and hydrated lime effects
The PA sandstone and MS chert/gravel are highly AS reactive.
This confirmed that softer binders are more susceptible to DIAIC-related damage.
Air Voids/Hydrated Lime Expt.: Virginia Gravel/PG 64-22

There is possibly some slight DIAIC damage at 7% air voids.
Air Voids/Hydrated Lime Effects: Mississippi Chert/PG 64-22

Lower air voids reduce DIAIC-related damage
In this case, HL also seems to reduce damage.
Site Visits

- Four airfields: Boston Logan; Colorado Springs; Boise, Idaho; and Friedman in Hailey, Idaho
- Inspection of HMA damage
- Photographs
- Cores
- Laboratory tests on cores
Friedman Airport
IT Test on Field Cores: Water and 2 % Potassium Acetate Solution

![Graph showing IT Test results for different treatments with water and potassium acetate solutions.]
Conclusions: IT Test

- The IT test demonstrated DIAIC-related damage in the laboratory for one aggregate (Mississippi chert).
- Significant DIAIC-related damage was not observed in mixes made using other aggregates or in field cores.
- Based on IT testing, DIAIC-related damage does not appear to be a widespread problem.
Acknowledgments

- Support of the AAPTP program
- Monte Symons
- Co-authors at ARA and WRI
- Laboratory personnel
Chemical Testing and Moisture Damage Study

- Very Little Background to Work From
  - Canadian Study
  - Finnish Study

- Our work was based on the bleeding and stripping observed

- Attempts to establish a quick test that indicates potential deicer problems with carboxylate deicers
Testing Protocols

- Ultrasonic Horn Conditioning
  - Increased moisture damage tendencies
- PAV/FTIR
  - Carboxylate salt concentration
- NMR Surface Tension Analysis
  - Densities
  - Surface Tensions
  - Penetration Depths
Potential Chemical Effects

KOAC + H₂O → KOH + HOAc
RCOOH + KOH → RCOOK + H₂O

- pH increases; NaOH used for oil sands
- Density ↑ vs. water
- Hydrophillic Salts
Initial Moisture Damage Results

- 20 kHz, 500 watt ultrasonic horn
- -20/+35 range sieved aggregate
- 2% Aq solutions of KOAc, NaOe
De-ionized Water
Potassium Acetate
Sodium Formate

1189 = PG58-28; 1364 = PG64-22
VA = Diabase, MS = Gravel

Softer asphalt – greater pitting
NaOF potentially more aggressive
Inconclusive due to low deicer concentration and horn pitting
pH Measurements

- Deionized water = 6.3
- 2% KOAc = 6.9
- 2% NaOf = 6.8

Higher concentrations in field
- 50% solutions pH between 9 and 12
  - Likely increased stripping
PAV/FTIR Study

- A chemical flag for deicer damage
- FTIR functional group analysis for carboxylate salt concentrations.
- PAV for 96 hours at 20 atm and 60°C
  - Dry Briquette
  - Vacuum Saturated with: deionized H₂O, 2% and 35% KOAc and NaOf
- Extraction in Toluene/EtOH, IR in THF
2% solutions appear to have good correlation except NaOf

Potential flag!
Huge variation in salt concentration

Formates more soluble in EtOH than Acetates
### Surface Tension Study

<table>
<thead>
<tr>
<th>Solution</th>
<th>Concentration</th>
<th>DuNuoy Surface Tension</th>
<th>Density g/mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Water</td>
<td>72.4</td>
<td>1.000</td>
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<tr>
<td>II</td>
<td>2% sodium formate</td>
<td>69.1</td>
<td>1.0144</td>
</tr>
<tr>
<td>III</td>
<td>2% potassium acetate</td>
<td>71.3</td>
<td>1.0084</td>
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<tr>
<td>IV</td>
<td>2% 1,2 propane diol</td>
<td>68.0</td>
<td>1.0096</td>
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<tr>
<td>V</td>
<td>35 % 1,2 propane diol</td>
<td>51.5</td>
<td>1.0359</td>
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<tr>
<td>VI</td>
<td>35% sodium formate</td>
<td>52.6</td>
<td>1.2456</td>
</tr>
<tr>
<td>VII</td>
<td>35% potassium acetate</td>
<td><strong>65.3</strong></td>
<td>1.1945</td>
</tr>
</tbody>
</table>

Acetates have been observed to be less aggressive than Formates.
\[ \gamma_{aw} = \gamma_{w} \left( \frac{\cos \beta(t_1) - \cos \beta(t_2)}{\cos \alpha(t_2) - \cos \alpha(t_1)} \right) \]
<table>
<thead>
<tr>
<th>Asphalt</th>
<th>Deicer</th>
<th>Asphalt-air&lt;sup&gt;c&lt;/sup&gt;-H&lt;sub&gt;2&lt;/sub&gt;O</th>
<th>Asphalt-air&lt;sup&gt;c&lt;/sup&gt;-H&lt;sub&gt;2&lt;/sub&gt;O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1189</td>
<td>Water</td>
<td>29</td>
<td>48</td>
</tr>
<tr>
<td>1189</td>
<td>2% sodium formate</td>
<td>31</td>
<td>43</td>
</tr>
<tr>
<td>1189</td>
<td>2% potassium acetate</td>
<td>21</td>
<td>53</td>
</tr>
<tr>
<td>1189</td>
<td>2% 1,2 propane diol</td>
<td>27</td>
<td>45</td>
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<tr>
<td>1189</td>
<td>35 % 1,2 propane diol</td>
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<td>41</td>
</tr>
<tr>
<td>1189</td>
<td>35% sodium formate</td>
<td>9</td>
<td>45</td>
</tr>
<tr>
<td>1189</td>
<td>35% potassium acetate</td>
<td>28</td>
<td>47</td>
</tr>
<tr>
<td>1364</td>
<td>Water</td>
<td>34</td>
<td>45</td>
</tr>
<tr>
<td>1364</td>
<td>2% sodium formate</td>
<td>27</td>
<td>44</td>
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<tr>
<td>1364</td>
<td>2% potassium acetate</td>
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<td>2% 1,2 propane diol</td>
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<tr>
<td>1364</td>
<td>35% potassium acetate</td>
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- Softer asphalt = lower interfacial surface tension
<table>
<thead>
<tr>
<th>Sample</th>
<th>Spreading Coefficient</th>
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<tr>
<td></td>
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<td>asphalt on water, $S_{aw}$</td>
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<tr>
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<tr>
<td>1364.VII</td>
<td>-61</td>
<td>-3</td>
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</tbody>
</table>

- More positive spreading coefficients indicate likelihood for wetting… asphalts will wet the solutions.
- 35% KOAc, AC 1189
- Decreased interfacial surface tension
- Increased solution density vs water
- Not observed for lower concentration deicers
Conclusions

- Ultrasonic conditioning is problematic for measuring moisture damage characteristics in asphalt briquettes.
- FTIR may be useful as a flag for presence of deicer.
- Increased pH = Increased Stripping
- Carboxylate salts of Na and K are hydrophillic – could lead to greater presence of moisture in mix.
- Carboxylate deicers decrease surface tension of water.
- Increased solution density brings moisture closer to the asphalt-aggregate interface due to increased penetration through the asphalt film.
- Formates are more aggressive than acetates
- Increased viscosity may help prevent deicer induced damage.
Acknowledgements

- WRI, AAT
- AAPTP/FAA