

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



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"Engineering Services for the Asphalt Industry"



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 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 AAPT 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

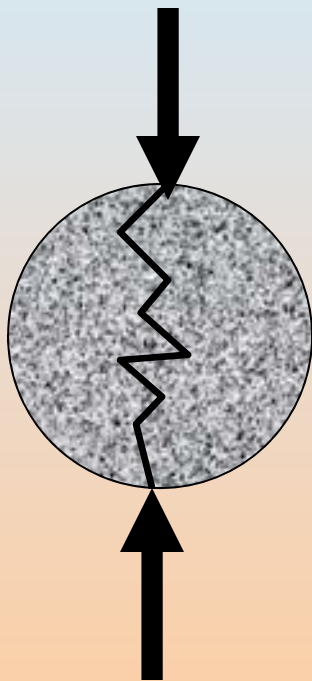
- PG 58-28
- Two PG 64-22s
- One PG 76-22, polymer modified



Lab Testing: DIAICs

- Propylene glycol
- Sodium formate
- Sodium acetate
- Potassium acetate
- All as 2 % solutions in water

Immersion/Tension (IT) Test



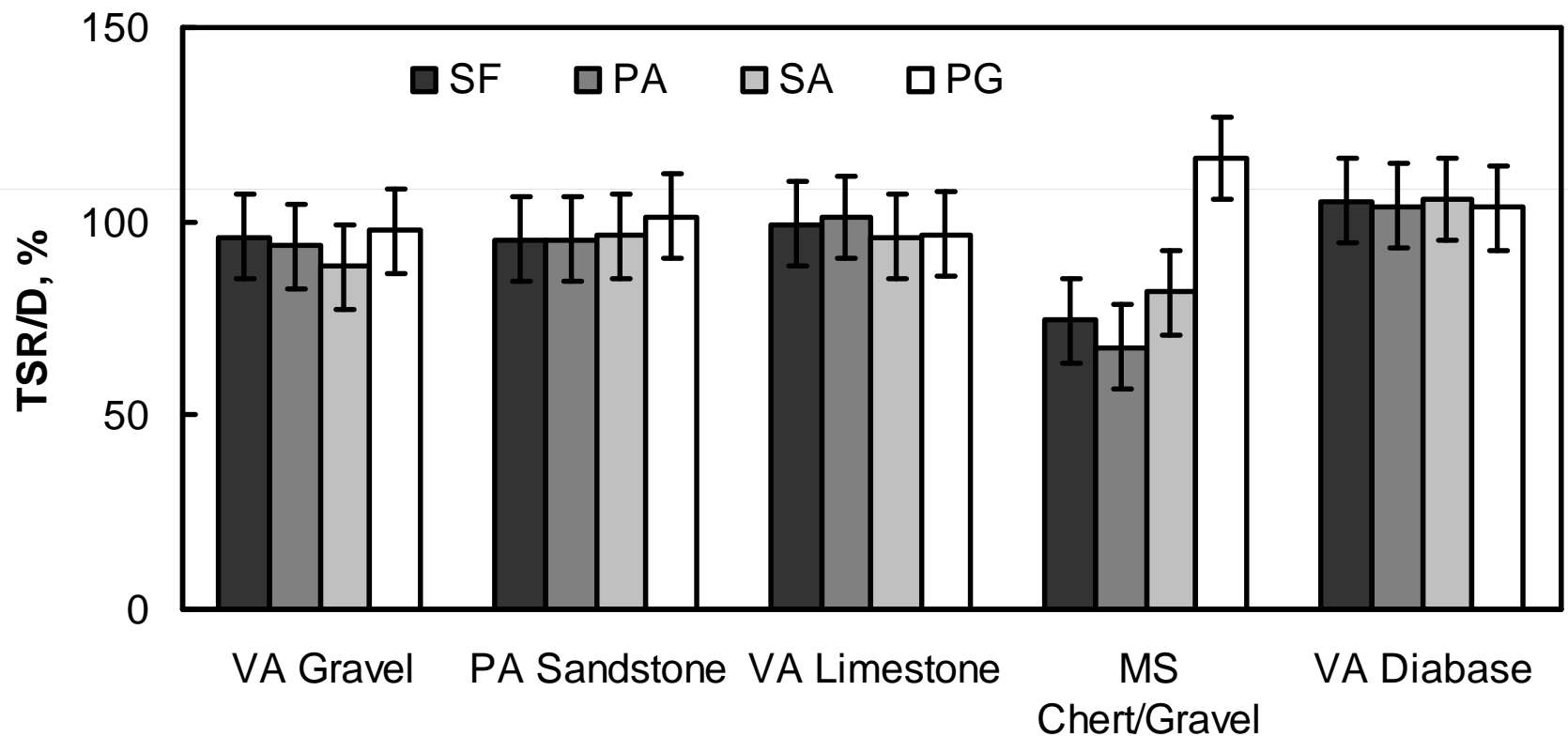
- Similar to AASHTO T 283
- Gyrotory specimens/cores
- No vacuum saturation
- 4 days in 2 % DIAIC solution at 60 C
- Control: 4 days water at 60 C
- Tensile strength ratio



Four Experiments with IT Test

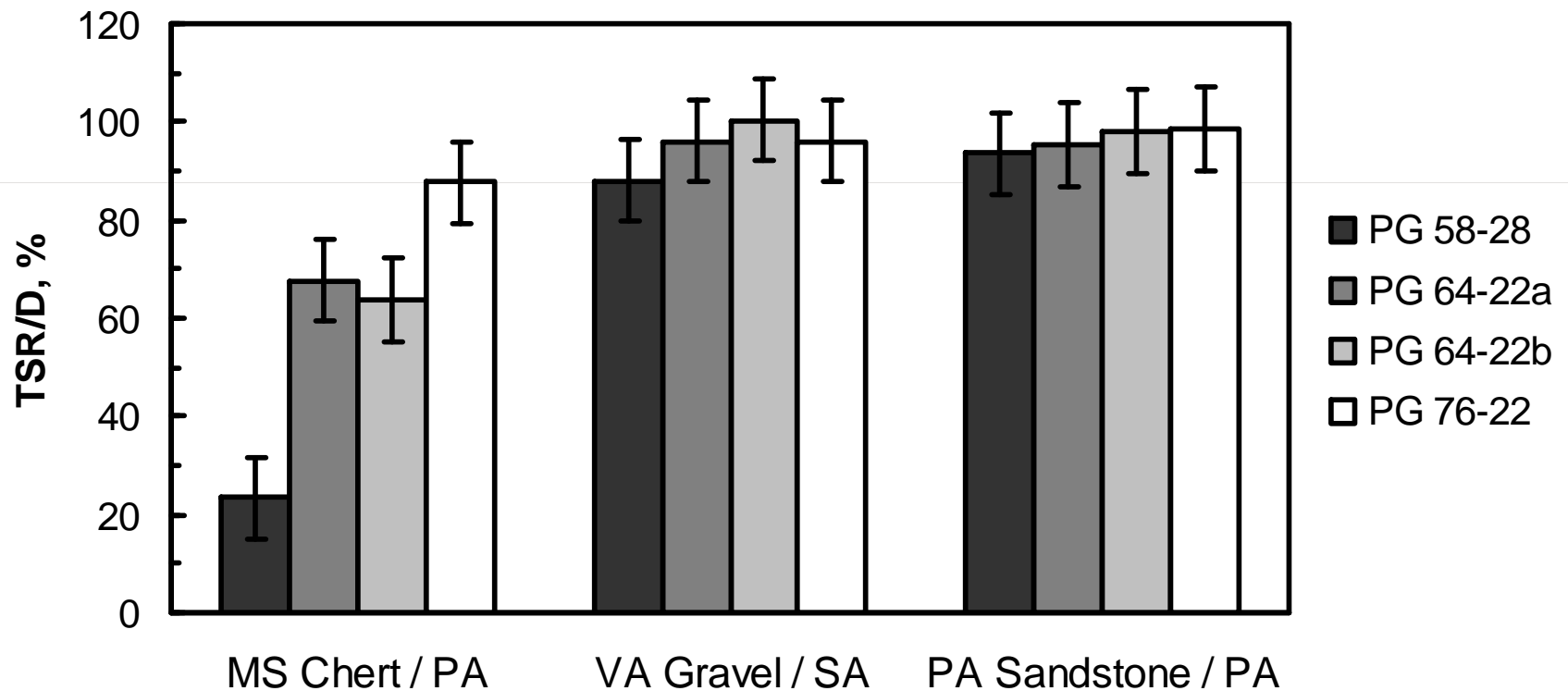
- Aggregate effects
 - Five aggregates
 - Single PG 64-22 binder
- Binder effects
 - Three aggregates
 - Four different binders
- Air Voids and hydrated lime effects

Aggregate Effects Experiment



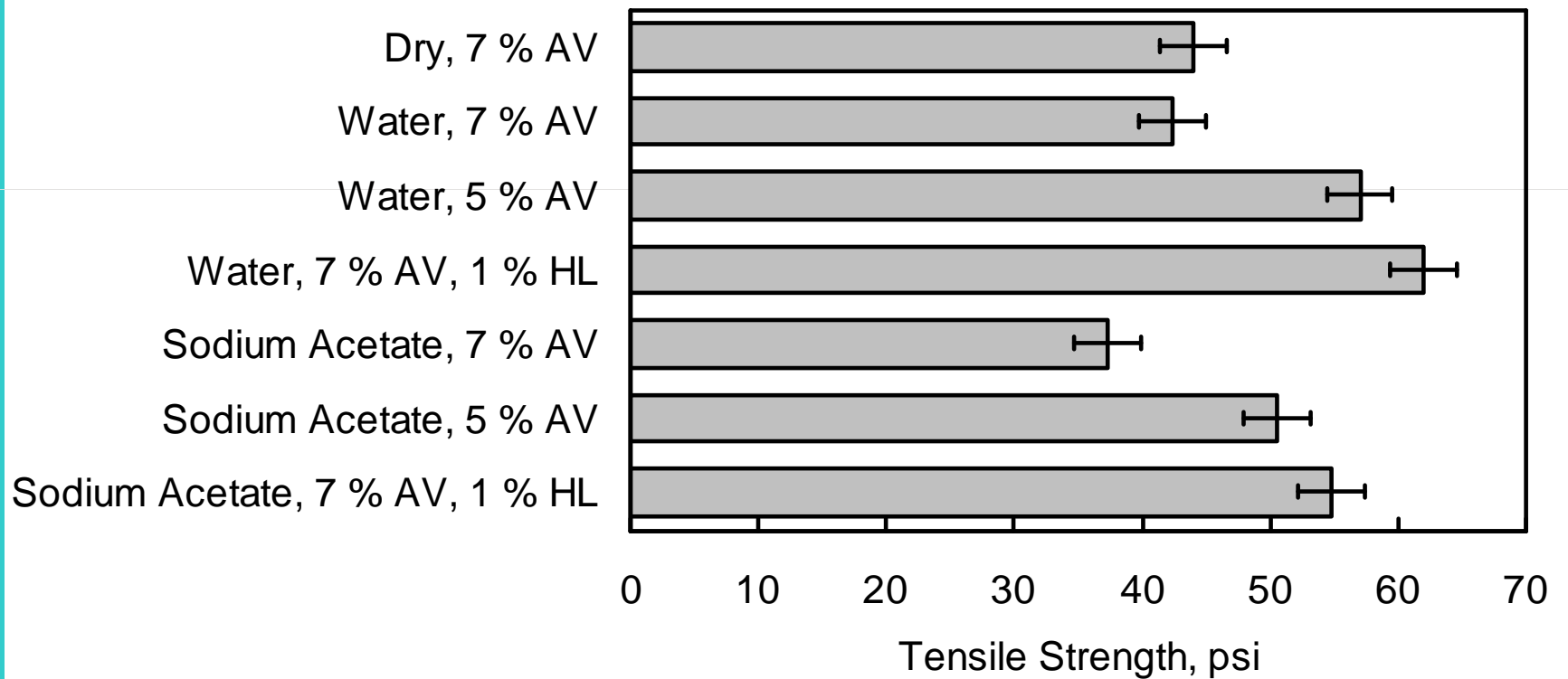
The PA sandstone and MS chert/gravel are highly AS reactive

Binder Effects Experiment



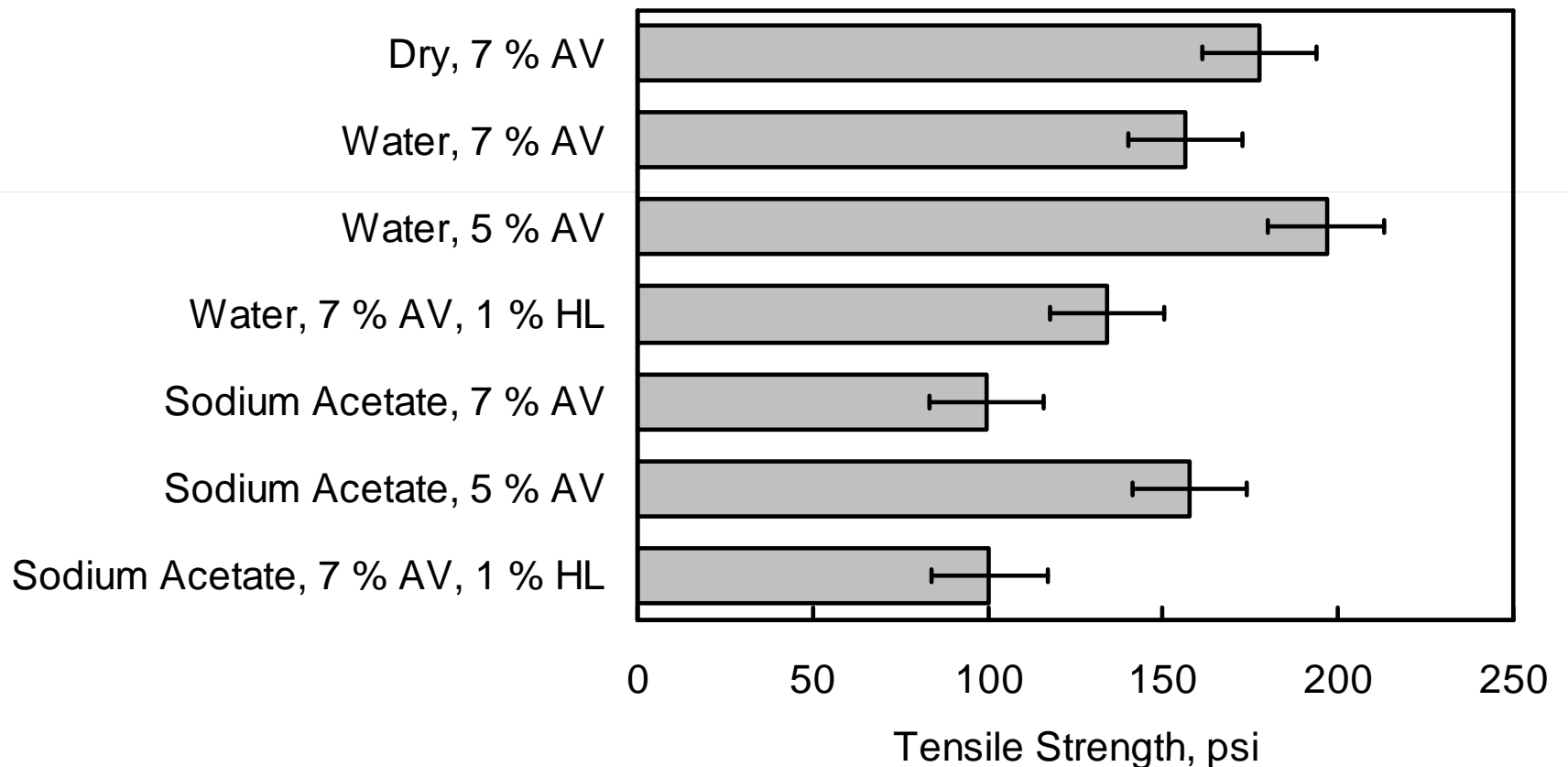
This confirmed that softer binders are more susceptible to DIAIC-related damage.

Air Voids/Hydrated Lime Expt.: Virginia Gravel/PG 64-22



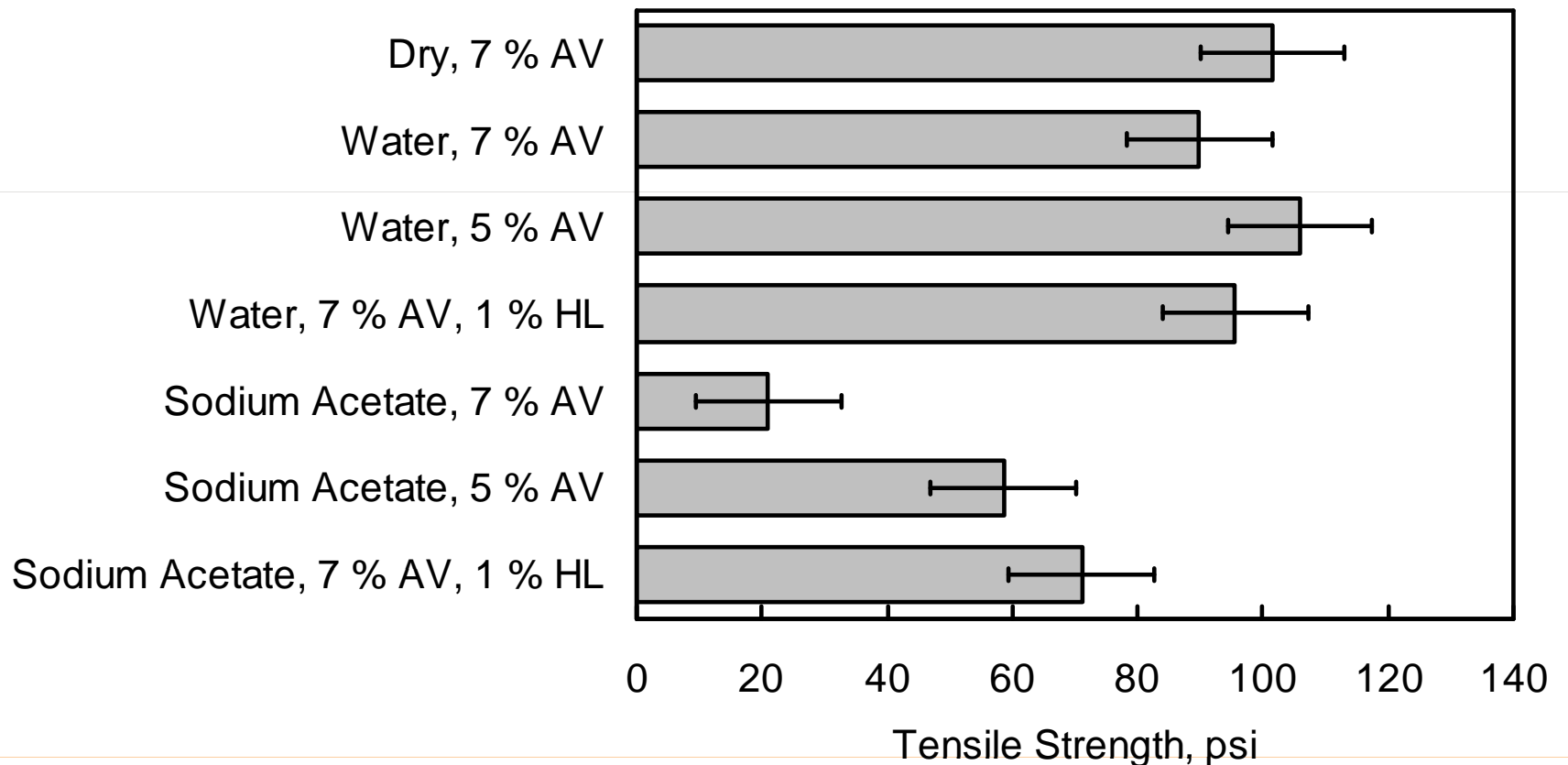
There is possibly some slight DIAIC damage at 7 % air voids

Air Voids/Hydrated Lime Effects: Mississippi Chert/PG 64-22



Lower air voids reduce DIAIC-related damage

Air Voids/Hydrated Lime Expt.: Mississippi Chert/PG 58-28



In this case, HL also seems to reduce damage



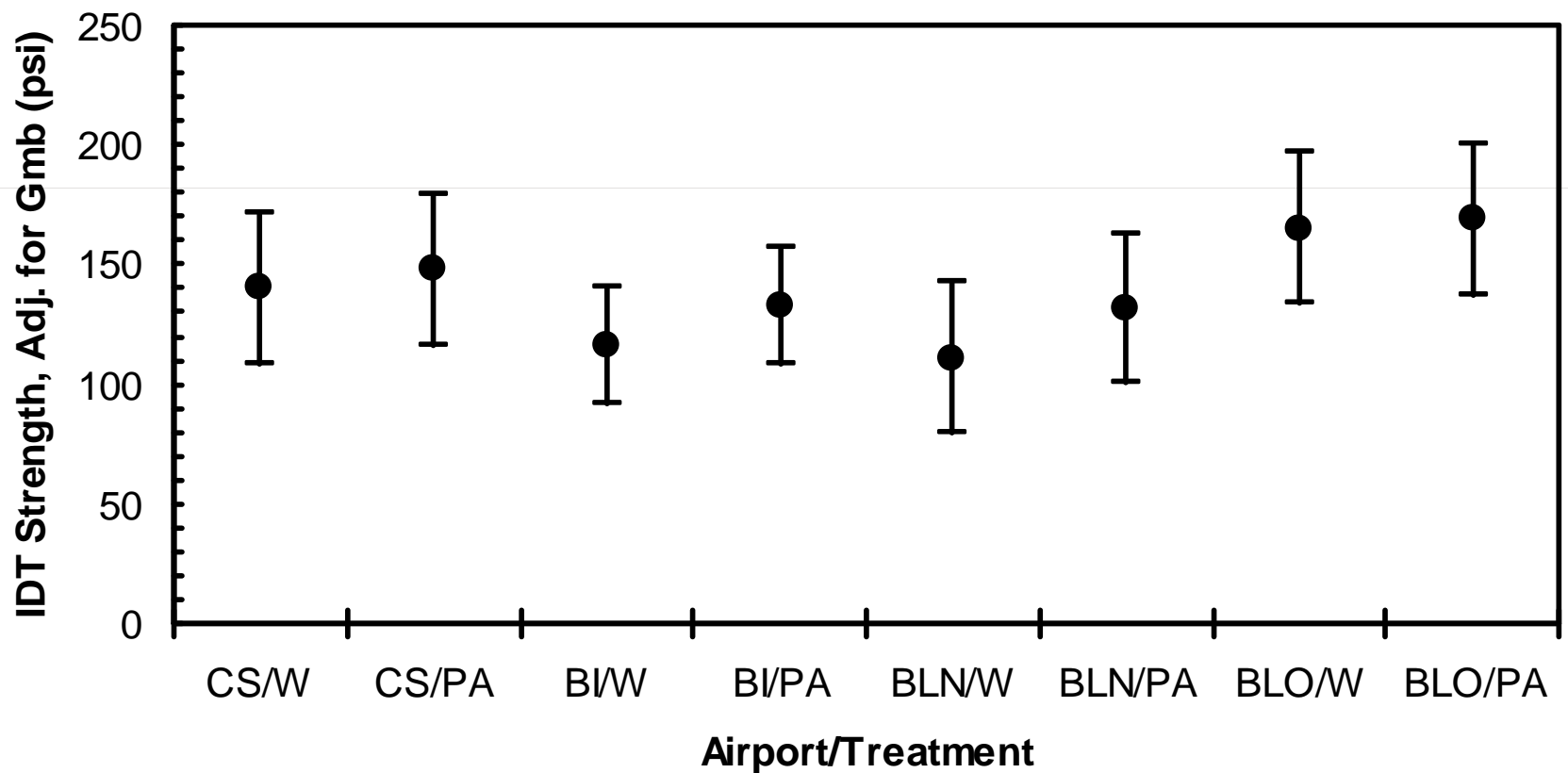
Site Visits

- 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





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



■ pH increases; NaOH used for oil sands

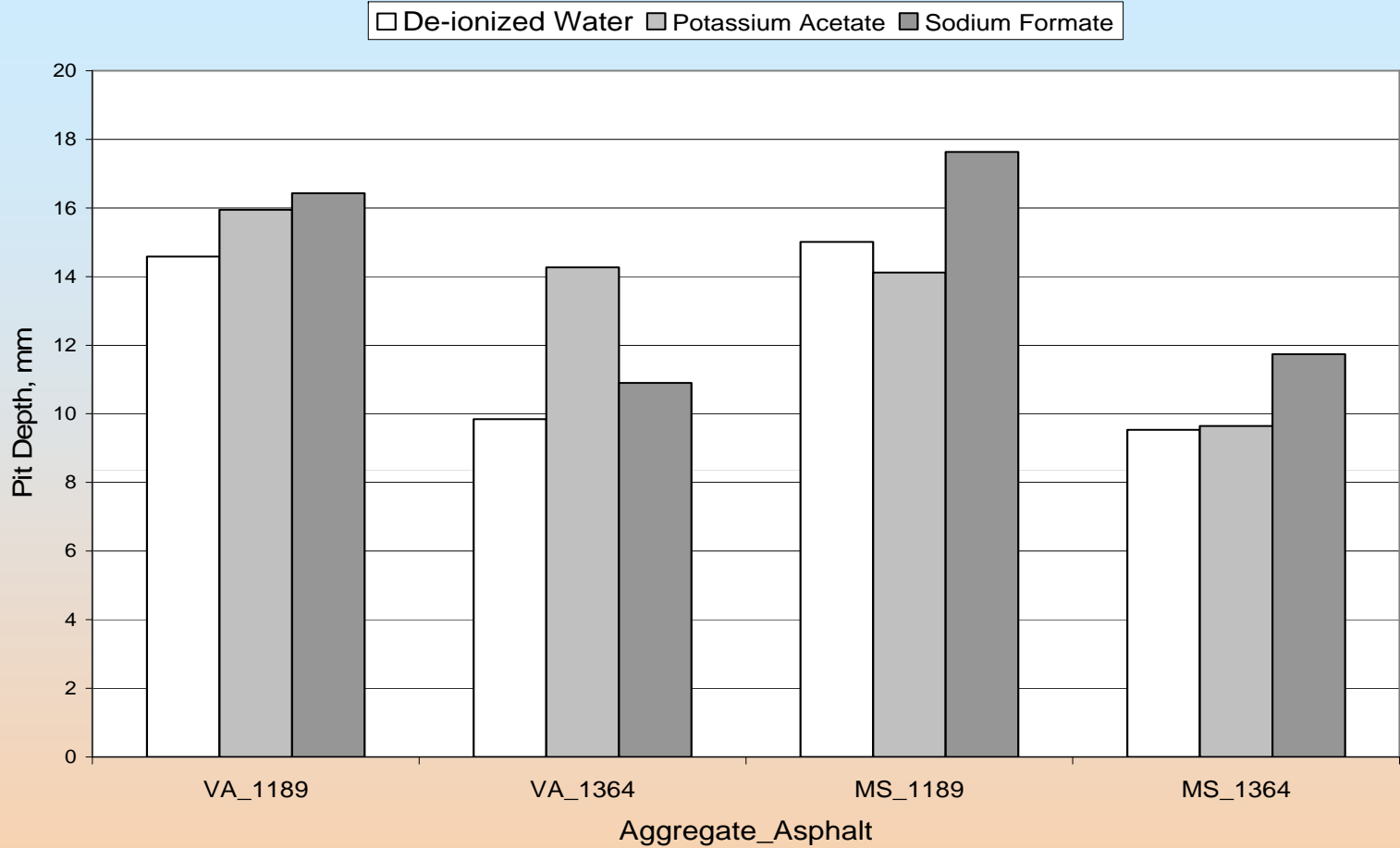
■ Density ↑ vs. water

■ Hydrophilic Salts

Initial Moisture Damage Results



- 20 kHz, 500 watt ultrasonic horn
- -20/+35 range sieved aggregate
- 2% Aq solutions of KOAc, NaOf



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

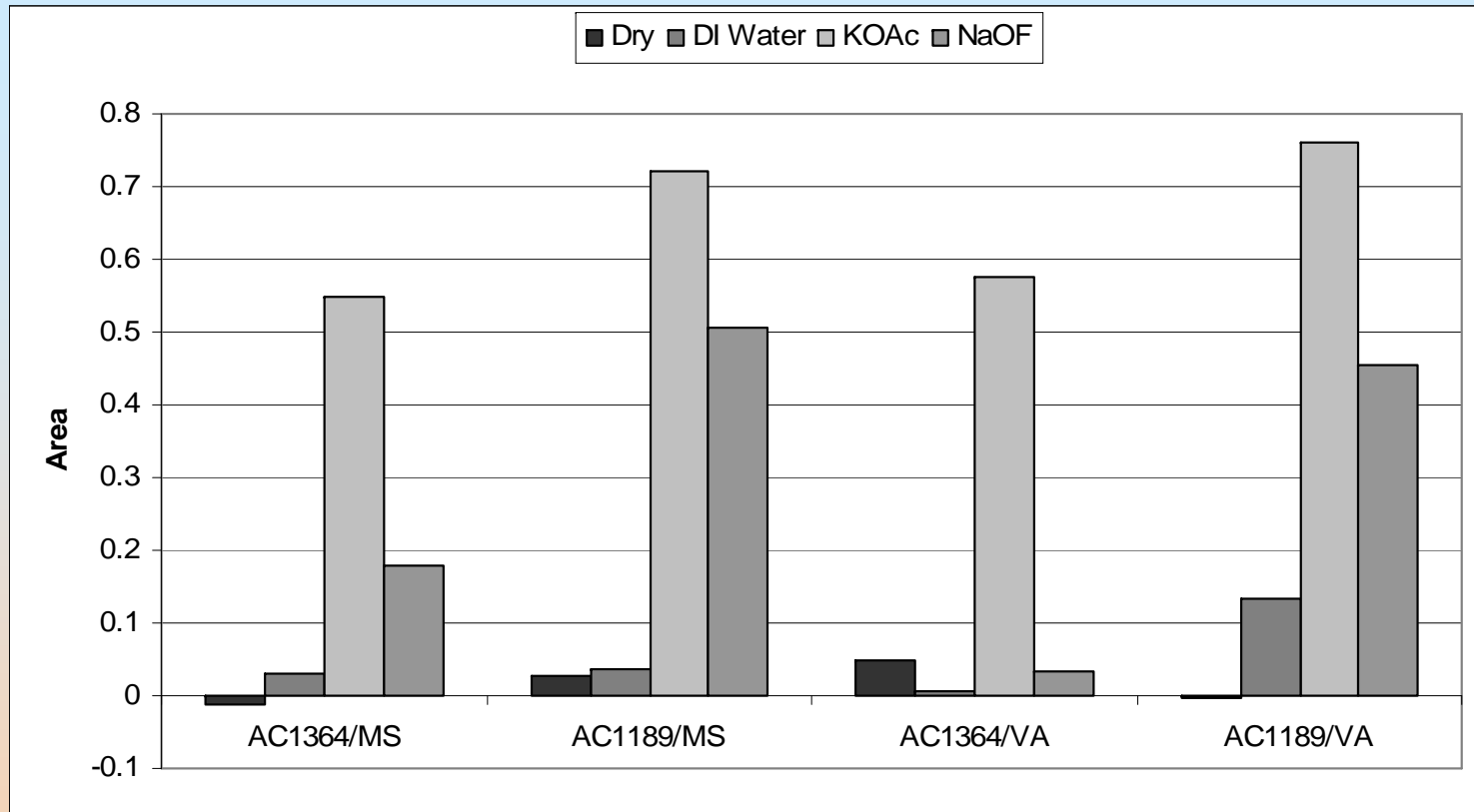


Higher concentrations in field

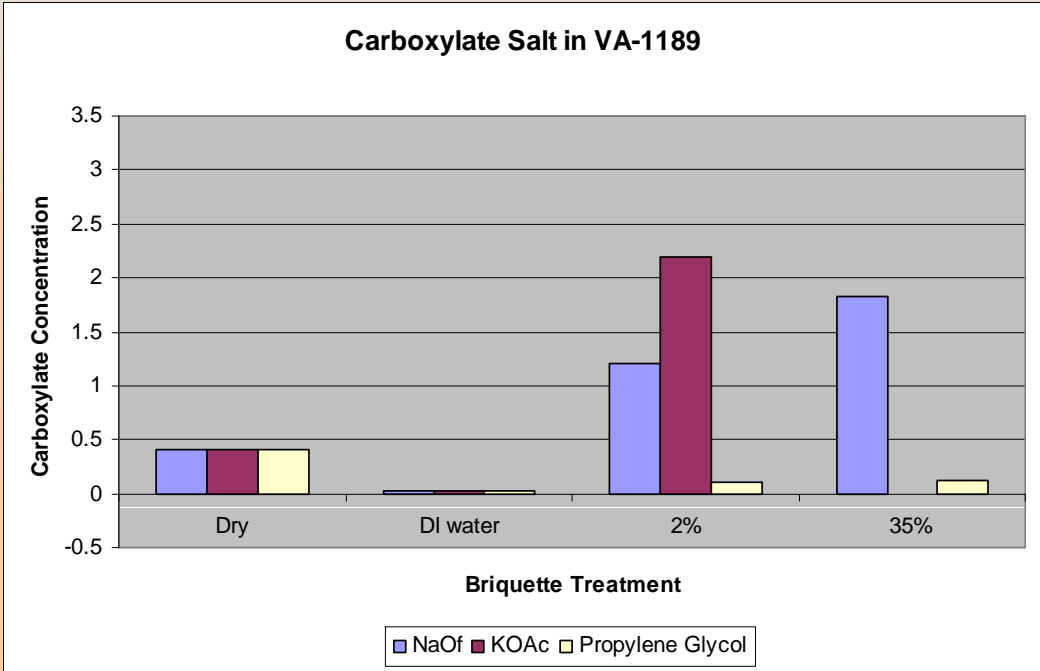
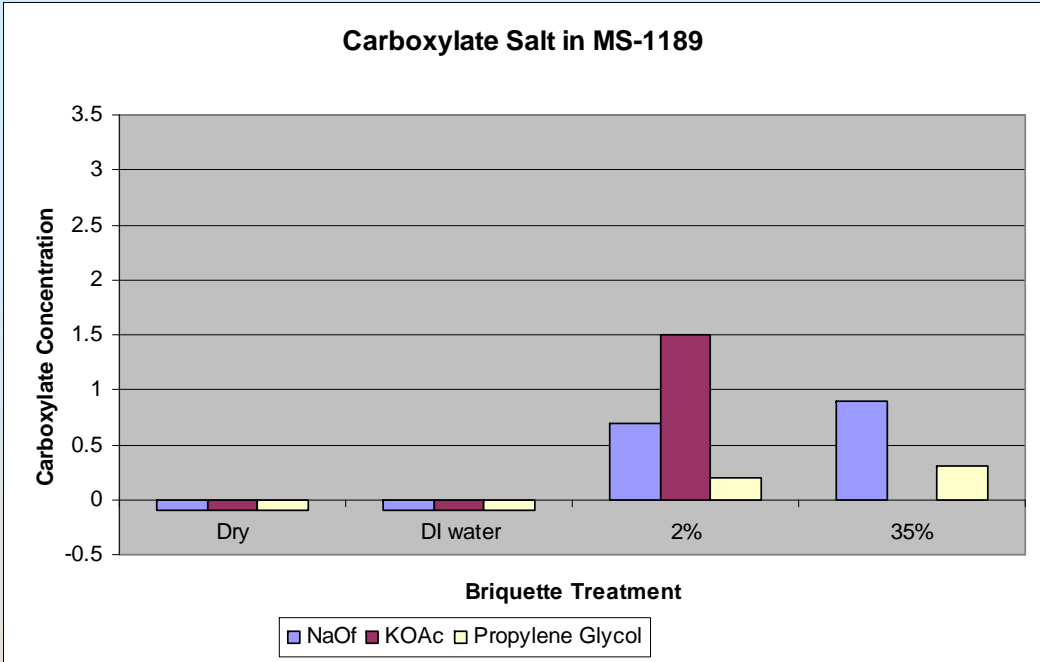
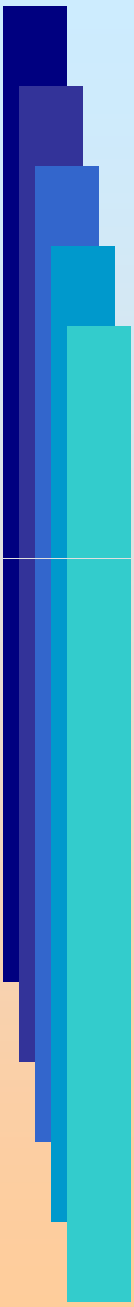
- 50% solutions pH between 9 and 12
 - *Likely increased stripping*

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 60C
 - 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

Solution	Concentration	DuNuoy Surface Tension Dynes/cm	Density g/mL
I	Water	72.4	1.000
II	2% sodium formate	69.1	1.0144
III	2% potassium acetate	71.3	1.0084
IV	2% 1,2 propane diol	68.0	1.0096
V	35 % 1,2 propane diol	51.5	1.0359
VI	35% sodium formate	52.6	1.2456
VII	35% potassium acetate	65.3	1.1945

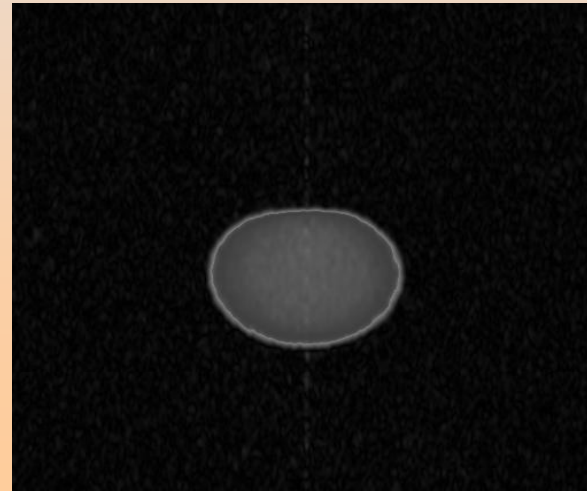


Acetates have been observed to be less aggressive than Formates

NMR Imaging




$$\gamma_{aw} = \gamma_w \left(\frac{\cos \beta(t_1) - \cos \beta(t_2)}{\cos \alpha(t_2) - \cos \alpha(t_1)} \right)$$



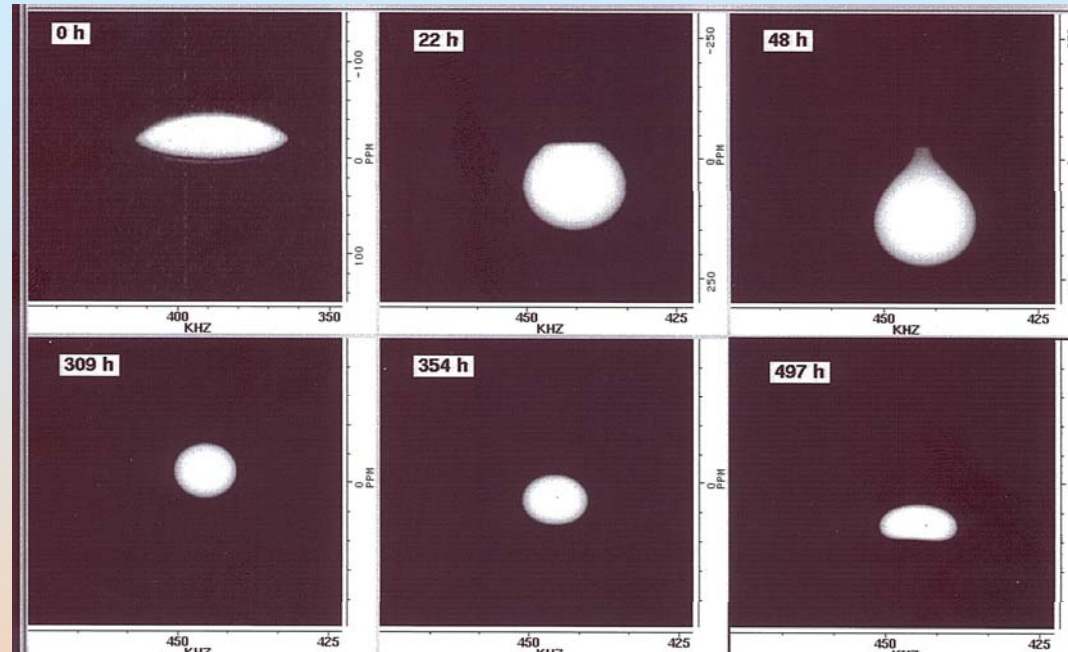
Asphalt	Deicer	Asphalt -H₂O	Asphalt-air^c
1189	Water	29	48
1189	2% sodium formate	31	43
1189	2% potassium acetate	21	53
1189	2% 1,2 propane diol	27	45
1189	35 % 1,2 propane diol	12	41
1189	35% sodium formate	9	45
1189	35% potassium acetate	28	47
1364	Water	34	45
1364	2% sodium formate	27	44
1364	2% potassium acetate	26	46
1364	2% 1,2 propane diol	30	44
1364	35 % 1,2 propane diol	19	37
1364	35% sodium formate	23	36
1364	35% potassium acetate	36	36

■ Softer asphalt = lower interfacial surface tension



Sample	Spreading Coefficient	
	water on asphalt, S_{wa}	asphalt on water, S_{aw}
1189.I	-52	-5
1189.II	-56	-4
1189.III	-43	-5
1189.IV	-47	-3
1189.V	-21	-1
1189.VI	-17	-1
1189.VII	-48	-10
1364.I	-56	-9
1364.II	-48	-1
1364.III	-53	-1
1364.IV	-54	-6
1364.V	-28	-2
1364.VI	-34	-5
1364.VII	-61	-3

- More positive spreading coefficients indicate likelihood for wetting....asphalt 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