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ACPA

Effects of Deicing Chemicals on Concrete and ASR Mitigation

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Airports and Pavement Technology

Count on Concrete PAVEMENT

Acknowledgements

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Innovative Pavement Research Foundation

Federal Aviation Administration

Background

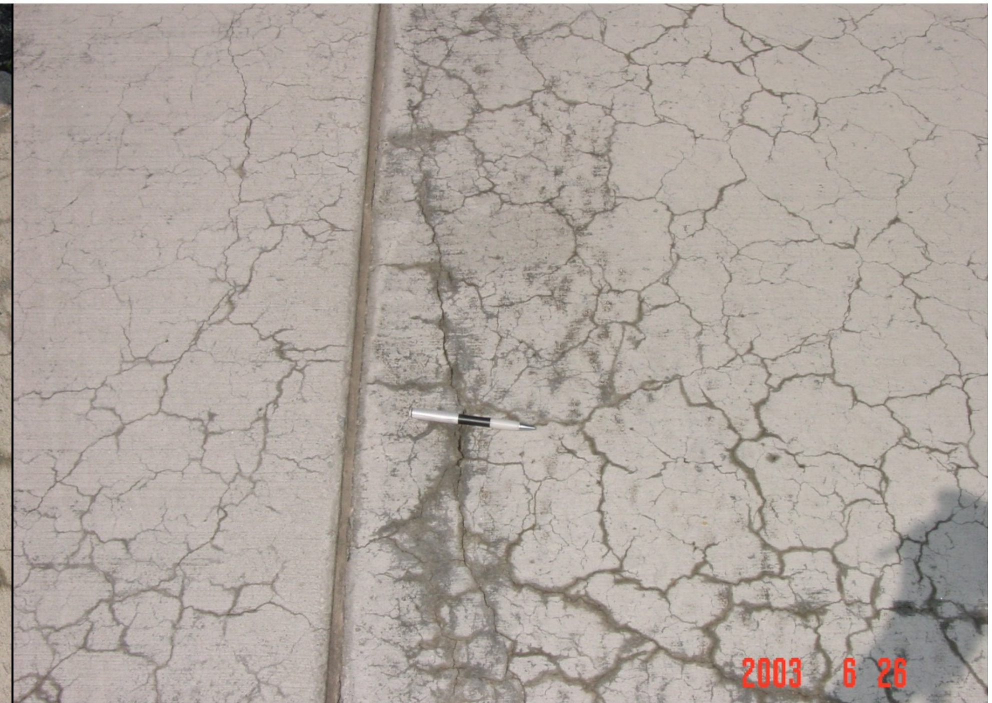
- Premature deterioration of concrete runways and taxiways was observed in several airports across U.S. in last few years, ex: Colorado Springs Airport (COS)
- Alkali-Silica Reaction (ASR) in concrete was suspected to be the principal cause.
- In some airports, distress was observed to be more pronounced in pavements treated with deicers

COS – Taxiway Echo

Seven year old taxiway


~ 10 year old pavement


2003 6 26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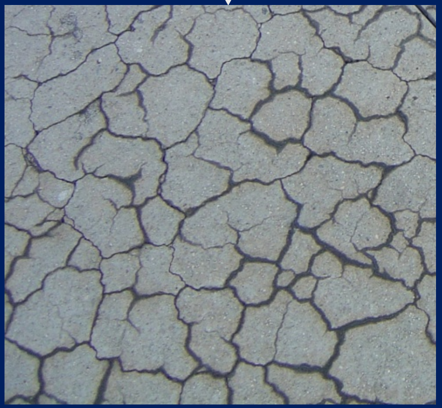
Concerns from ASR in Airfields

- Reduced Serviceability of the Airfield Pavement
- Expensive Repair, Rehabilitation and/or Replacement of Pavements
- Safety Issues
  - Foreign Object Debris (FOD) and Damage to Aircrafts and Safety Concerns to Airfield Workers and Passengers.

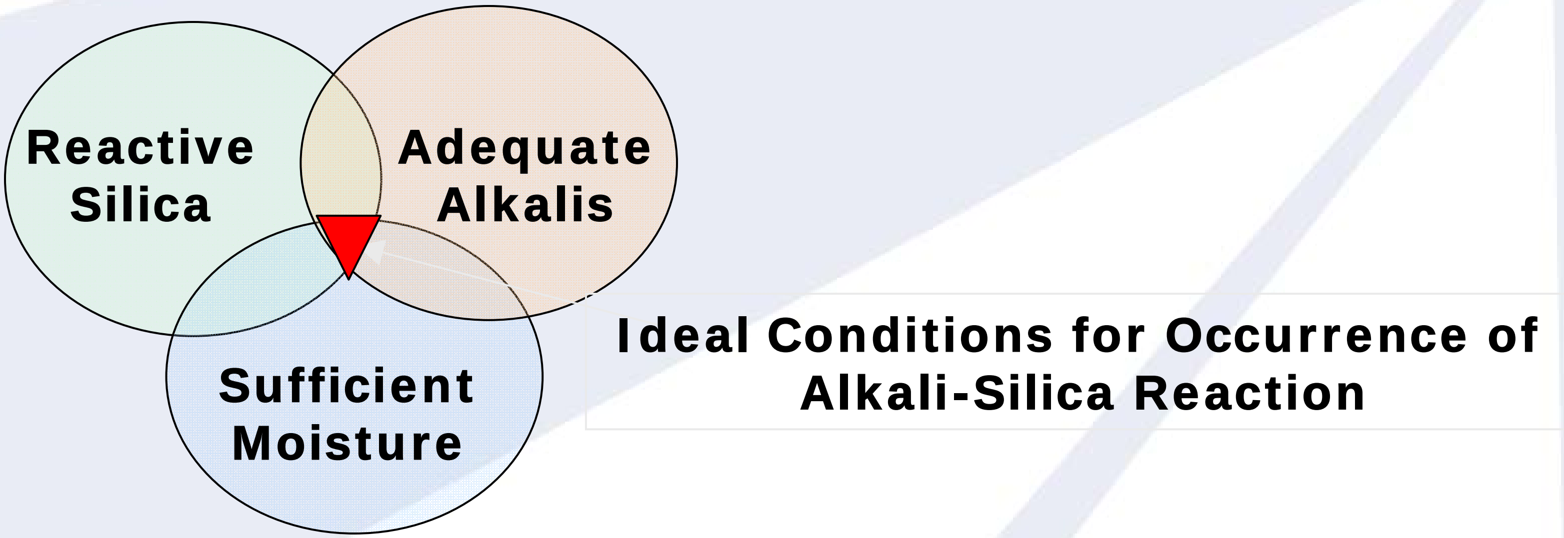
ASR Mechanism

Reaction: Reactive Silica + Alkali Hydroxides → ASR Gel
(Aggregate) (Primarily Cement)

Absorption: ASR gel → ASR Gel
(absorbs moisture)



Optimal Conditions for ASR



<u>Catalysts</u>

- Applied Loads (Traffic)
- Freeze-Thaw Damage
- Temperature

Sources of Alkalis (Na, K)

- INTERNAL SOURCES
  - Cement
  - Supplementary Cementing Materials
  - Admixtures
  - Aggregates
- EXTERNAL SOURCES
  - Deicing Chemicals
  - Marine Exposure
  - Brackish Waters

Common Airfield Pavement Deicers

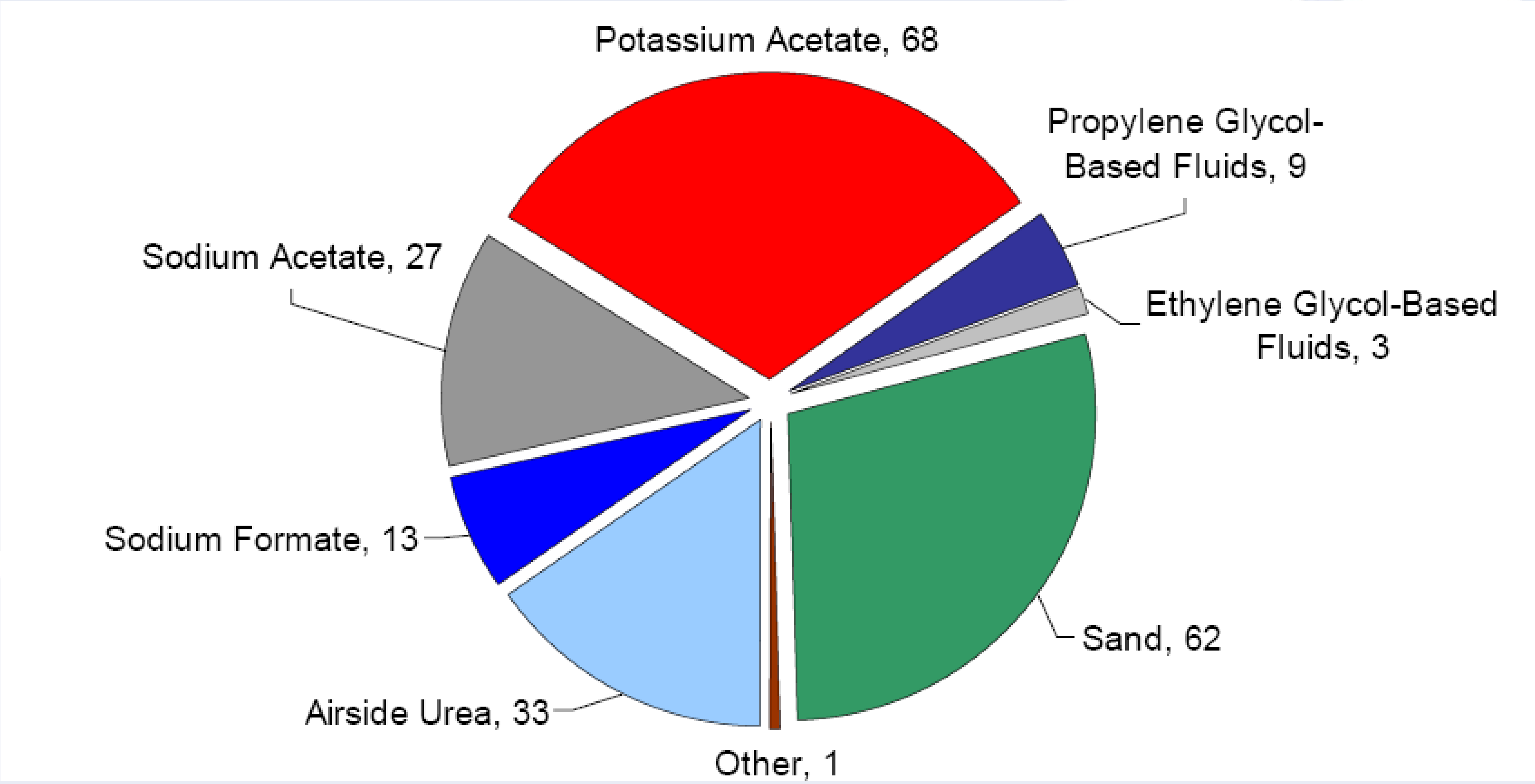
- Widely used deicers and anti-icers
  - Potassium Acetate (liquid)
  - Sodium Acetate (solid)

  (widely used on airfield pavements in the USA)

  - Sodium Formate (solid)
  - Potassium Formate (liquid)
- Other deicers (from past)
  - Urea
  - Ethylene Glycol
  - Propylene Glycol
  - Ethylene and Propylene Glycol Combinations

Deicer and Anti-Icer Usage on U.S. Airfield Pavements

(Survey of 95 Airports, 2004/5)



Source: *ACRP Synthesis 11-03/Topic S10-03*

IPRF/FAA Project

"Potential for Acceleration of ASR in the Presence of Pavement Deicing Chemicals"

Research started in 2003 program

Principal Findings from IPRF 03-9 and IPRF 04-8 Studies

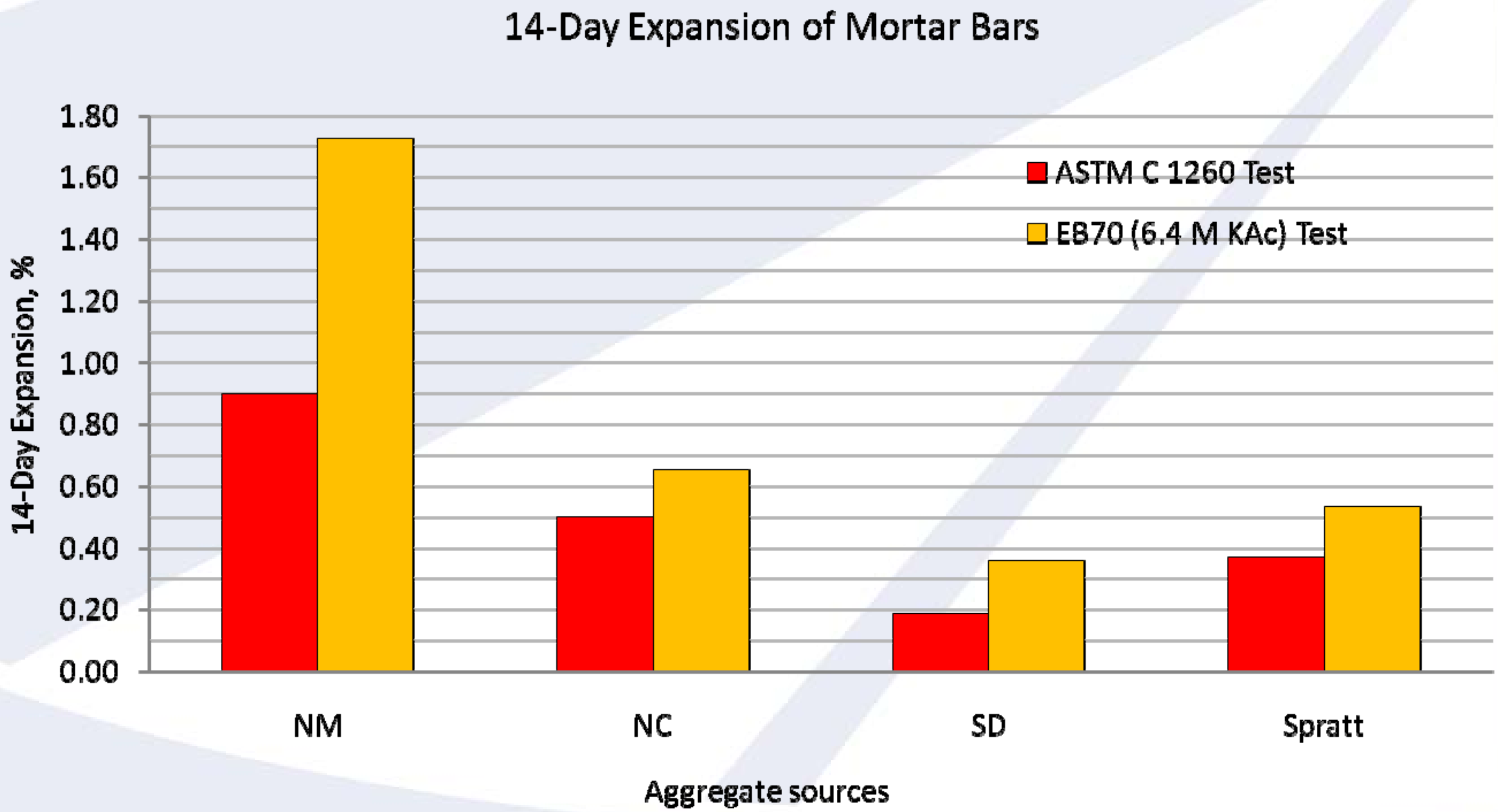
- Alkali-acetate and alkali-formate deicers have <u>significant</u> potential to cause ASR in concrete in lab studies.

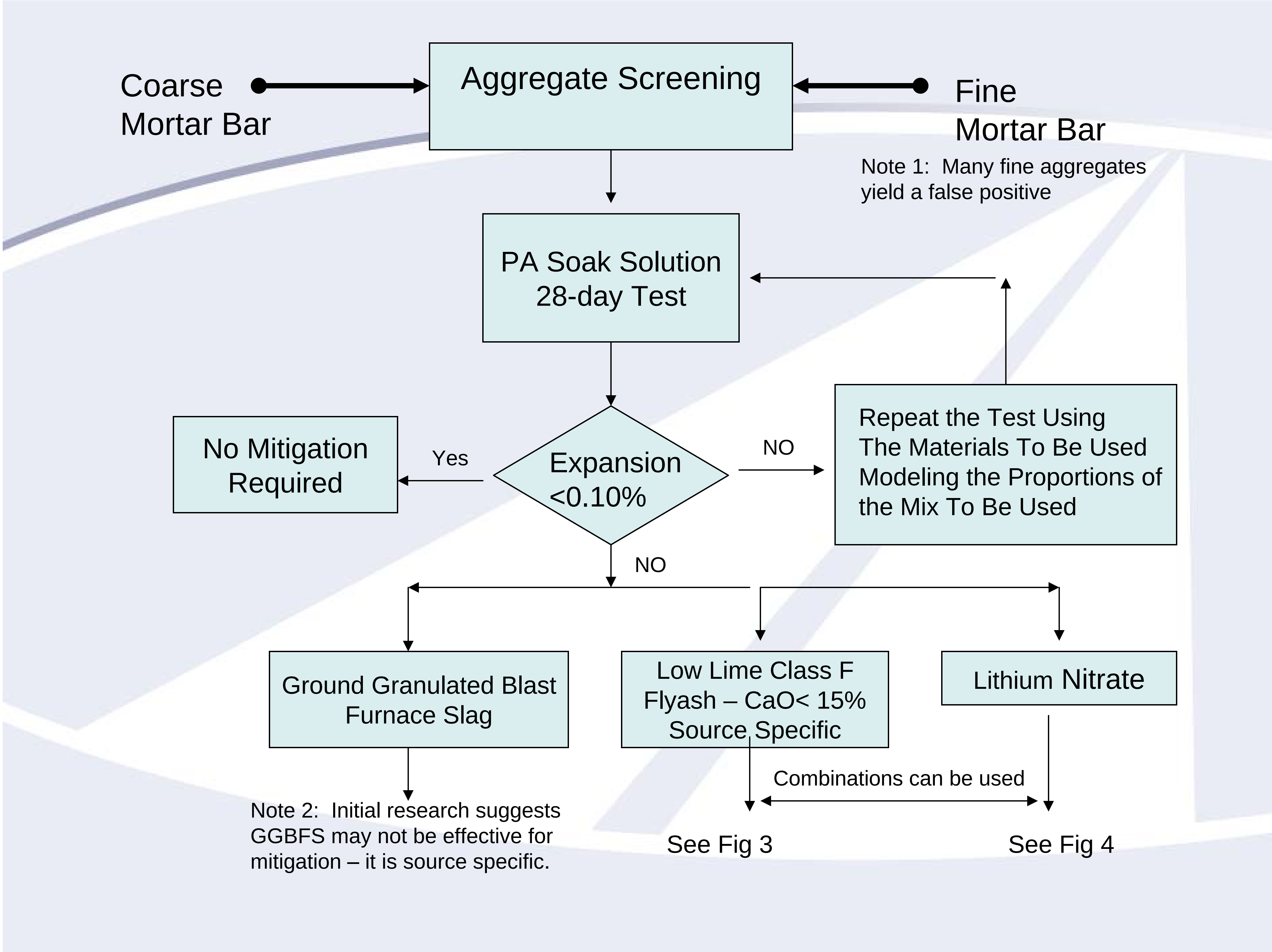
- Traditional ASR mitigation measures such as <u>Class F fly ash</u> can successfully mitigate the ASR damage in the presence of deicing chemicals.

Genesis of EB-70 Protocol

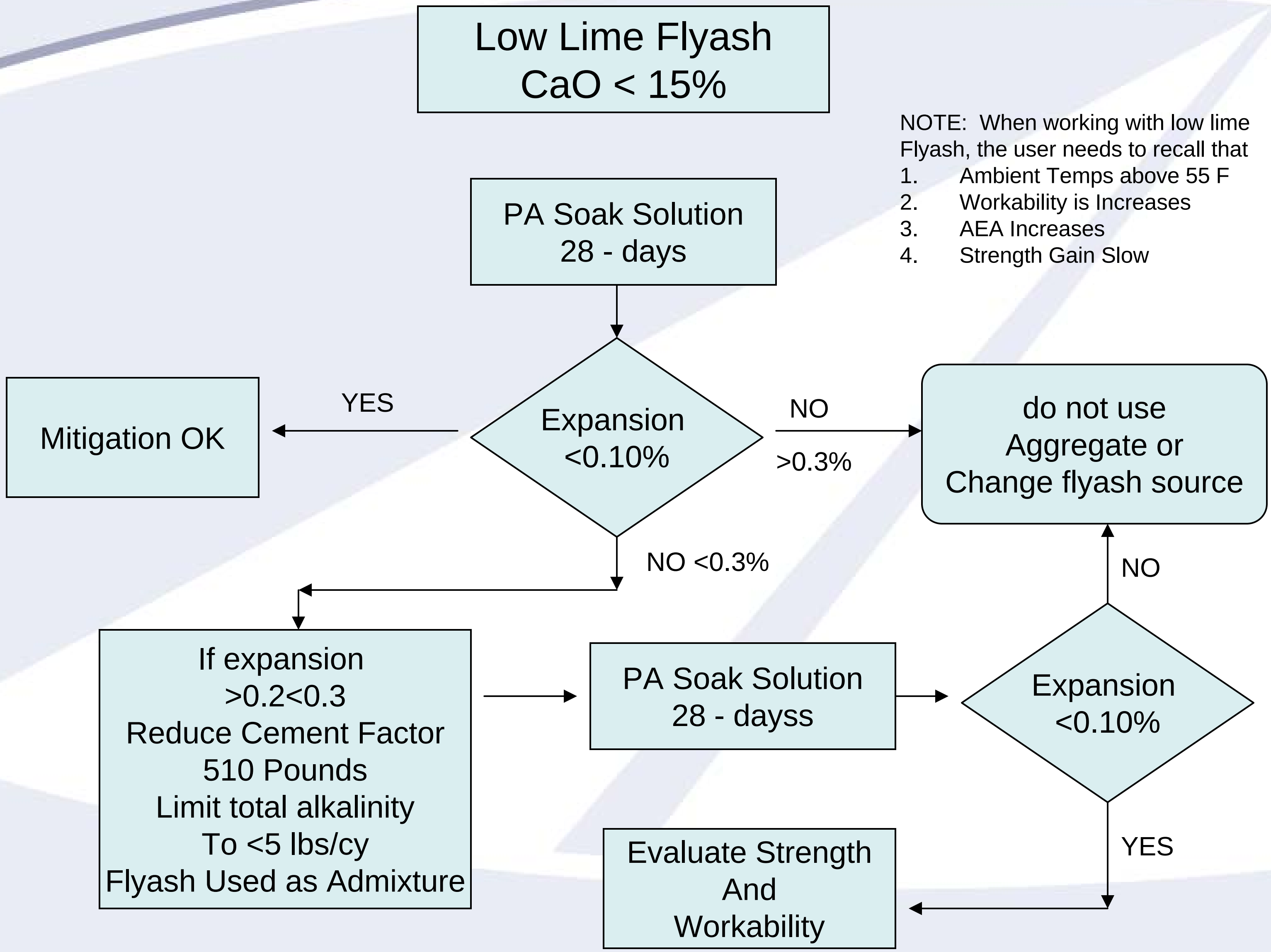
- Based on findings from IPRF 03-9 and 04-8 studies, a KAc deicer-based mortar bar test was proposed to screen aggregates that are sensitive to deicers.
- In 2005, the deicer-based test was adopted by FAA (EB-70) as one of the two standard protocols to screen aggregates for ASR. The other standard protocol is ASTM C 1260 test (Accel. Mortar Bar Test)

Comparison of 14-day Mortar Bar Expansions ASTM C 1260 *versus* EB-70 Protocol




Coarse Mortar Bar
Aggregate Screening
Fine Mortar Bar
Note 1: Many fine aggregates yield a false positive
PA Soak Solution 28-day Test
No Mitigation Required
Yes
Expansion <0.10%
NO
Repeat the Test Using The Materials To Be Used Modeling the Proportions of the Mix To Be Used
NO
Ground Granulated Blast Furnace Slag
Low Lime Class F Flyash – CaO< 15% Source Specific
Lithium Nitrate
Combinations can be used
Note 2: Initial research suggests GGBFS may not be effective for mitigation – it is source specific.
See Fig 3
See Fig 4

Mitigation of ASR - Airfield Pavement Deicers

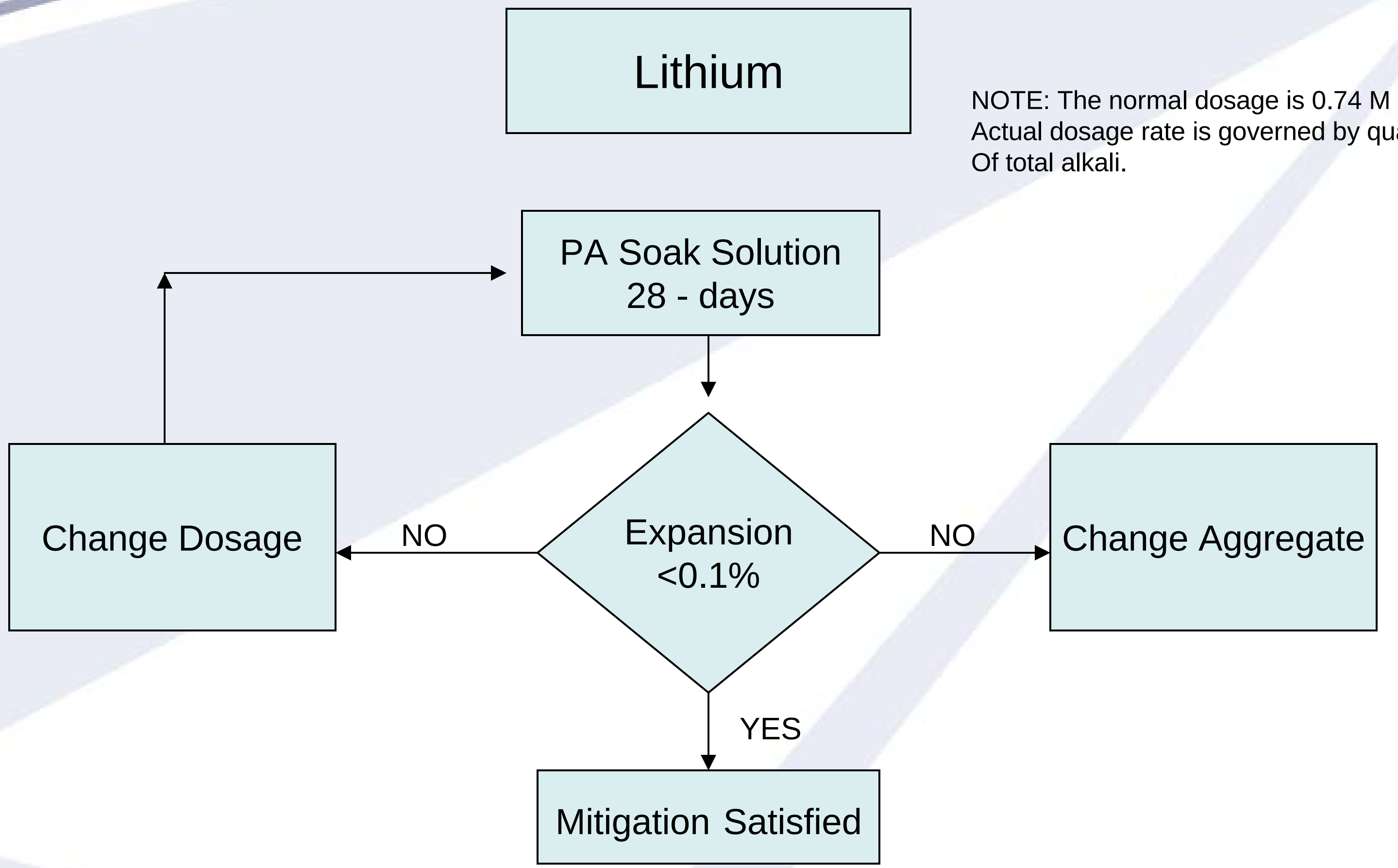


NOTE: When working with low lime Flyash, the user needs to recall that

1. Ambient Temps above 55 F
2. Workability is Increases
3. AEA Increases
4. Strength Gain Slow

Mitigation of ASR - Airfield Pavement Deicers

NOTE: The normal dosage is 0.74 M
Actual dosage rate is governed by quantity
Of total alkali.



R & T Update – interim protocol

- Based on limited studies
- Looked at only reactive aggregates
- Based only on lab result
- No correlation to actual field data
- Addressed only the deicer issue

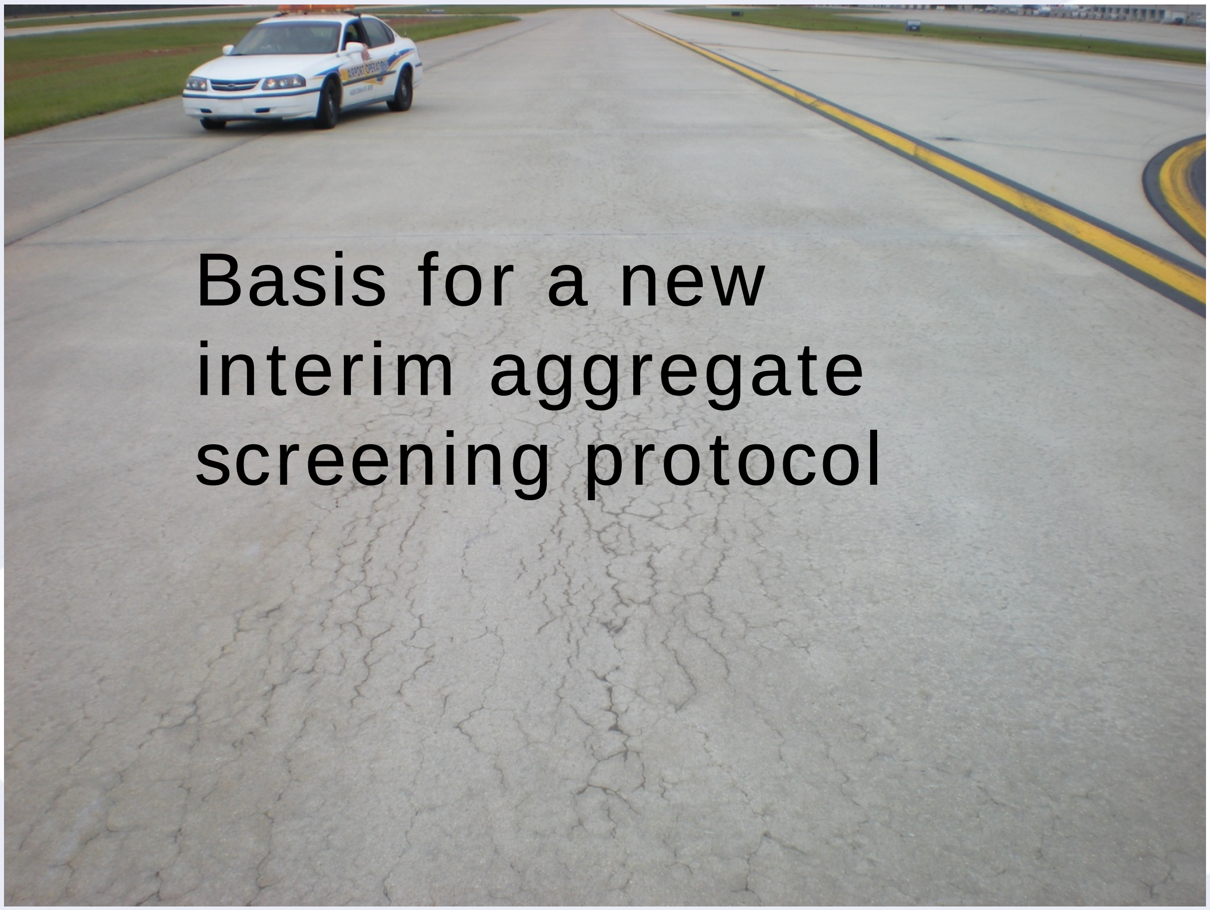
Further Research

- 2006 - Contract awarded to Clemson and Purdue Universities
- Study field performance
- Focus on forensic investigation
- Identify susceptibility of individual materials
- Develop new screening protocol

IPRF ASR Program Update

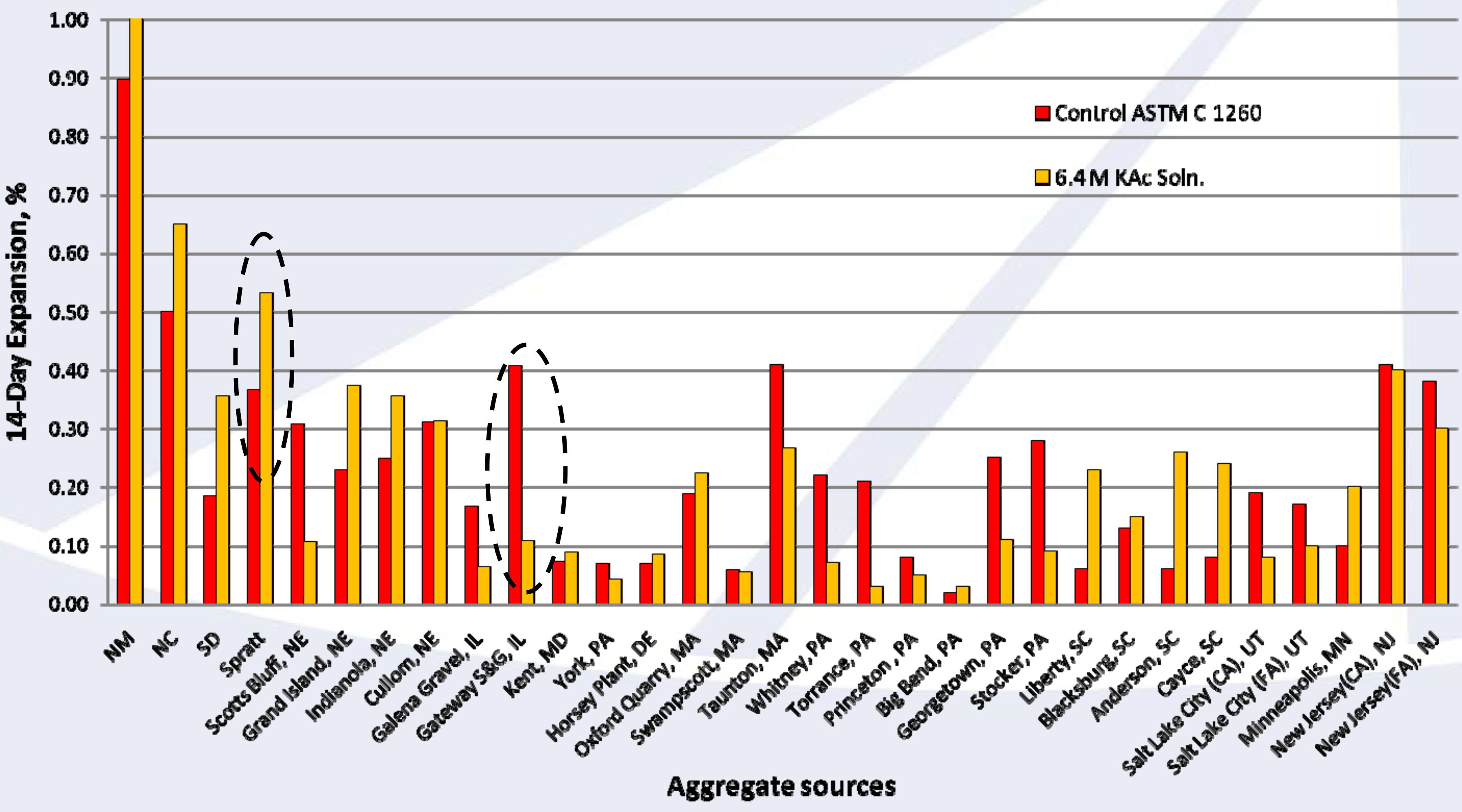
- **Project 05-7** - Airfield Pavement Deicers and Concrete Mix Design
  - Compare lab results to field performance
  - KAc deicer test did not correlate well with C 1260
  - Was intended to review airports that have potassium acetate problems.
  - Trouble finding related problems; problems are engineering and construction related
  - Class C fly ash issue (which doesn't mitigate ASR damage),
  - Improper screening of materials.

IPRF 05-7 Testing Preliminary Results

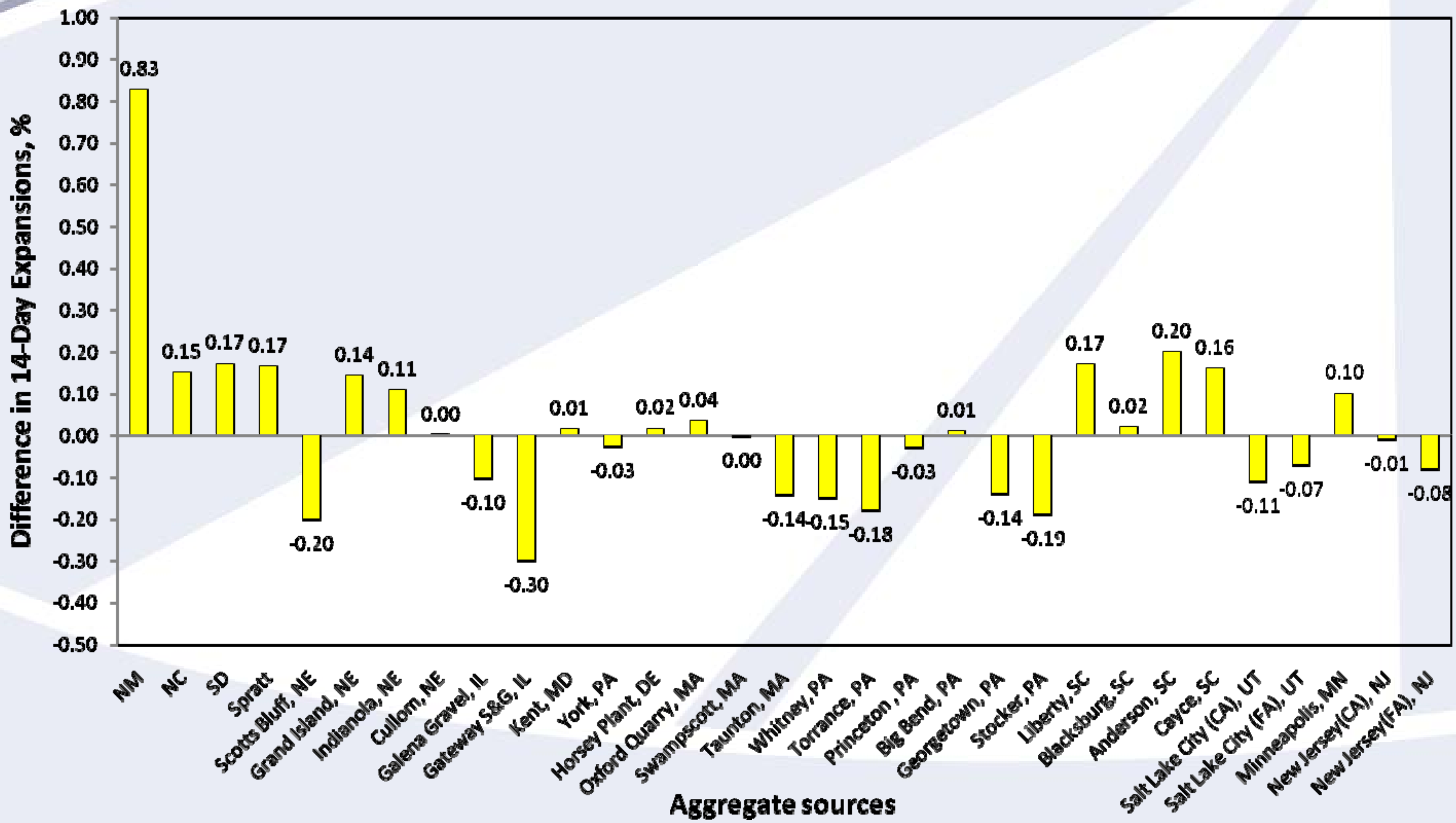


Basis for a new interim aggregate screening protocol

Upon further testing with additional aggregates… (14-day expansions)

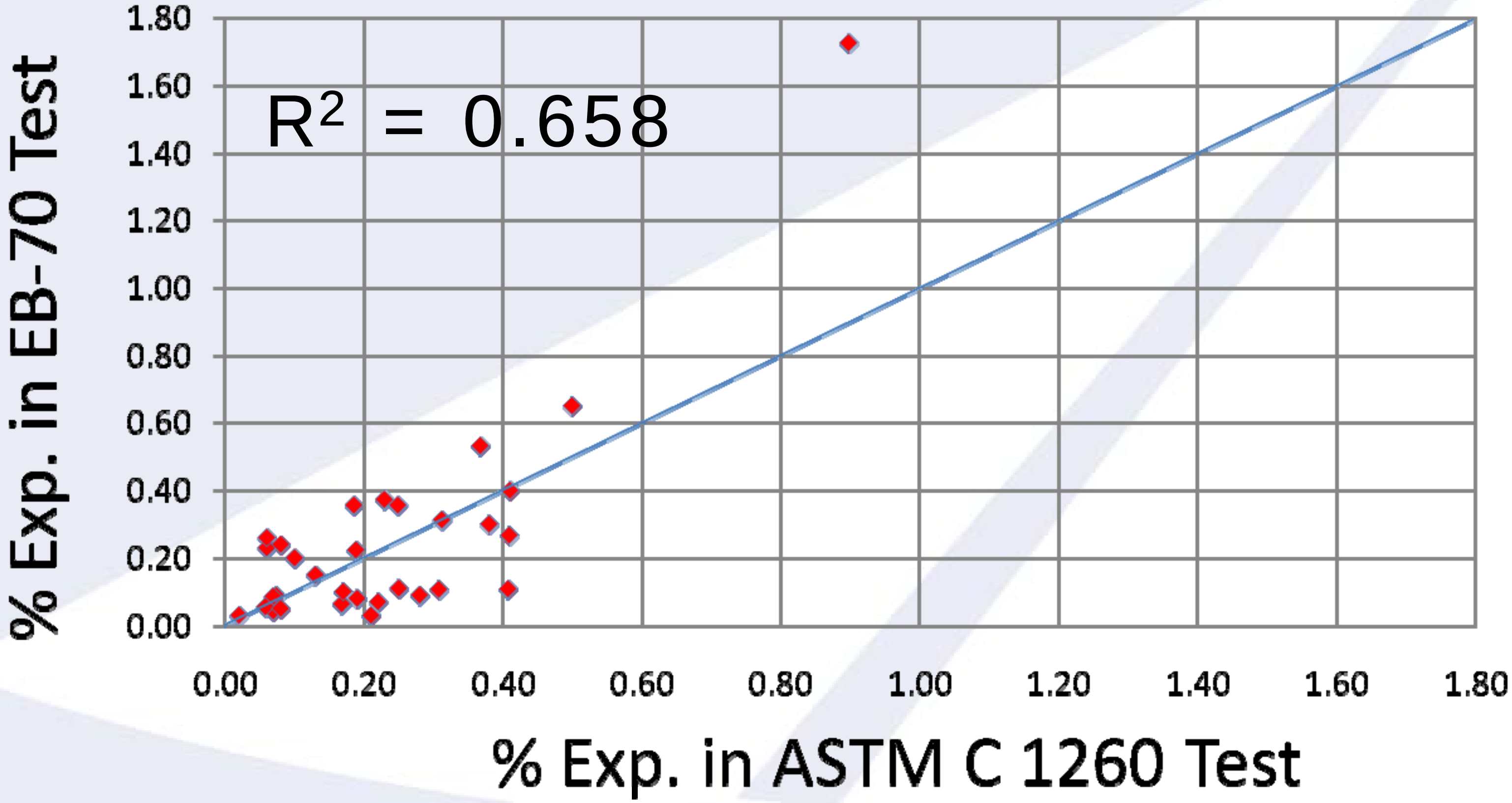


Mortar Bar Expansion in EB-70 Protocol relative to ASTM C 1260 Test



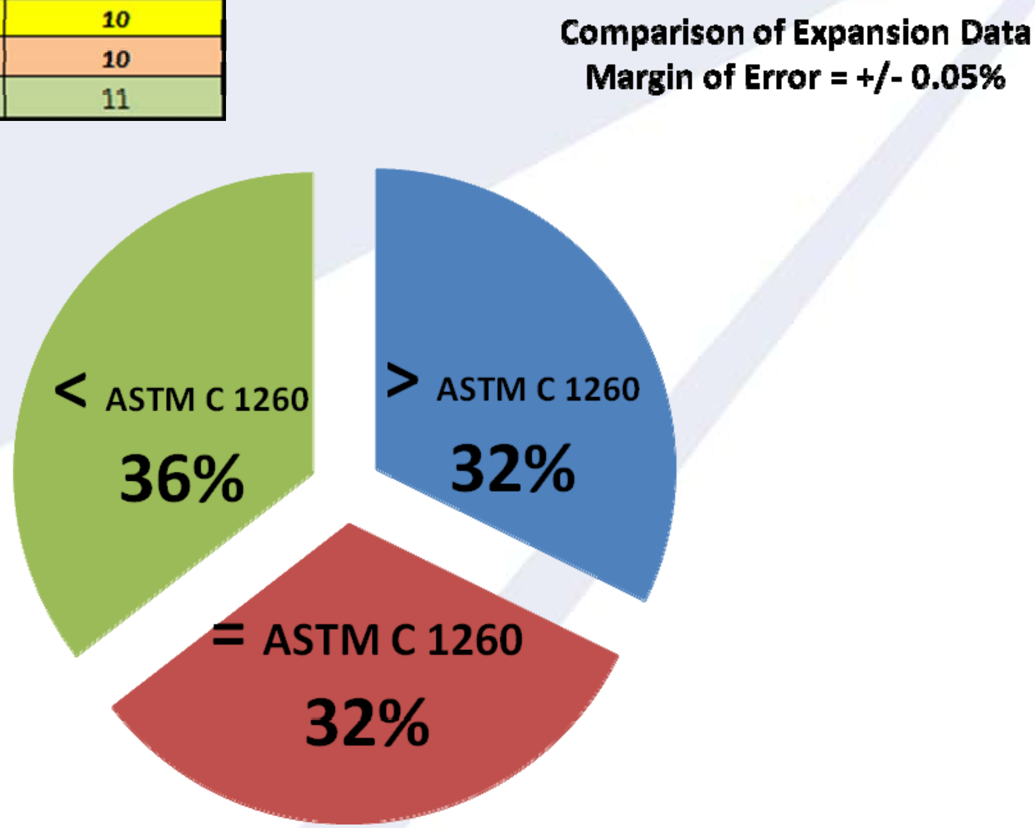
Comparison of Mortar Bar Expansion (14-days)

Std. ASTM C 1260 *versus* EB – 70 Protocol



EB-70 *versus* ASTM C 1260 Test Results

Comparision of Mortar Bar Expansions	# of Aggregates
EB 70 > ASTM C 1260	10
EB 70 = ASTM C 1260	10
EB 70 < ASTM C 1260	11



Mechanism for Deicer-Induced ASR Distress

- One of the principal findings from IPRF 03-9 and 04-8 studies was the "pH jump" phenomenon in deicer solution interacting with portland cement pastes.

- The underlying mechanism for such "pH jump" was determined to be due to increase in OH^- ion activity coefficient and therefore the OH^- ion activity in concentrated deicer solutions.

Comparison of Soak Solutions Characteristics

	Soak Solution	Avg. pH @ 21°C
	6.4M KAc (~ 10 m)	10.76
EB-70	6.4M KAc (~ 10 m) with Sat. $Ca(OH)_2$	14.54 (Low OH^- Conc., but High Activity)
	1N NaOH	13.69
Rev. EB-70	**1N NaOH + 3M KAc (~ 5 m)**	**14.47** **(High OH^- Conc., but High Activity)**

Revised EB-70 Protocol

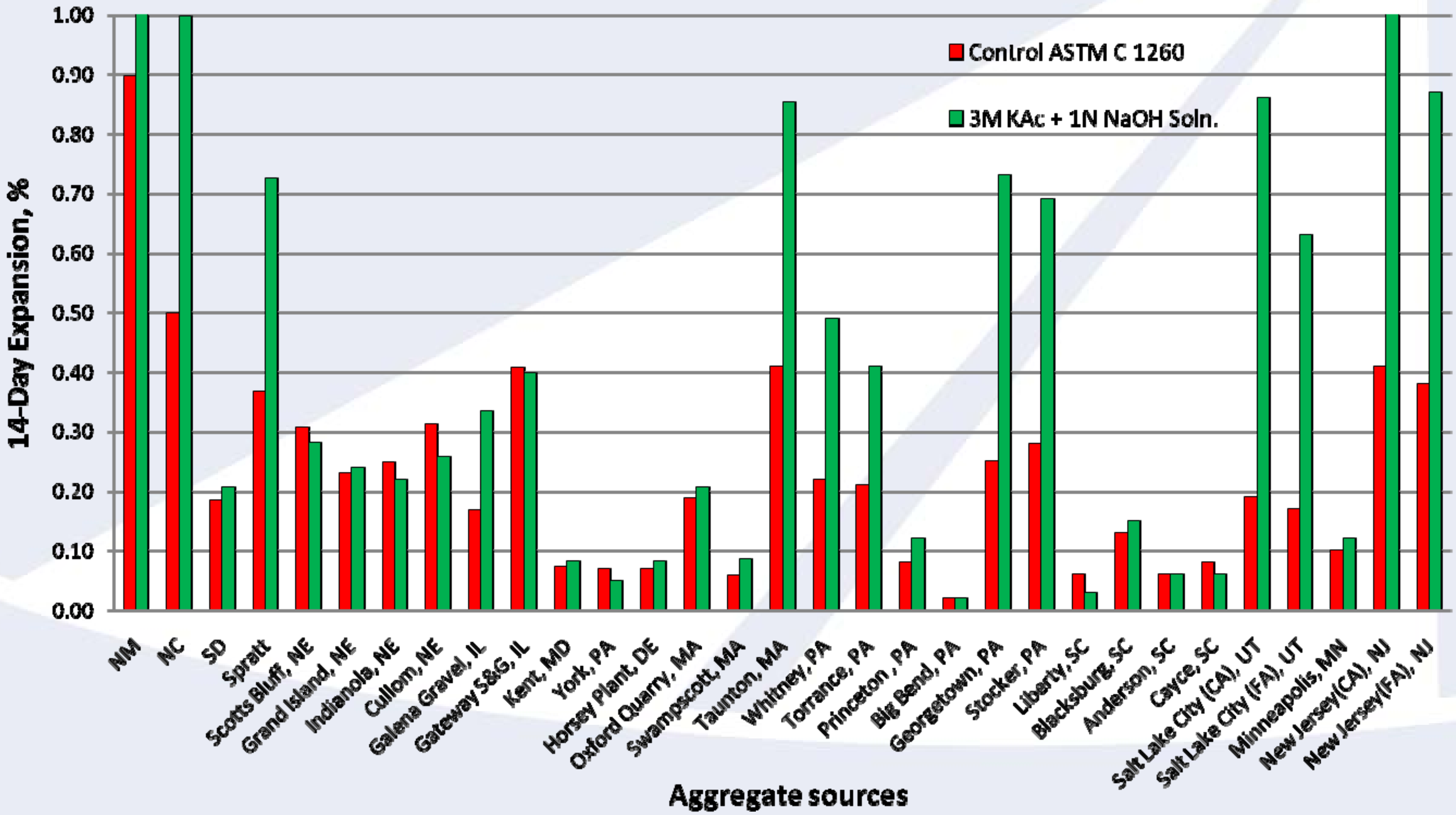
- Test method is similar to EB-70 Protocol, with exception of soak solution composition.

- Proposed soak solution is:

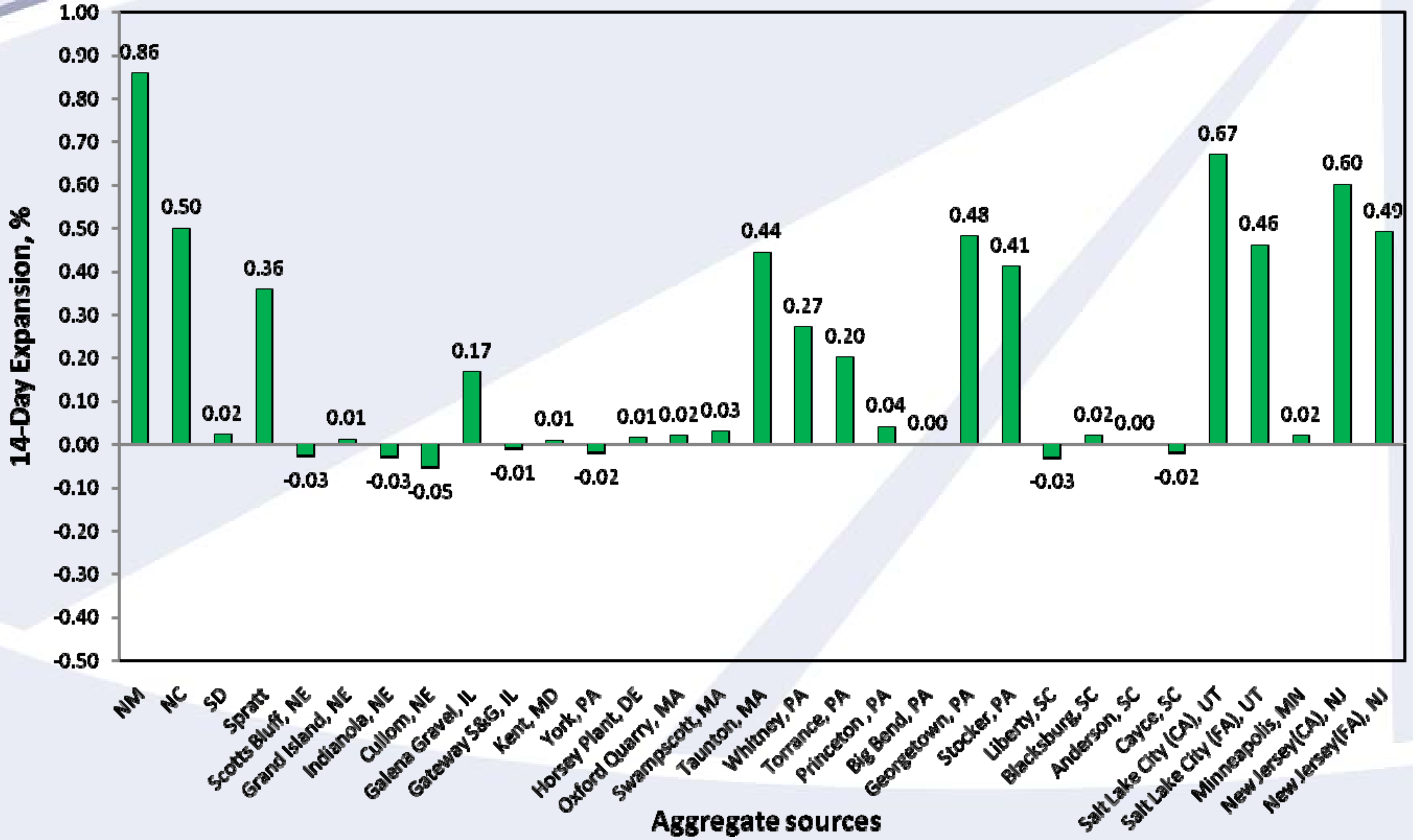
  1N NaOH + 3M KAc solution

- Test duration and expansion limits are similar to the standard ASTM C 1260 test
  (i.e. <0.1% expansion at 14 days of soak)

Comparison of Mortar Bar Expansion Std. ASTM C 1260 *versus* Revised EB – 70 Protocol (14-Day)

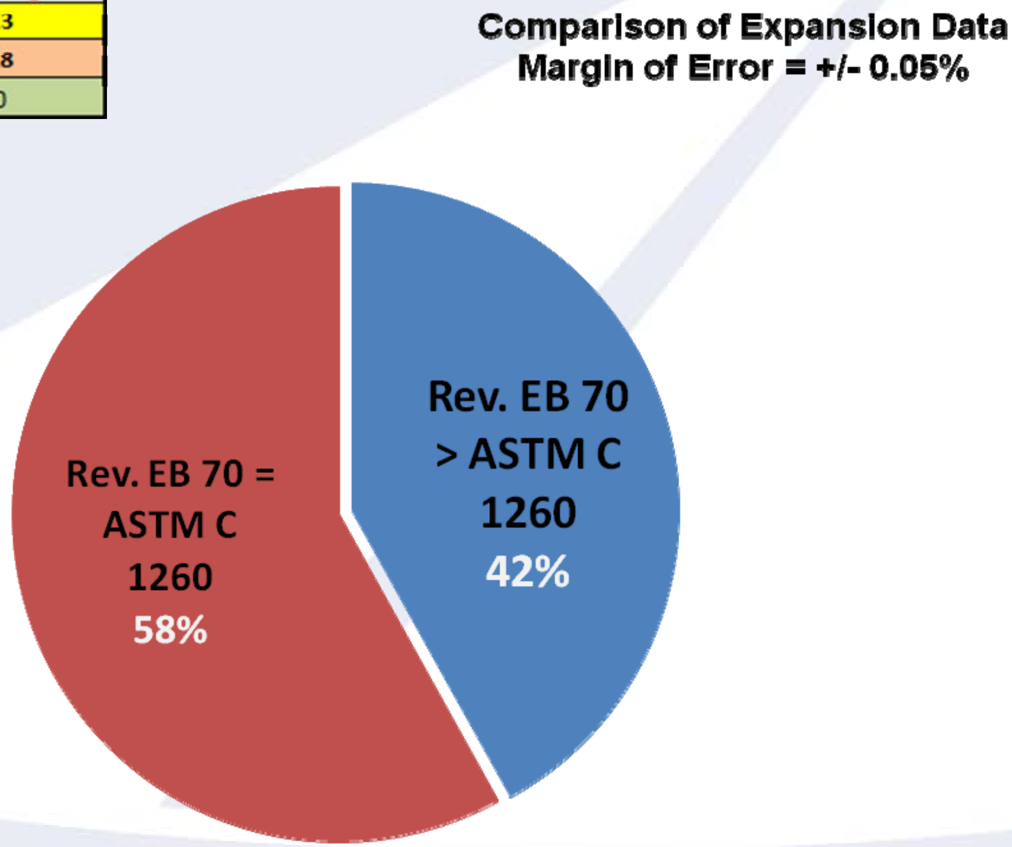


Mortar Bar Expansion in Revised EB-70 Protocol relative to ASTM C 1260 Test



Revised EB-70 *versus* ASTM C 1260 Results

Comparision of Mortar Bar Expansions	# of Aggregates
Revised EB 70 > ASTM C 1260	13
Revised EB 70 = ASTM C 1260	18
Revised EB 70 < ASTM C 1260	0



Interim Test Protocol Conclusions

- The revised EB-70 test protocol for evaluating ASR potential of aggregate in presence of deicing chemicals ***corrects*** the deficiencies of the existing EB-70 method.

- The proposed soak solution in the revised EB70 test method, i.e. 1N NaOH + 3 M KAc solution, captures the interaction between KAc deicer solution and reactive aggregates more accurately.

- 100% of aggregates evaluated in the <u>*revised EB-70 protocol*</u> are shown to be either similarly or much more reactive as compared to the results from the standard ASTM C 1260 test method. Thus, ***both tests show a consensus*** in assessing aggregate reactivity based on 0.1% expansion limit on 14-day expansions.

IPRF 05-7 Study Conclusions

- Distress at different airports had different causes
- Damage associated with KAc was not consistent between airports
- C666 F/T showed rapid deterioration
- Found formation of Potassium Sulfate (KS)
- Minor penetration of KAc
- Did not look at the microrfines coating aggregates

IPRF 06-5: Role of Dirty Aggregates in the Performance of Concrete Exposed to Deicers

- Principal Investigators
  - Marc A. Anderson, Ph.D.
  - Steven M. Cramer, Ph.D., P.E.
- Contributing Authors
  - Jessica Silva
  - Jose Munoz
  - Isabel Tejeodor

THE UNIVERSITY of WISCONSIN MADISON

IPRF 06-5: Specific Questions Studied

- Do microfines accelerate and/or generate ASR?
- Does the combination of microfines and deicers accelerate ASR? (KAc in particular)
- Are the micro fines involved in other harmful delayed chemical reactions, similar to ASR?
- Do microfines cause distress by themselves?
- Does KAc cause damage to the cement paste microstructure?

Aggregates Selected for Study

Table 6. Summary of results for microfines

Sample	Methylene Blue	CA Clean Test	Pozzolanic Activity	ASR
CA	Low	High	Low	High
CO-I	Very High	Very Low	Mod	Low
UT	High	Low	Mod	High
CO-II	Mod High		Mod	High
CO-III	Mod High	High	Low-Mod	Low
WY	Very High	Low	High	High
AZ	Very High	Limit	Mod	Mod
WI	Mod High	High	Low-Mod	Low

Used 5 in study:
CA, CO-I, UT, WY, WI

Test Conducted on Concrete with Coated Aggregates

Table 13. Test matrix for Task 5 concrete evaluation
This matrix was completed for two aggregate sources, Utah aggregate and Wisconsin aggregate.

Sample	Modified ASTM C1293-Humid	Modified ASTM C1293-Deicer	Modified ASTM C666
California	X	X	X
Colorado	X	X	X
Control (No coatings)	X	X	X
Utah	X	X	X
Wisconsin	X	X	X
Wyoming	X	X	X

Issues with air entraining

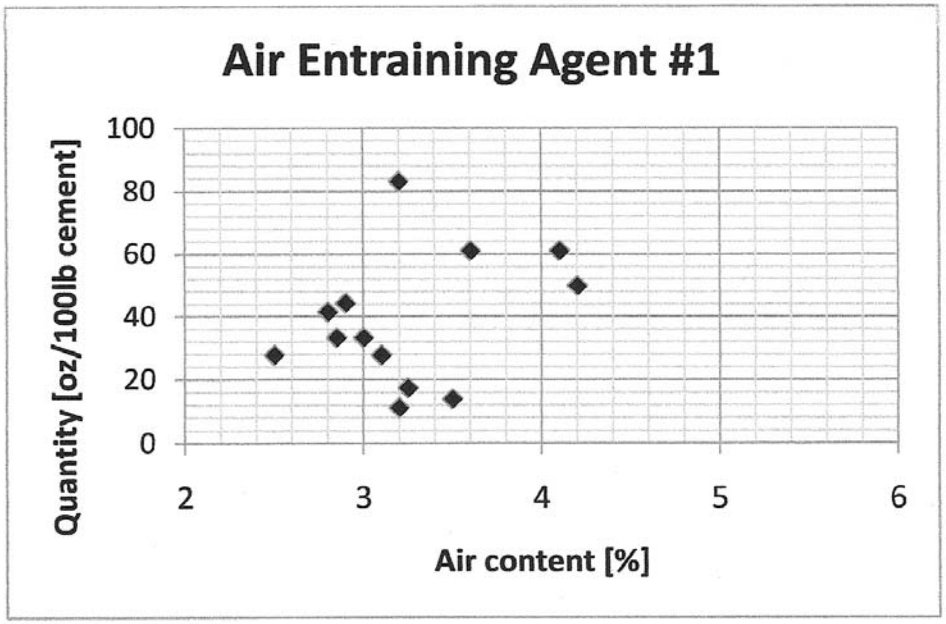


Figure 4. Air content achieved in concrete batches containing WY microfines with different dosages of air entraining agent No. 1. The manufacturer's recommended typical field dosage falls between 1 and 3 fl. oz. per 100 lbs of cement.

Entrained Air/Dosage per Microfine Used

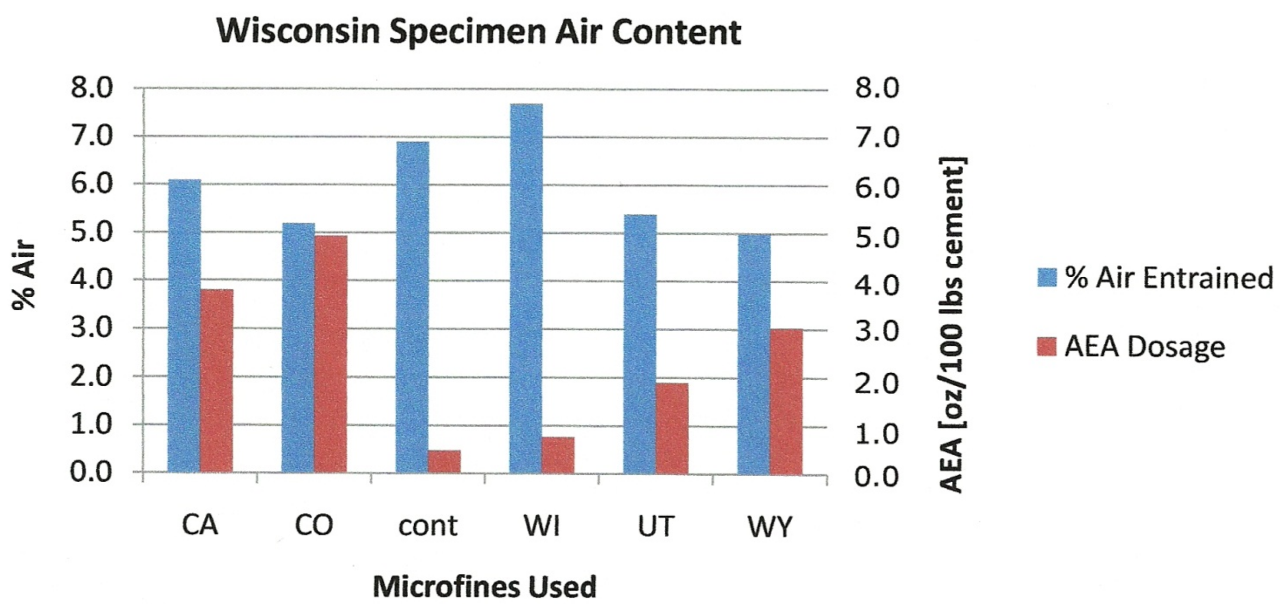
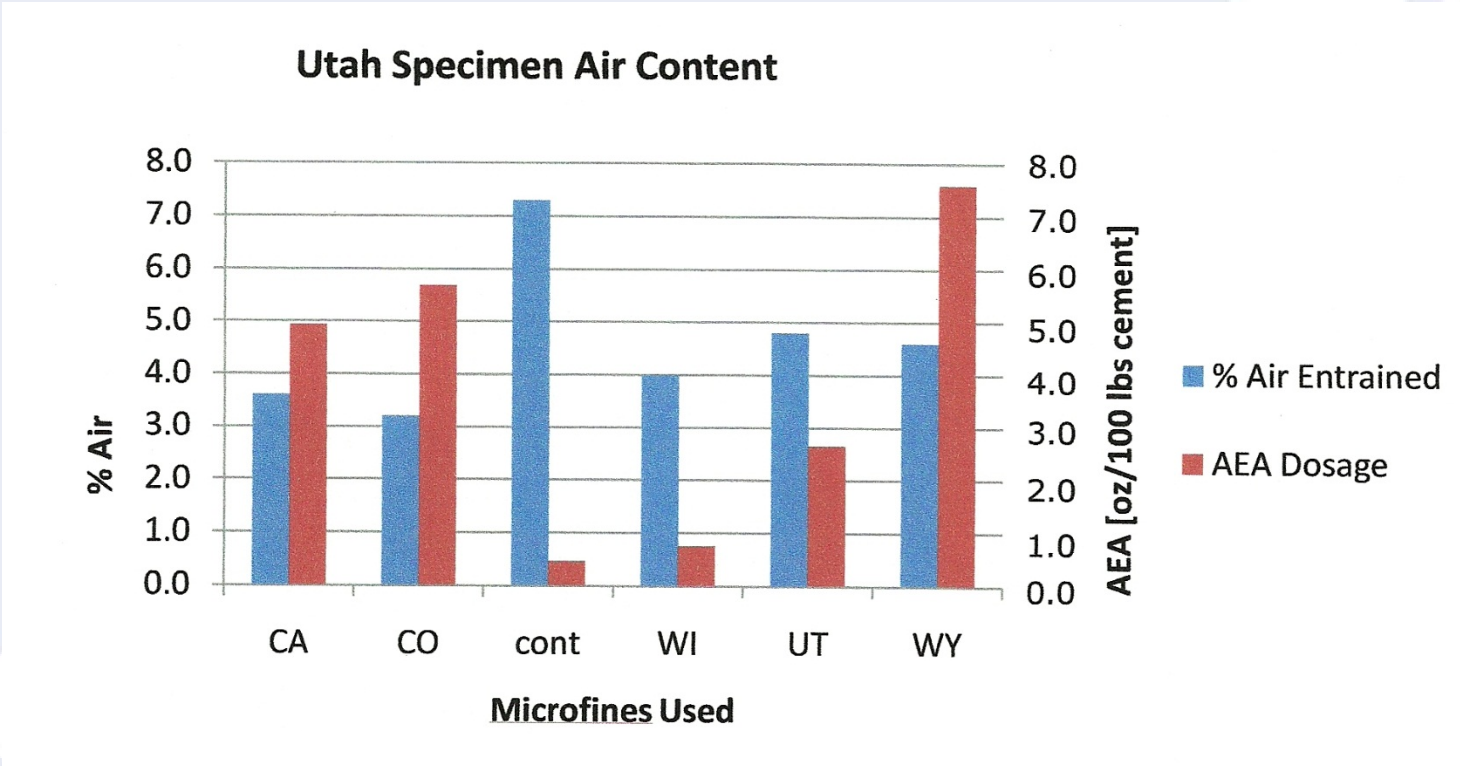


Figure 6. Air content and air entraining agent dosages for concrete batches using Wisconsin aggregate.

Entrained Air/Dosage per Microfine Used



ASTM C1293 Results

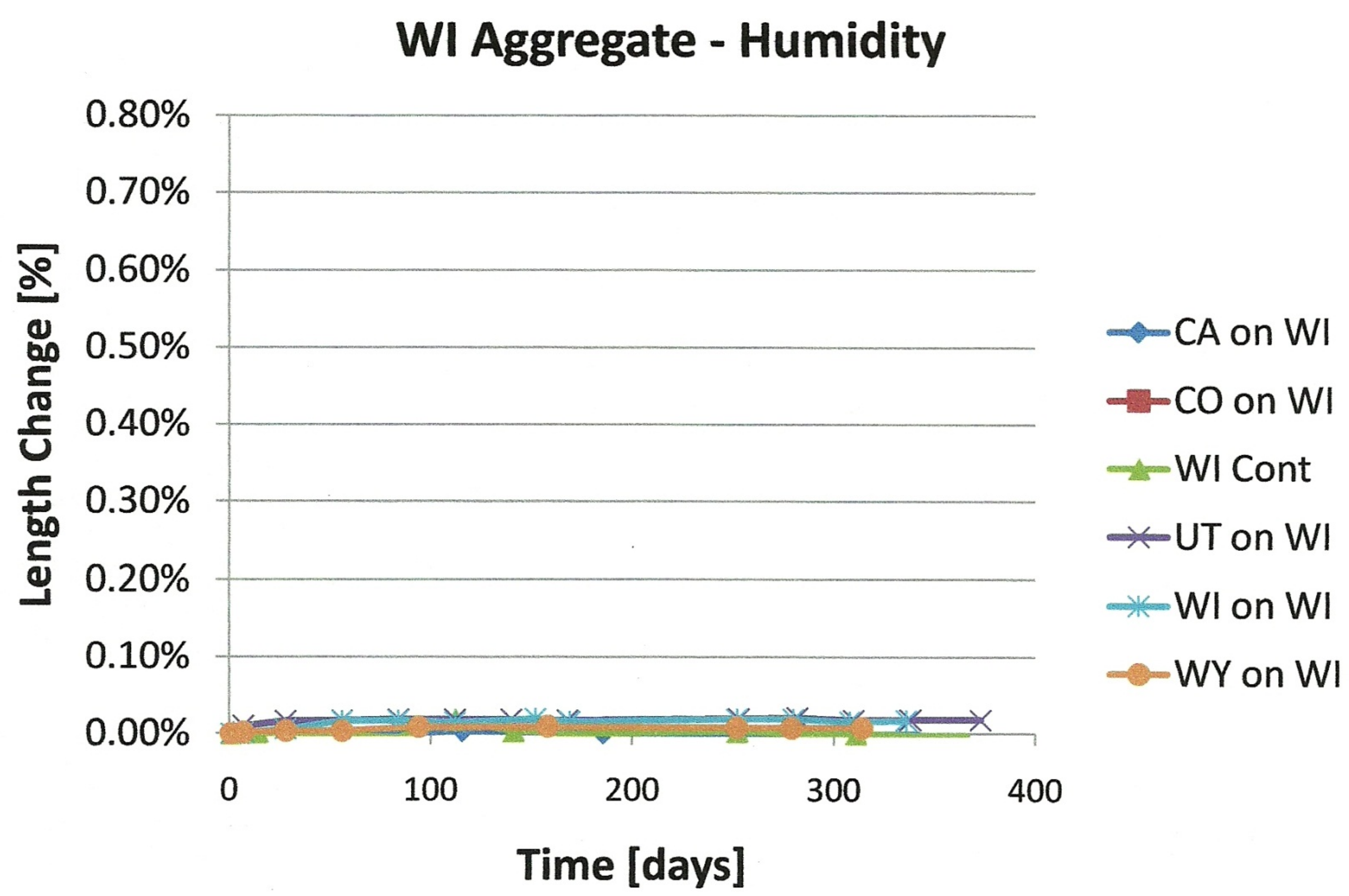


Figure 10. Length change for C1293 Humid specimens based on Wisconsin aggregate

ASTM C1293 Results

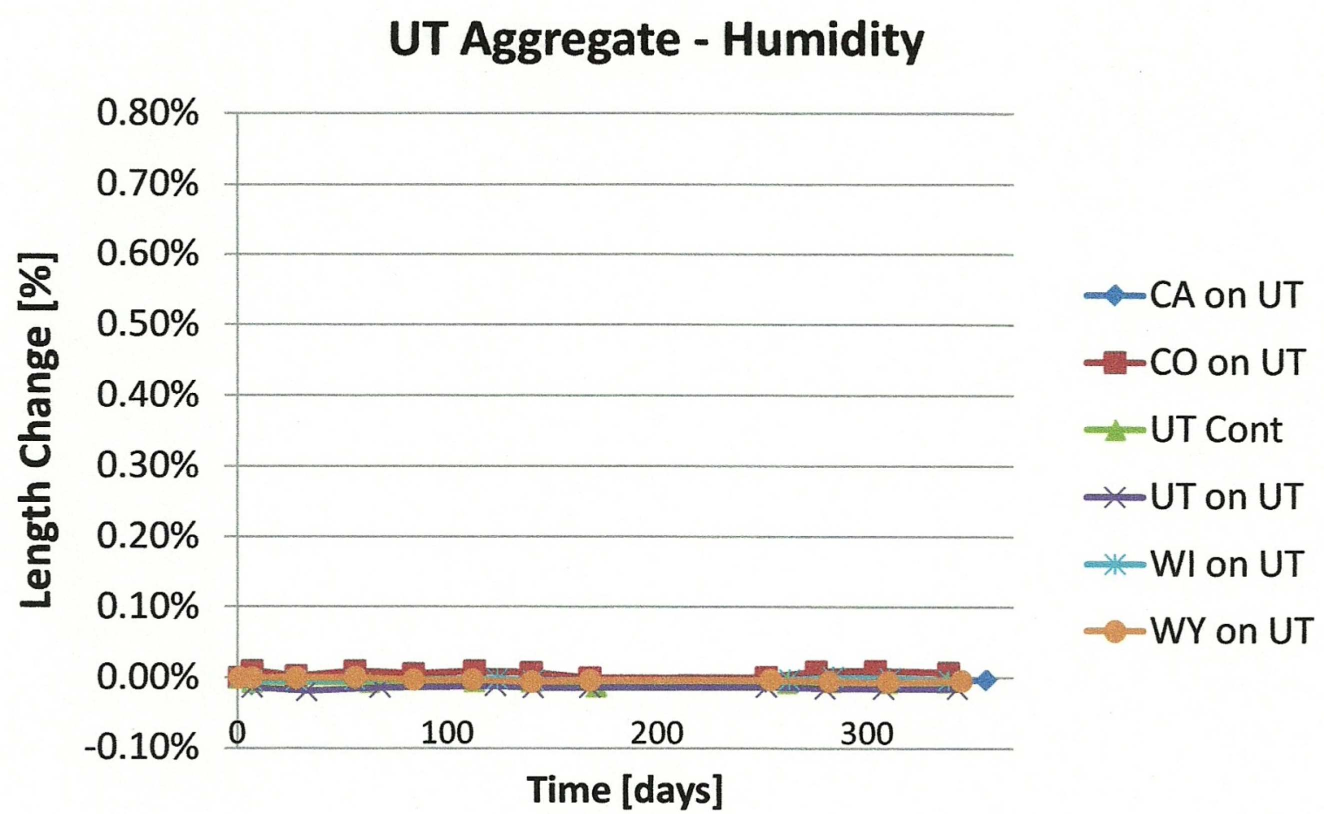


Figure 11. Length change for C1293 Humid specimens based on Utah aggregate

ASTM C1293 Results/with deicer

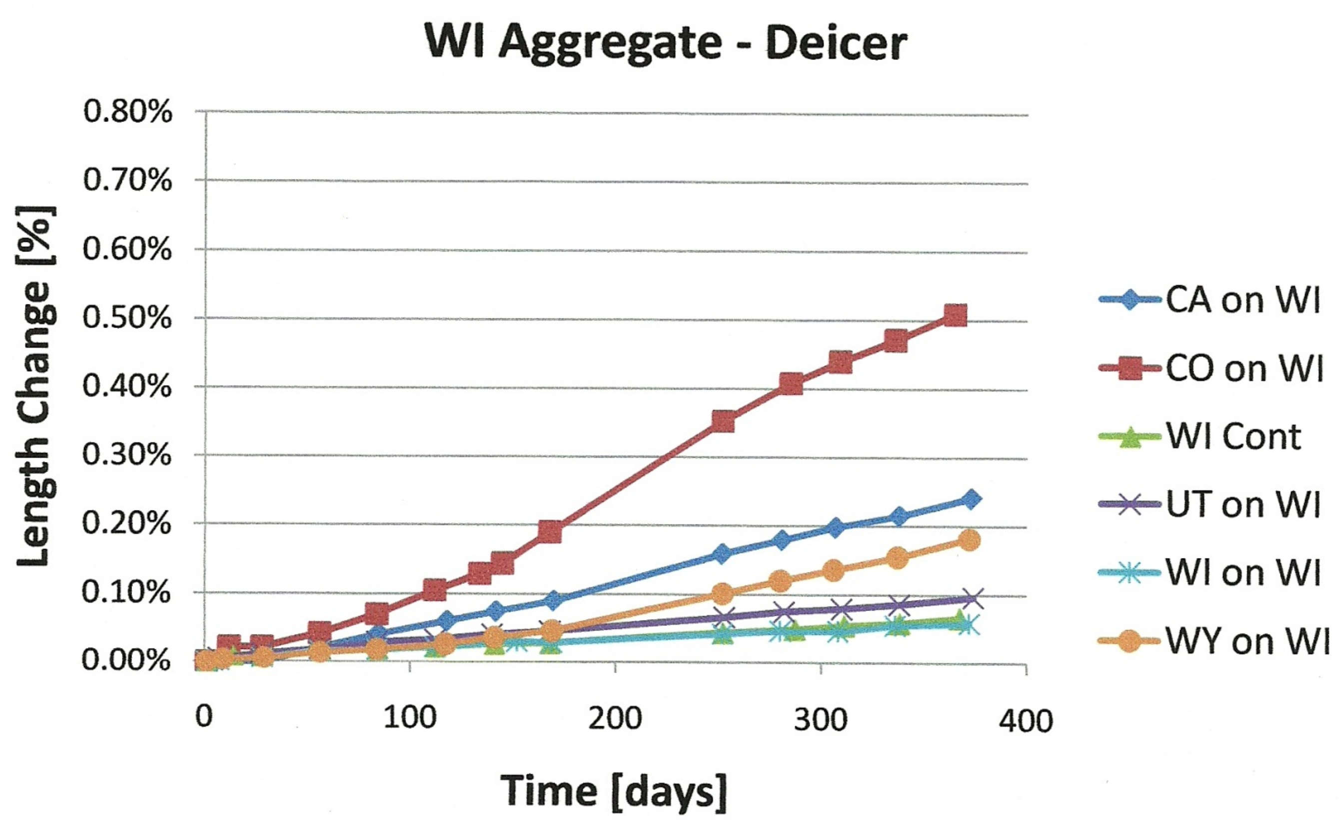


Figure 12. Length change for C1293-Deicer specimens based on Wisconsin aggregate

ASTM C1293 Results/with deicer

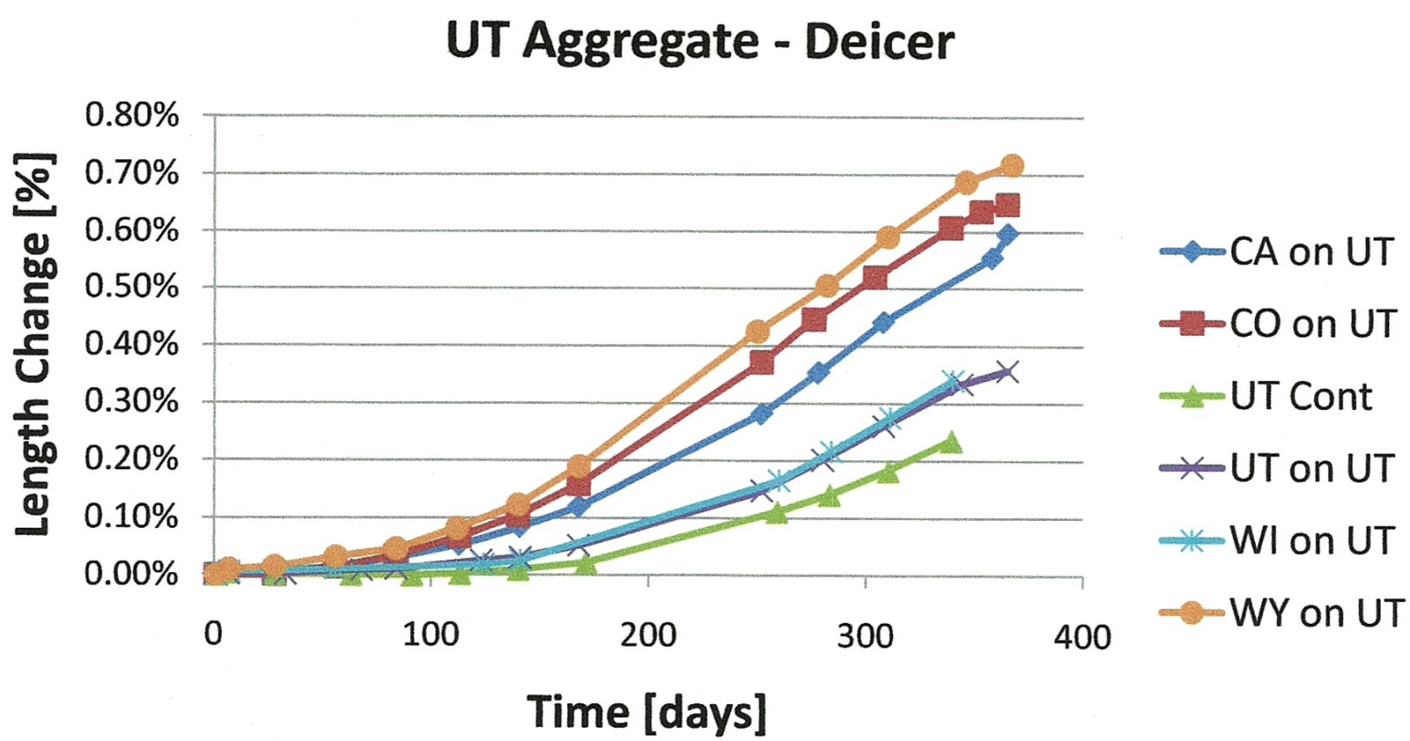


Figure 13. Length change for C1293-Deicer specimens based on Utah aggregate

ASTM C-1260 Results

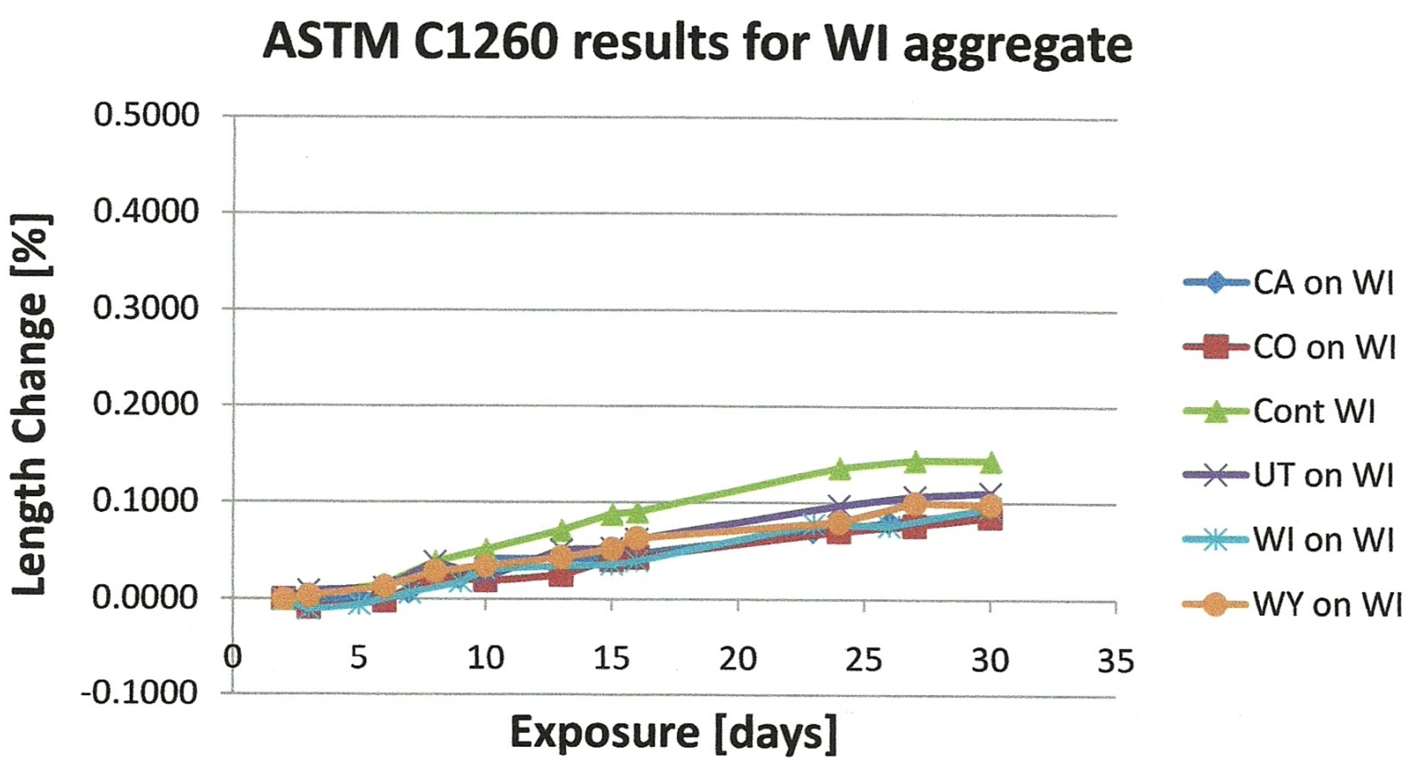


Figure 14. ASTM C1260 expansion for specimens containing Wisconsin fine aggregate different sources of microfines

ASTM C-1260 Results

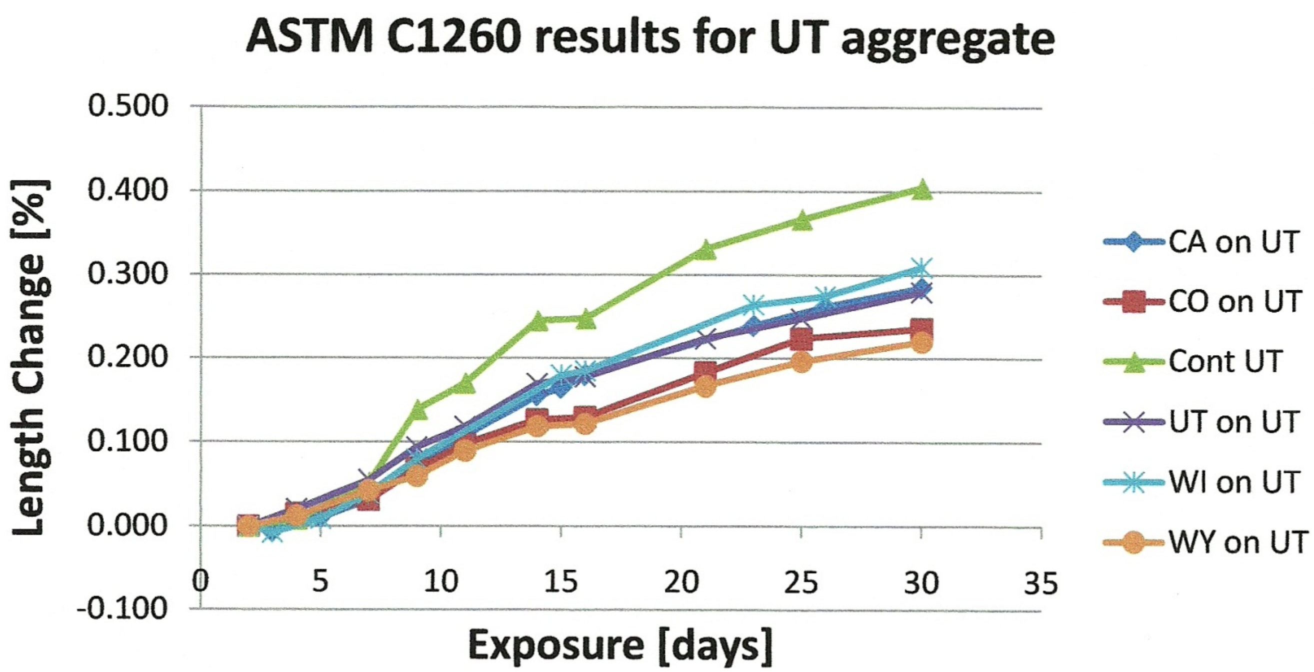


Figure 15. ASTM C1260 expansions for specimens containing Utah fine aggregate and different sources of microfines

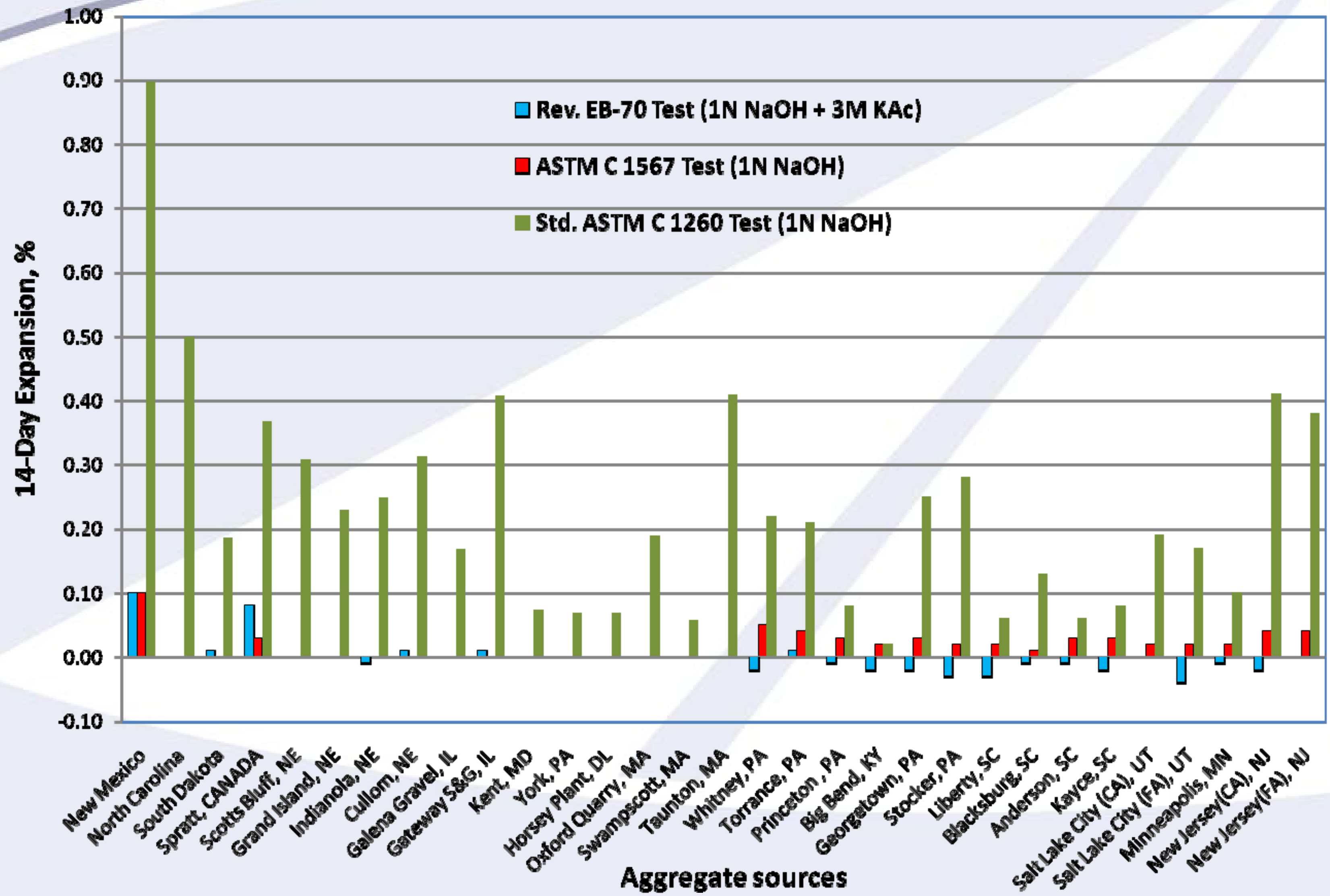
Findings of IPRF 06-5

- Microfines approaching 5% has significant impact of concrete mixing
- Slump reduction - prompt water addition
- Specific microfine interaction with AEA made it impossible to achieve freeze-thaw resistance
- Microfines produced negligible expansion under normal conditions
- Microfines produced significant expansion in the presences of deicer

Findings of IPRF 06-5

- Expansions were larger with known reactive base aggregates
- Microfines reaction with KAc combined with reduced F/T durability due to mineralogy affecting AEA increased distress.
- KAc transformed in concrete pore solution to form potassium sulfate and calcium-bearing KS compounds
- Transformation of silica species do not appear to be ASR – environment for expansion

Effectiveness of ASR Mitigation (Class F Fly Ash) in ASTM C 1567 and Rev. EB-70 Test Methods (25% Class Fly Ash; CaO Content = 1%)



Recommended Screening Protocol

- Meet ASTM C 666 for freeze thaw
- ASTM C 1260 on aggregates individually
- ASTM C 1567 – effects of mitigation
- If Airfield deicers are used …Might consider
- Modified ASTM C-1260 with 1N NaOH + 3M KAc
- Modified ASTM C-1567 with 1N NaOH + 3M KAc
  - Indicator of effectiveness of Class F ash
- FAA has canceled EB#70

THANK YOU!

Please contact Gary L. Mitchell with questions or comments:

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