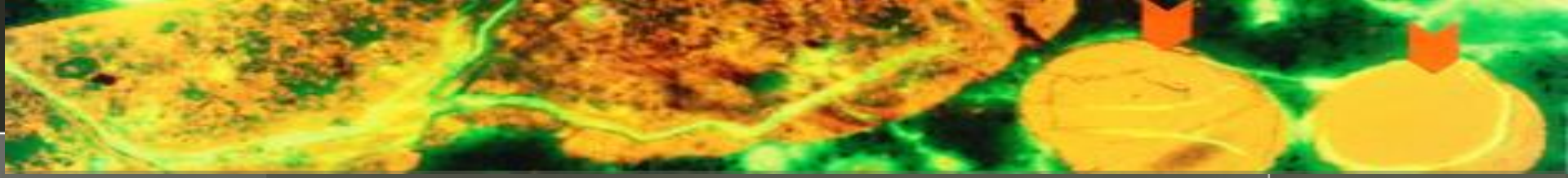

Considerations in Application of MCPT in Evaluating ASR Potential of Job Concrete Mixtures

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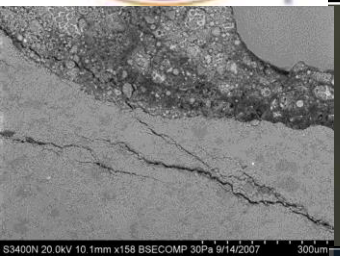


Advances in AAR Test Methods for Evaluation of Job Concrete Mixtures, Part I

aci Spring 2016 | Milwaukee

Acknowledgements

- Federal Highway Administration
- Portland Cement Association
- Lehigh Cement
- ARGOS Cement
- Aggregate Suppliers

Overview

- Brief Review of Existing Test Methods for ASR
- Review of Mini Concrete Prism Test (MCPT)
- Field Concrete Factors that affect ASR Testing
- Experimental Investigation To Evaluate Role of Specific Concrete Mixture Variables (Job Concrete) on Expansion due to ASR
- Conclusions

Existing AAR Test Methods in ASTM

ASR

- ASTM C 227 – Mortar Bar Test
- ASTM C 289 – Quick Chemical Test
- ASTM C 295 – Petrographic Examination
- ASTM C 1260 – Accelerated Mortar Bar Test (AMBT)
- ASTM C 1293 – Concrete Prism Test (CPT)

ACR

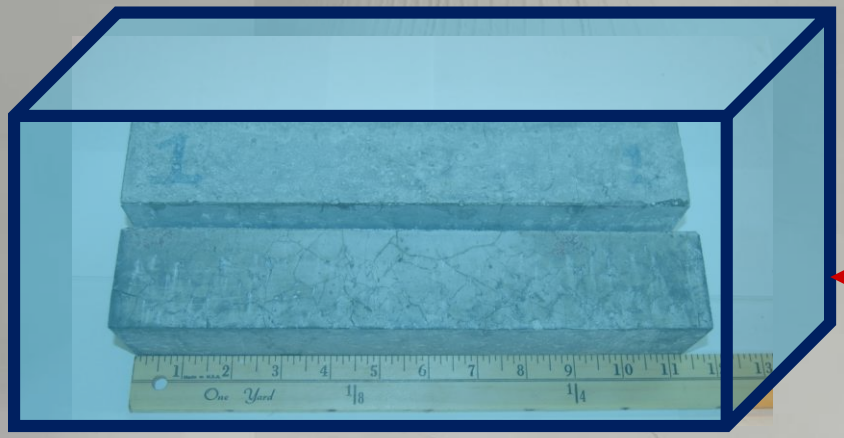
- ASTM C 295 – Petrographic Examination
- ASTM C 586 – Rock Cylinder Test
- ASTM C 1105 – Concrete Prism Test

Miniature Concrete Prism Test (AASHTO TP110)

- MCPT is developed based on modifications to CPT and AMBT methods. The improvements over the standard test methods are :
  - No significant aggregate crushing is involved
  - No alkali leaching
  - Short test duration
    - 56 days (8 Weeks) for majority of aggregates
    - 84 days (12 weeks) for slow reacting aggregates
  - Can detect both ASR and ACR
  - Can evaluate both aggregate reactivity and SCM effectiveness
  - Potential to evaluate job concrete mixtures

MCPT Method (AASHTO TP 110)

- Cement Content = 708 lb/yd^3 (420 kg/m^3)
- Cement Alkali Content = 0.9% ± 0.1% $Na_2O_{eq.}$
- Alkali Boost, (Total Alkali Content) = 1.25% $Na_2O_{eq.}$
- Water-to-cement ratio (fixed) = 0.45
- Coarse Agg. Dry-Rodded Vol. Frac. = 0.65 (MSA: ½ in.)
- Storage Environment* (Soak) = 1N NaOH Solution
- Storage Temperature = 60^{0}C
- Specimen Size = 2 in. x 2 in. x 11.75 in.



1 N NaOH @ 60ºC

MCPT Measurements

- 1st Day = Water bath at 60 ^{0}C
- Subsequent Storage = 1N NaOH @ 60^{0}C
- Length Change Measurement = 1, 3, 7, 10, 14, 21, 28, 42, 56, 70, 84 days

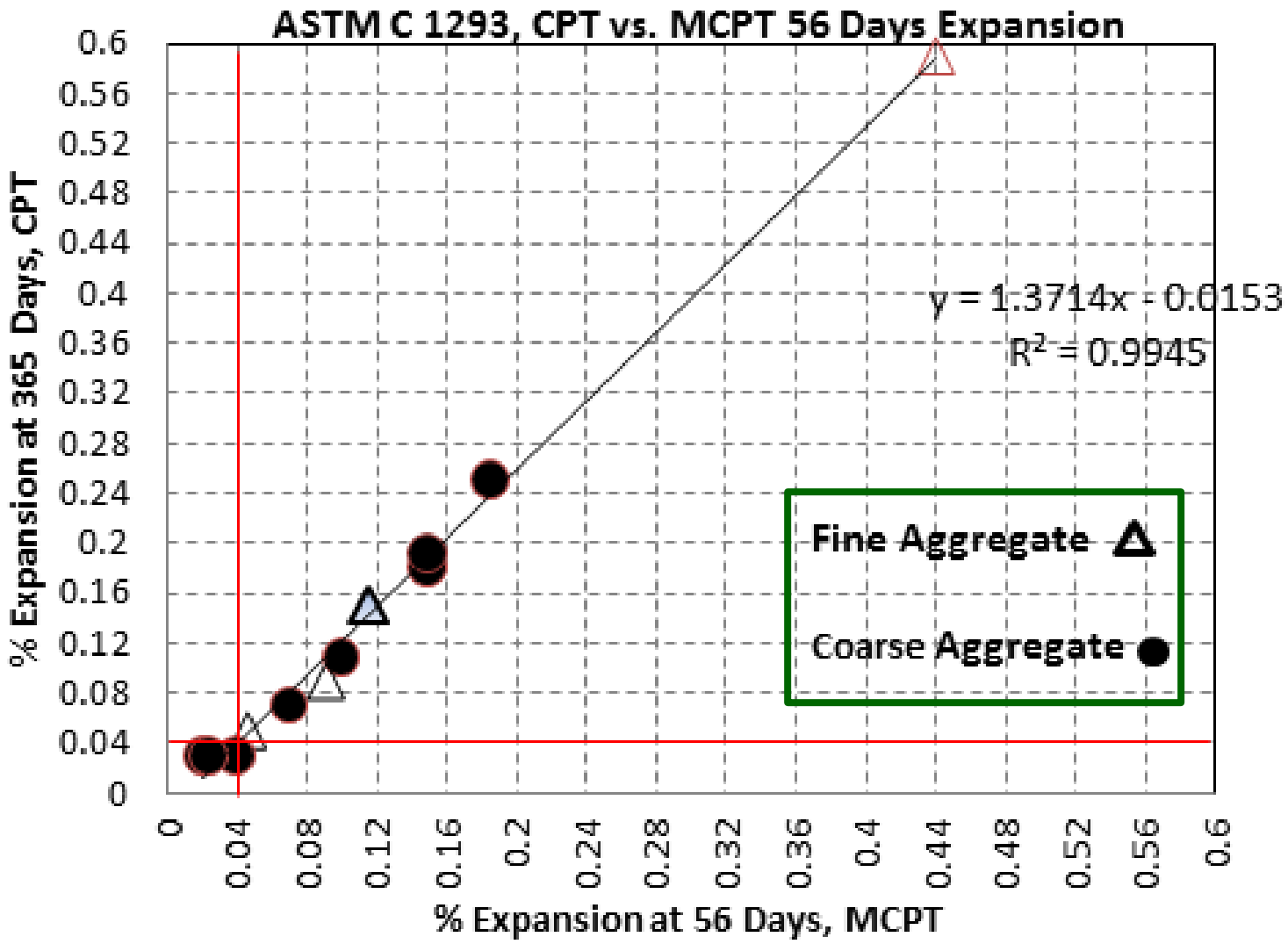
- Non-reactive sand is used with reactive coarse agg, and vice-versa.

MCPT Specimen Size

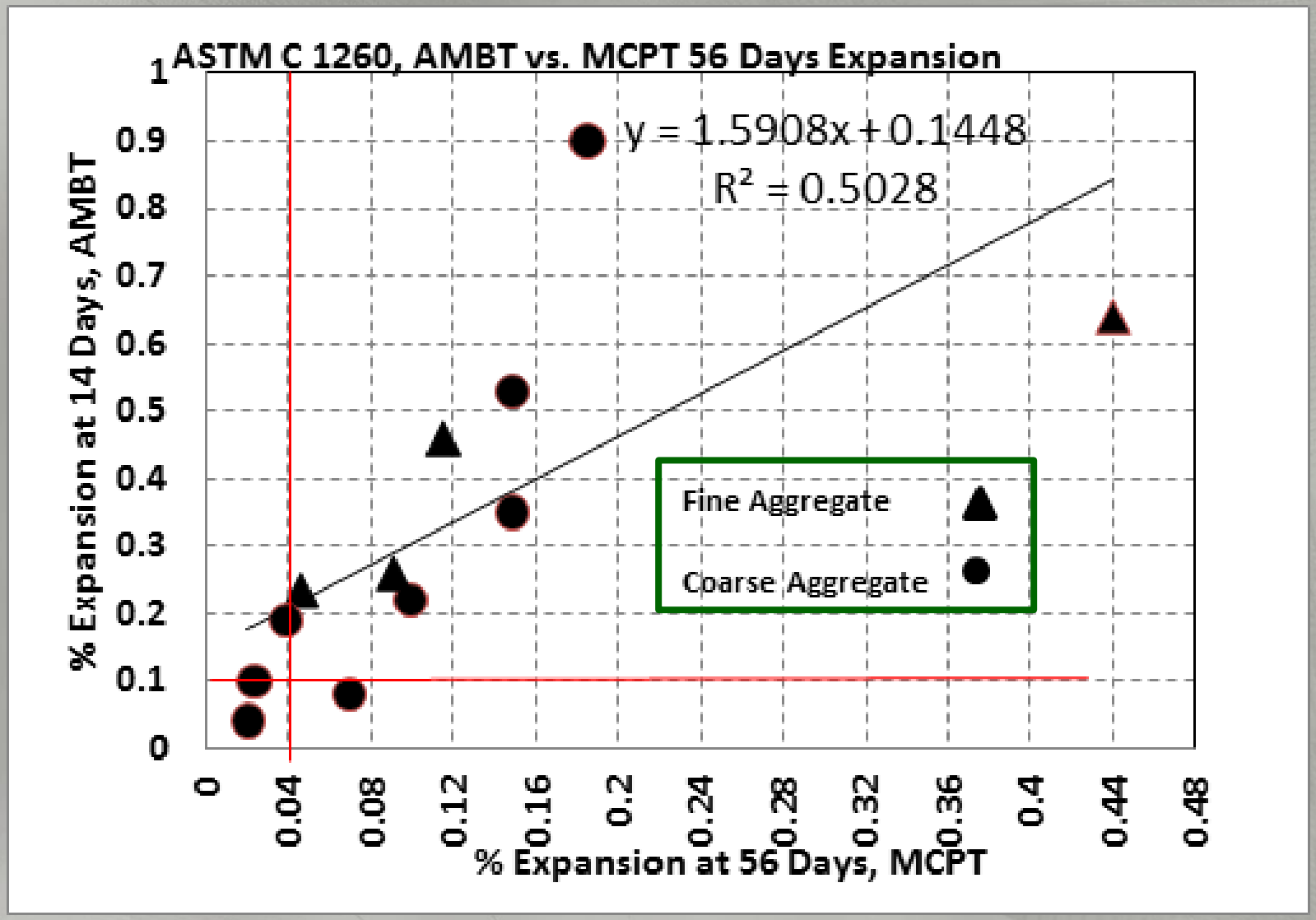
MCPT Validation

- Evaluated 33 aggregates with known field performance
- Limited set of 12 aggregates were tested in MCPT, CPT and AMBT for correlations
- Evaluated 20 different SCMs (fly ash, slag, meta-kaolin, silica fume)

MCPT-56 day *versus* CPT – 365 day



MCPT-56 day *versus* AMBT – 14 day



Expansion Criteria for Classifying Aggregate Reactivity (Latifee and Rangaraju, 2015)

Degree of Reactivity	% Expansion at 56 Days (8 Weeks)	Average Two-Week Rate of Expansion from 8 to 12 weeks
Non-reactive	≤ 0.030 %	N/A*
Non-reactive	0.031% - 0.040%	≤ 0.010% per two weeks
Low/Slow Reactive	0.031% – 0.040%	> 0.010% per two weeks
Moderate Reactive	0.041% – 0.120%	N/A*
High Reactive	0.121% - 0.240%	N/A*
Very Highly Reactive	> 0.240%	N/A*

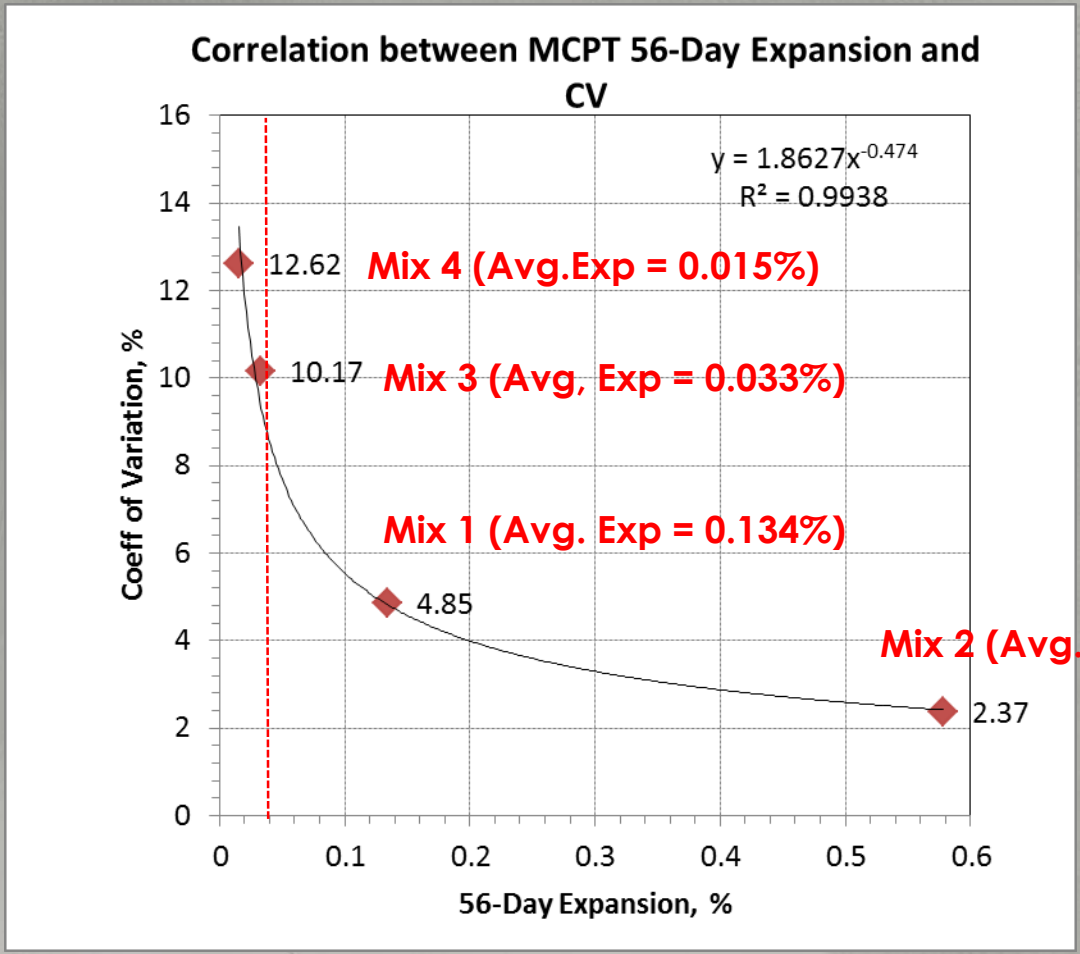
* N/A – Not Applicable

Expansion Criteria for characterizing effectiveness of ASR Mitigation measures (MCPT)

Efficiency of Mitigation	**% Expansion at 56 Days (8 Weeks)**
Effective	$\leq 0.020\%$
*Uncertain**	$0.021\% - 0.025\%$
Not effective	$\geq 0.026\%$

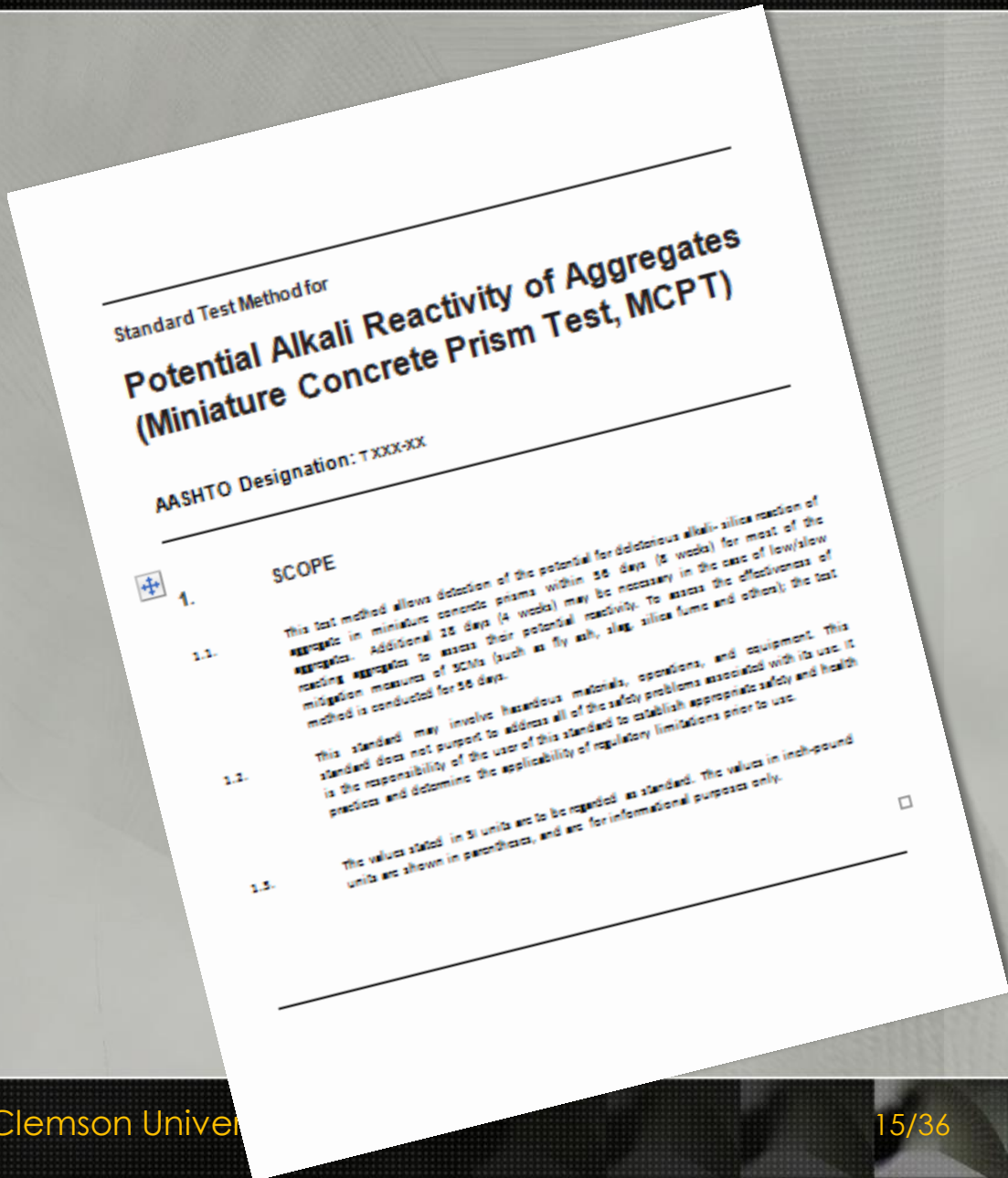
* - Recommend retest with MCPT using a higher dosage of mitigation

Multi-lab Testing of MCPT
Correlation between 56-Day % Exp. and COV



MCPT - AASHTO TP 110

- AASHTO has approved this method as a provisional standard AASHTO TP 110



Standard Test Method for

Potential Alkali Reactivity of Aggregates (Miniature Concrete Prism Test, MCPT)

AASHTO Designation: TXXX-XX

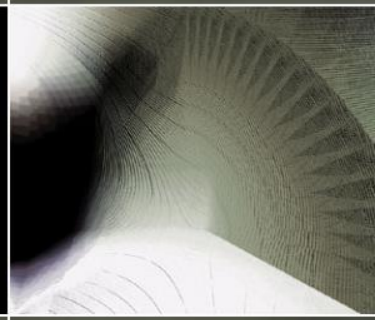
1. SCOPE

1.1. This test method allows detection of the potential for deleterious alkali-silica reaction of aggregate in miniature concrete prisms within 56 days (8 weeks) for most of the aggregates. Additional 28 days (4 weeks) may be necessary in the case of low/slow reacting aggregates to assess their potential reactivity. To assess the effectiveness of mitigation measures of SCMs (such as fly ash, slag, silica fume and others); the test method is conducted for 56 days.

1.2. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.3. The values stated in SI units are to be regarded as standard. The values in inch-pound units are shown in parentheses, and are for informational purposes only.

MCPT for Evaluating ASR Potential of Job Mixtures



Influence of Job mix parameters on ASR expansion

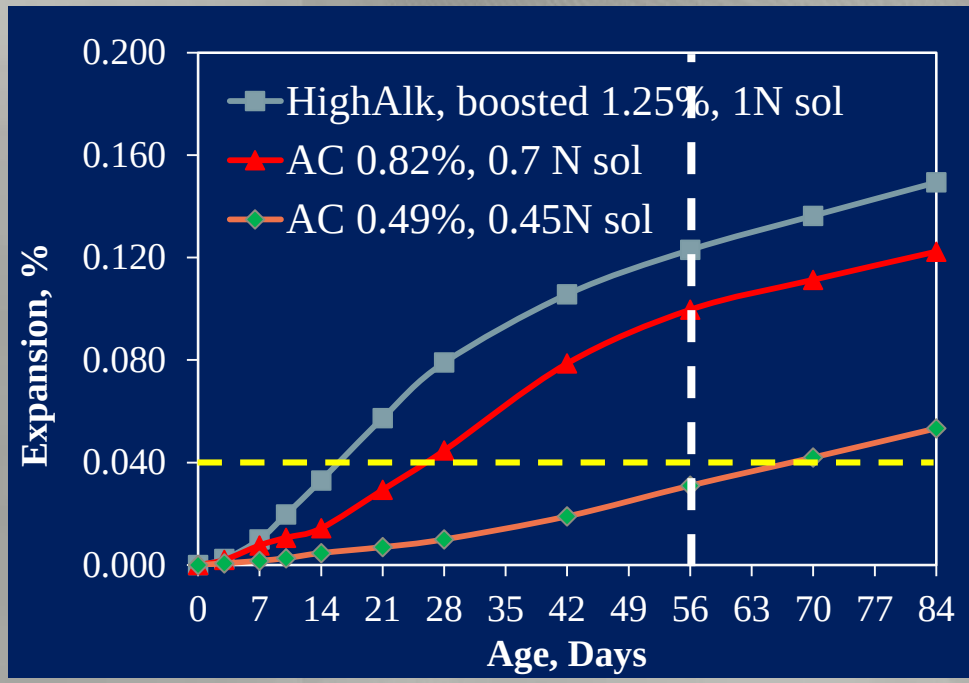
- Typical job mix parameters that differ from the standard MCPT method were considered.

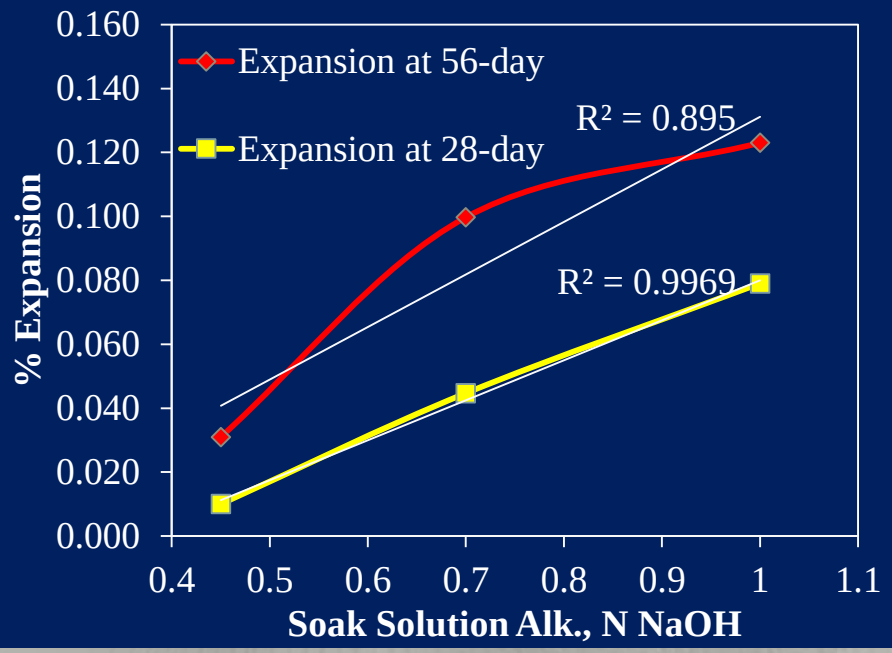
- Univariate analysis:
  - Influence of w/c (0.40 – 0.50)
  - Influence of total cement content (600 -800 lb/yd^3)
  - Influence of total alkali loading in concrete (2.9 – 10lb/yd^3)
  - Influence of dosage of SCM (15% - 35% Class F fly ash)
  - Influence of vol. fraction of CA content in concrete (0.65 – 0.75)

- Influence of pore solution alkalinity

Effect of pore solution on the % expansion in the MPCT

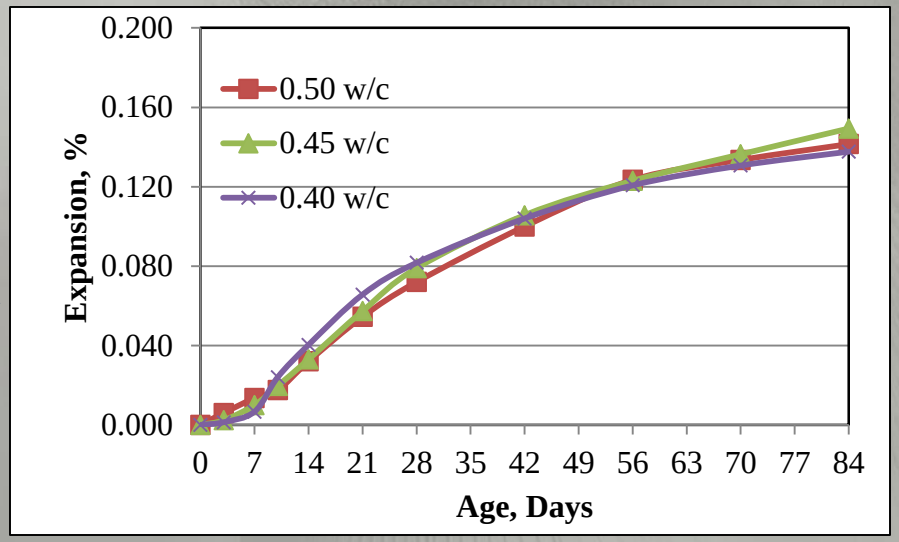
- SHRP C-342 (Helmuth et.al. 1993) proposed the following:
- [OH-] = 0.339 Na_2O % / (w/c) + 0.022 +/- 0.06 mol/L



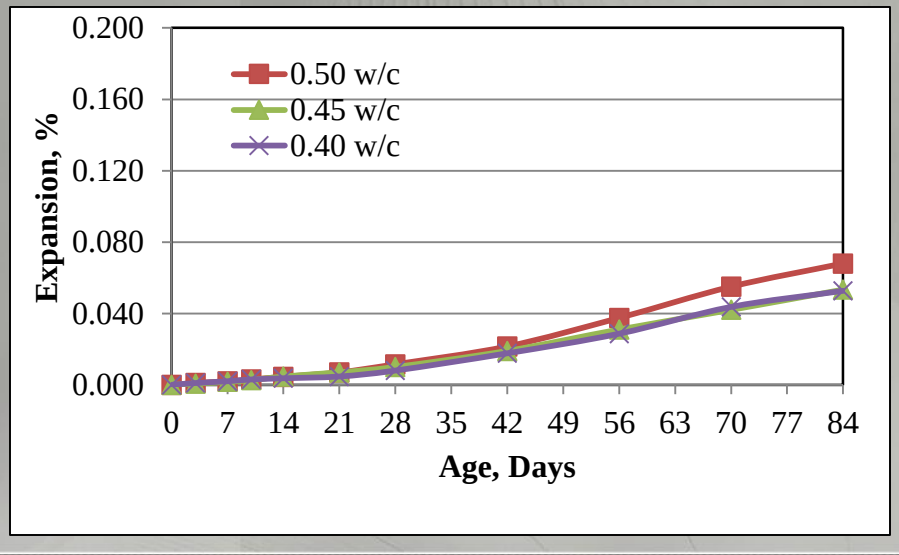


Effect of w/c ratio on the expansion of test specimens with high- and low-alkali cement

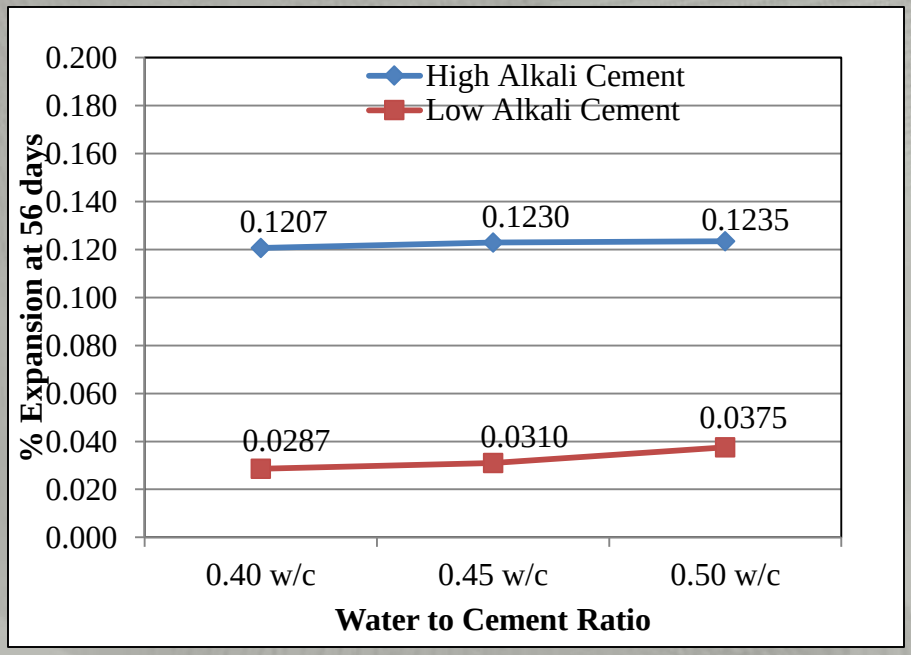
HA



LA

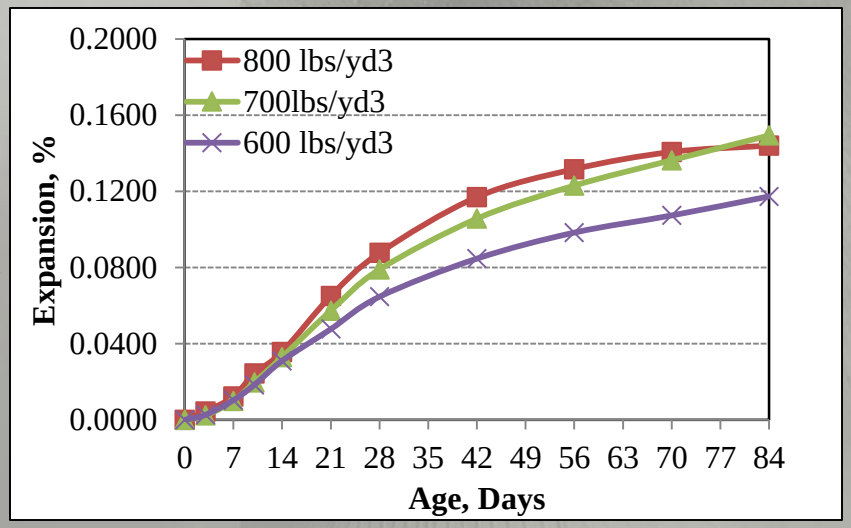


Cement Content = 708 lb/yd^3



Effect of cement content on expansion in MCPT with High and Low Alkali Cement

HA



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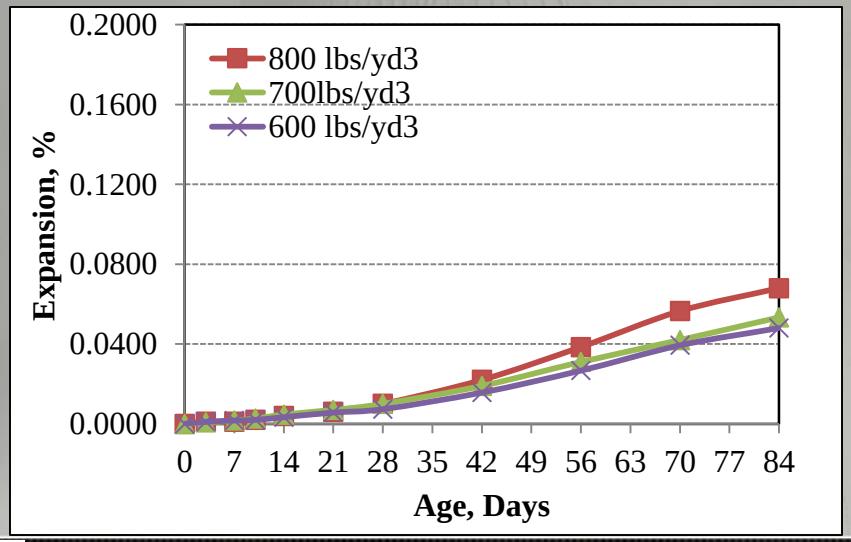
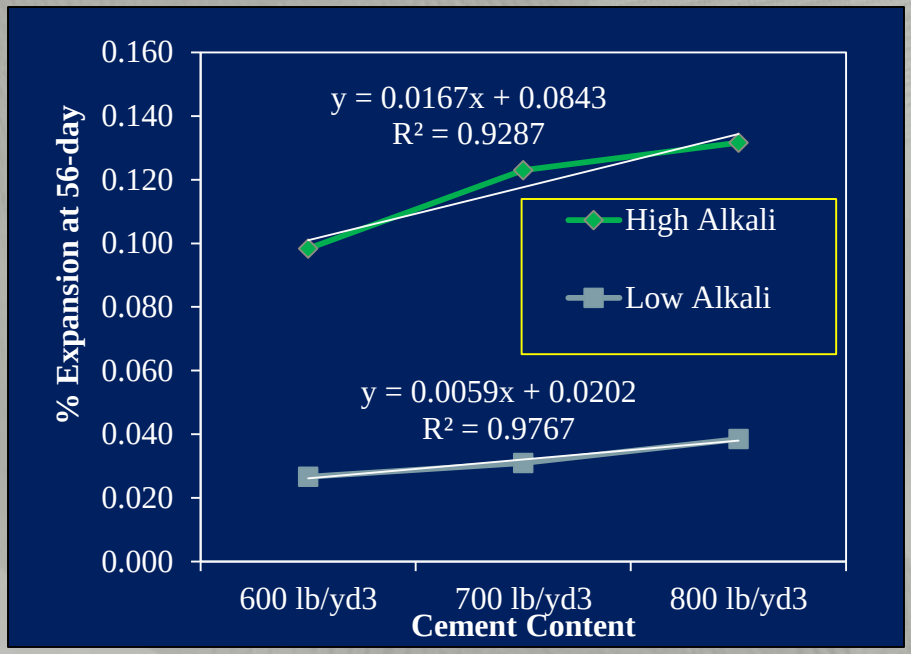


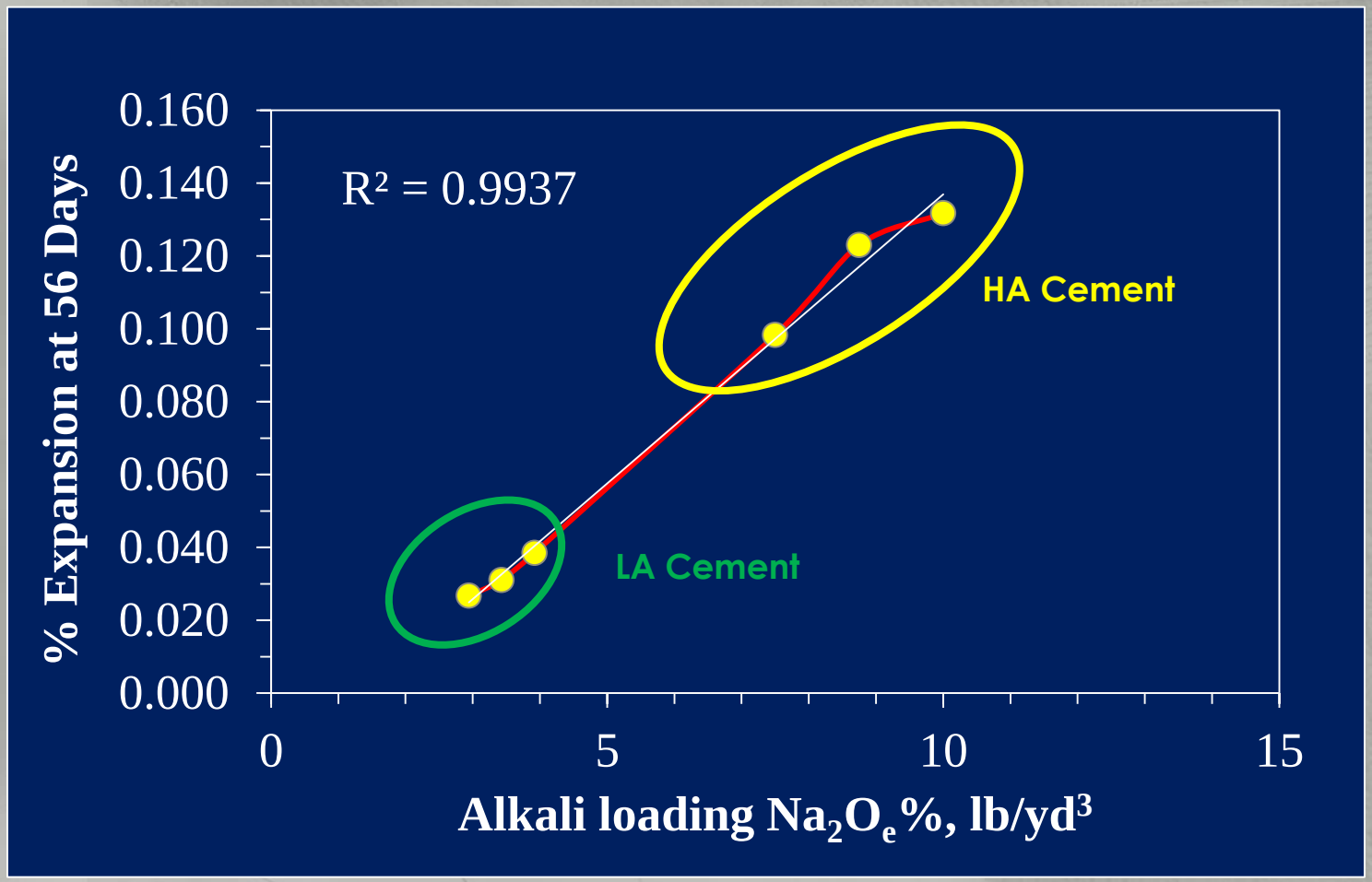
w/c =0.45



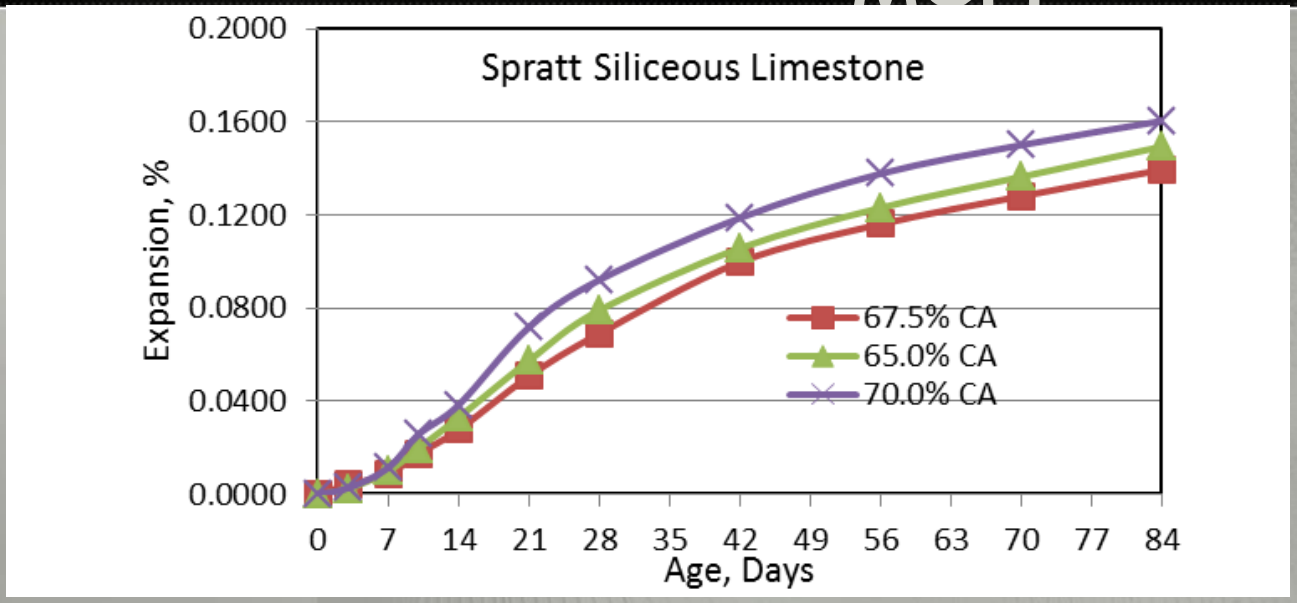
Effect of total alkali loading in concrete on MCPT expansion

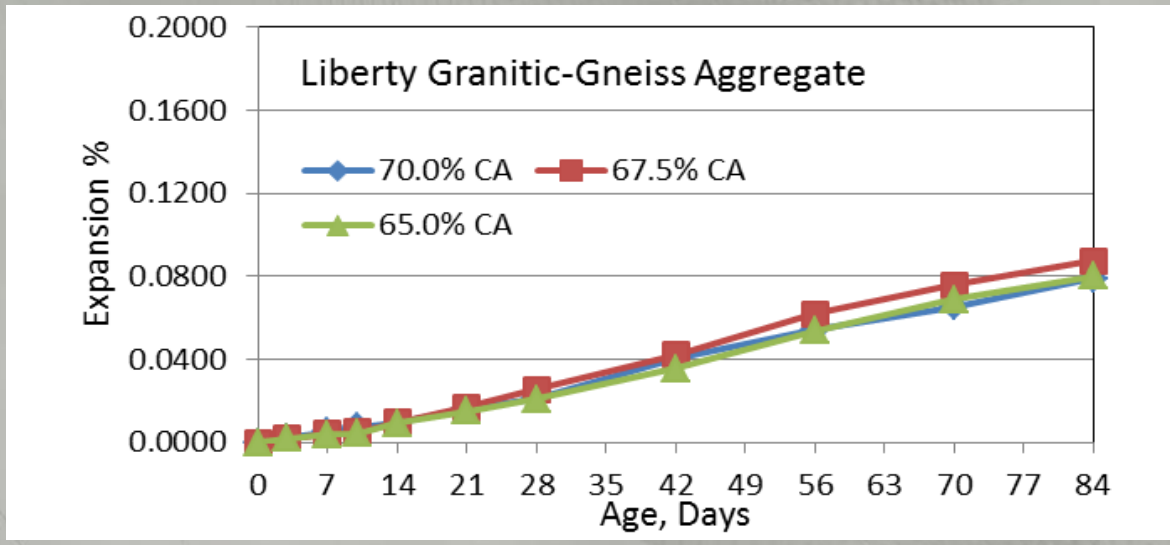
Cement Content, lb/yd^3	Total Alkali Loading (lb/yd^3)	56-Day Expansion (%)
600 ($Na_2O_{eq.}$ = 0.49%)	2.94	0.027
700 ($Na_2O_{eq.}$ = 0.49%)	3.43	0.031
800 ($Na_2O_{eq.}$ = 0.49%)	3.92	0.039
600 ($Na_2O_{eq.}$ = 1.25%)	7.5	0.098
700 ($Na_2O_{eq.}$ = 1.25%)	8.75	0.123
800 ($Na_2O_{eq.}$ = 1.25%)	10	0.132

Effect of Alkali Loading in Concrete on Expansion in MCPT

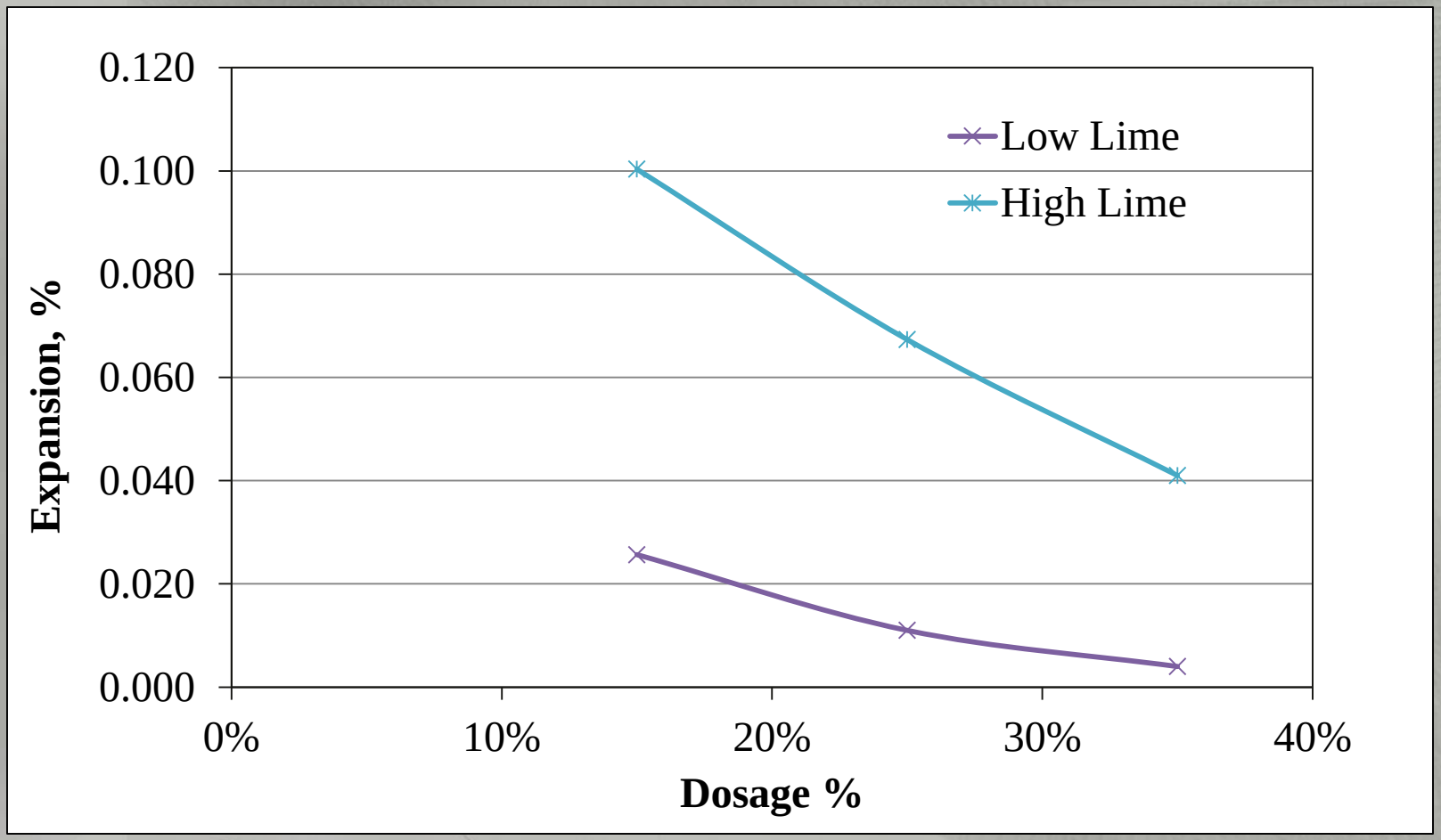


Effect of Vol.Fraction of CA on Expansion in MCPT





Effect of Fly Ash Dosage on Expansion in MCPT



Evaluating Job Mixture ASR Potential

- (a) Standard MCPT tests
  - Control Test - 100% Cement (Std. Test Proportions)
  - Mitigation Test – SCM Dosage (Std. Test Proportions)
- (b) Job MCPT test
  - Control Test – 100 % Cement (per job mix proportions)
  - Mitigation Test – SCM Dosage (per job mix proportions)

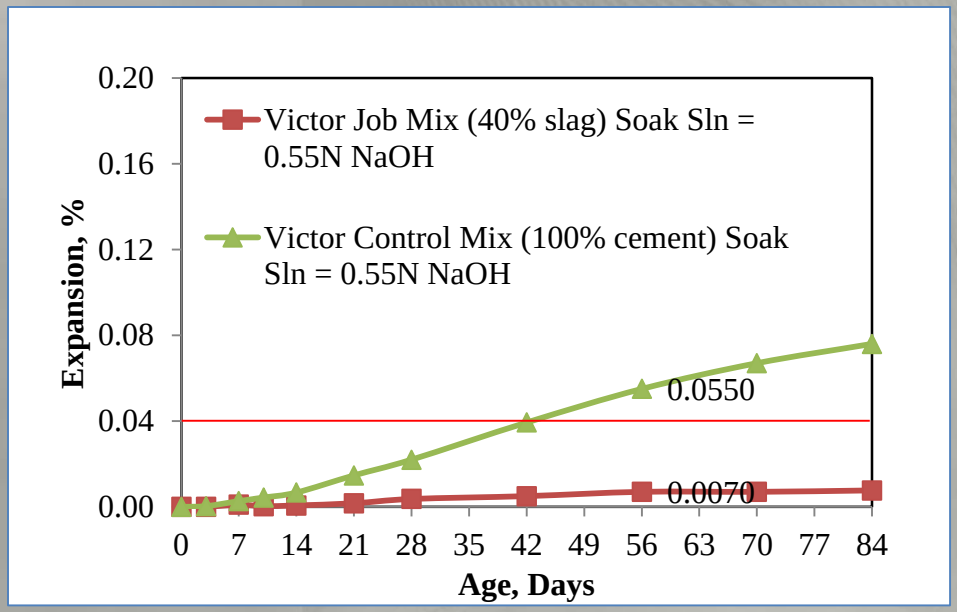
ASR Performance Index of Concrete (PI)

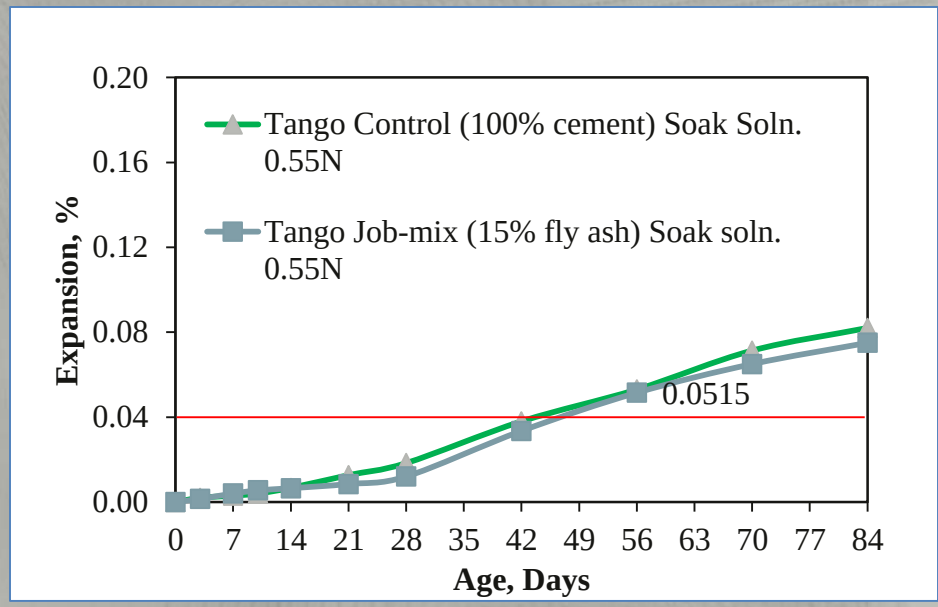
- **ASR Performance Index (PI) can be defined as follows:**

$$PI = [(Ec - Ej) \times 100\%] / Ec$$

  - **Ec = 56-day MCPT expansion of control MCPT mixture**
  - **Ej = 56-day MCPT expansion of mitigated MCPT mixture**

Job mix and Job control mix expansion curves





Pi_{job} = 87%

Pi_{job} = 1%

ASR Performance Index of Concrete (PI)

- $PI_{standard} = [(E_{sc} - E_{sm}) \times 100\%] / E_{sc}$
- $PI_{Job} = [(E_{jc} - E_{jm}) \times 100\%] / E_{jc}$
- **Example Specification Could be:**

  $PI_{Job} > 0.90 \times PI_{standard}$

Conclusions

- The proposed MCPT method overcomes many of the deficiencies of existing standard ASR test methods
- MCPT Method shows potential to be a reliable and a rapid test method to evaluate wide range of aggregates and ASR mitigation measures and provides a result comparable to ASTM C 1293 test in a much shorter duration of only 8 to 12 weeks.
- Among the mixture proportion variables considered, the alkali loading in concrete and SCM dosage level appear to be the dominant factors affecting the ASR expansion.
- Preliminary testing to evaluate job mixtures using MCPT appears to be promising, and the performance index (PI) may provide a quantifiable way to assess ASR potential of job mix.

Questions?

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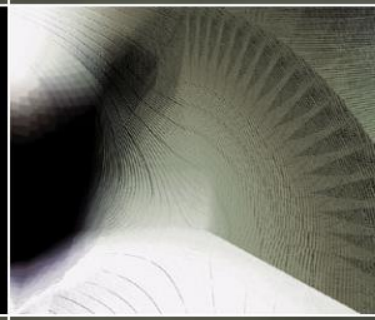

Key Questions for MCPT

- Why 56 days?
- Why 60°C storage temperature?
- Why 1N NaOH Soak Solution?
- Why a dry-rodded aggregate volume fraction of 0.65 in the concrete?