Integrating MCPT-Based ASR Testing into Performance-Based Specification of Concrete Mixtures

Research Need

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Background

- Typically majority of the specs to influence durability have either been prescriptive or recipe-specified performance tests (Ex: ASTM C1260/C1567/ C1293)
  - Prescriptive Ex: Cement content, w/c ratio, alkali content, etc.
  - Performance Ex: ASTM C1260/ASTM C1293/ASTM C441

- Performance-based specifications on job concrete mixtures are gaining importance as we design and construct infrastructure with longer service lives.

- Typical performance-based specs that are based on JOB CONCRETE MIX for concrete infrastructure include:
  - Workability/Unit Weight/Setting Time/Heat of Hydration
  - Compressive strength/Flexural strength
  - RCPT
  - ASR ??

AASHTO PP65

- **Performance/Prescriptive Based Approach to deal with ASR/ACR in Concrete:**
  - **Step 1 – Determine Agg. Reactivity Class**
  - **Step 2 – Determine Level of ASR Risk**
  - **Step 3 – Determine Level of Prevention**
  - **Step 4 – Identification of Preventive Measures**

AASHTO PP65 Procedure

Table 1. Classification of aggregate reactivity.

Aggregate-Reactivity Class	Description of Aggregate Reactivity	One-Year Expansion in CPT (%)	14-Day Expansion in AMBT (%)
R0	Non-reactive	≤ 0.04	≤ 0.10
R1	Moderately reactive	$> 0.04, \leq 0.12$	$> 0.10, \leq 0.30$
R2	Highly reactive	$> 0.12, \leq 0.24$	$> 0.30, \leq 0.45$
R3	Very highly reactive	> 0.24	> 0.45

Table 2. Determining the level of ASR risk.

	Aggregate-Reactivity Class			
Size and exposure conditions	**R0**	**R1**	**R2**	**R3**
Non-massive[2] concrete in a dry[3] environment	Level 1	Level 1	Level 2	Level 3
Massive[2] elements in a dry[3] environment	Level 1	Level 2	Level 3	Level 4
All concrete exposed to humid air, buried or immersed	Level 1	Level 3	Level 4	Level 5
All concrete exposed to alkalis in service[4]	Level 1	Level 4	Level 5	Level 6

AASHTO PP65 Procedure

Table 3. Determining the level of prevention.

	Classification of Structure (Table 4)			
Level of ASR Risk (Table 2)	S1	S2	S3	S4
Risk Level 1	V	V	V	V
Risk Level 2	V	V	W	X
Risk Level 3	V	W	X	Y
Risk Level 4	W	X	Y	Z
Risk Level 5	X	Y	Z	ZZ
Risk Level 6	Y	Z	ZZ	††

Table 5. Maximum alkali contents in portland cement concrete to provide various levels of prevention.

Prevention Level	Maximum Alkali Content of Concrete (Na_2Oe)	
	lb/yd^3	kg/m^3
V	No limit	
W	5.0	3.0
X	4.0	2.4
Y	3.0	1.8
Z[8]	Table 8	
ZZ[8]		

AASHTO PP65

Option 2 – using supplementary cementing materials, SCM[9] (Table 6)

Table 6. Minimum levels of SCM to provide various levels of prevention.

Type of SCM[10]	Alkali level of SCM (% Na_2Oe)	Minimum Replacement Level[11] (% by mass of cementitious material)				
		Level W	Level X	Level Y	Level Z	Level ZZ
Fly ash ($CaO \leq 18\%$)	≤ 3.0	15	20	25	35	Table 7
	> 3.0, ≤ 4.5	20	25	30	40	
Slag	≤ 1.0	25	35	50	65	
Silica Fume[12] ($SiO_2 \geq 85\%$)	≤ 1.0	1.2 x LBA or 2.0 x KGA	1.5 x LBA or 2.5 x KGA	1.8 x LBA or 3.0 x KGA	2.4 x LBA or 4.0 x KGA	

AASHTO PP65 - Aggregate Reactivity

In AASHTO PP65, the reactivity of aggregates is classified on the basis of either the 1-year expansion in the concrete prism test (ASTM C 1293) or the 14-day expansion in the accelerated mortar bar test (AASHTO T 303, ASTM C 1260) (see Table 1). The guidelines published by the Federal Highway Administration, report FHWA-HIF-09-001 (Thomas et al. 2008), which was the precursor to PP65, recommended that only the concrete prism test be used to classify the reactivity of aggregates, as it was generally considered that the accelerated test was too aggressive and insensitive to differences in aggregate reactivity. This was in agreement with the 2004 edition of CSA A23.2-27A.

AMBT vs. CPT

Agg. ID	Source	[1]AMBT at 14 days (%)	[2]CPT	
			1 year at 38°C (%)	60 days at 60°C (%)
Coarse Aggregates				
1	Halfway Bridge, Kauai	-	-	-
2	Ameron, Oahu	0.084	-0.003	-0.013
3	Hilo	0.633		
4	Halawa, Oahu	0.627	0.003	0.007
5	Halawa – Grade B	0.221	0.016	-
6	Waimea	0.015	-	-
7	Waikoloa (2011)		-	-
8	Waikoloa (2013)	-	-	-
Fine Aggregates				
9	Halfway Bridge, Kauai	-	0.018	
10	Ameron, Oahu	0.076	0.004	-0.001
11	Hilo	0.718	0.029	
12	Halawa, Oahu	0.526	0.019	0.230*
13	Waimea	0.007		
14	Waikoloa (2011)	0.522	0.287	
15	Orca (British Columbia)	0.222	0.003	0.001
16	Maui Dune Sand	0.015	0.011	0.014

[1]AMBT = Accelerated Mortar-Bar Test, ASTM C1260 or AASHTO T303

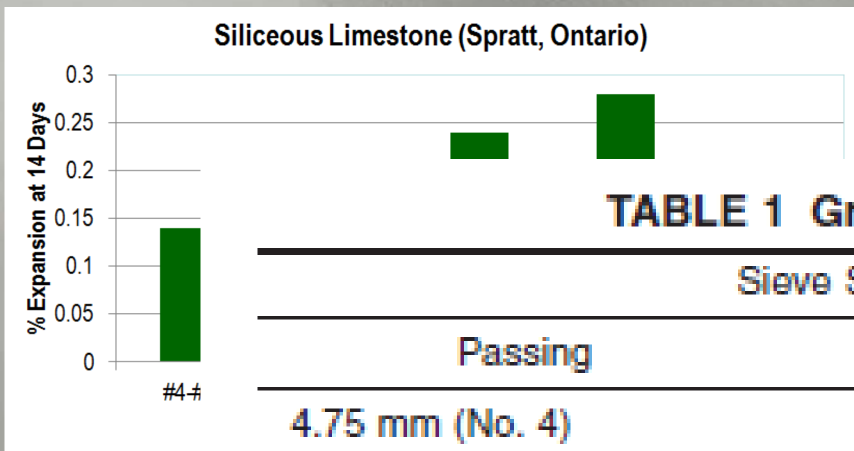
[2]CPT = Concrete Prism Test, ASTM C1293

*Expansion value at 6 months

Thomas et al. "Methods for Preventing ASR in New Construction: Results of Field Exposure Sites", FHWA-HIF-14-004, Dec. 2013.

Figure 1. Completed Exposure Site at the University of Hawaii at Manoa, Hawaii (January 2013)

Influence of Aggregate Size on Expansion in ASTM C1260



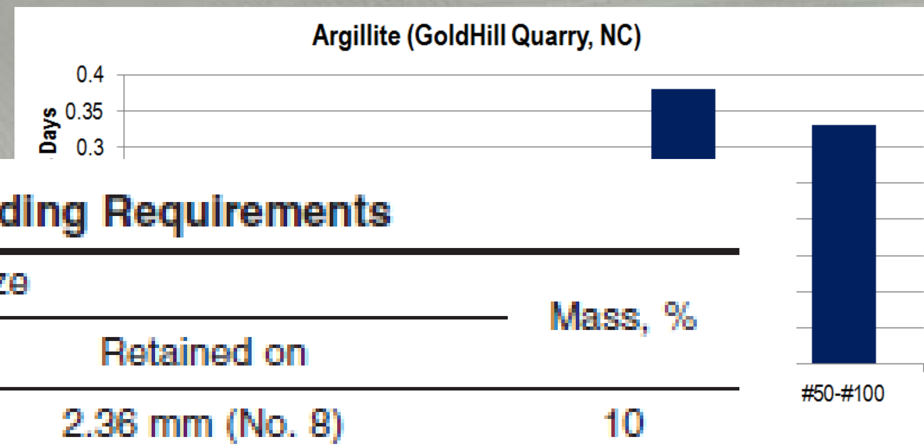
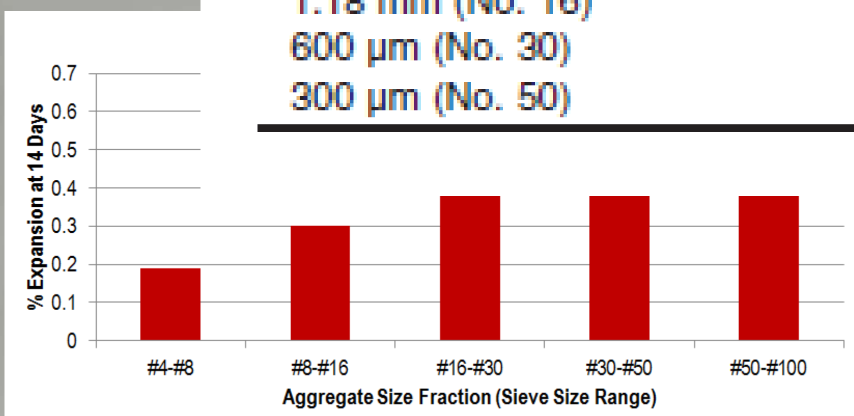
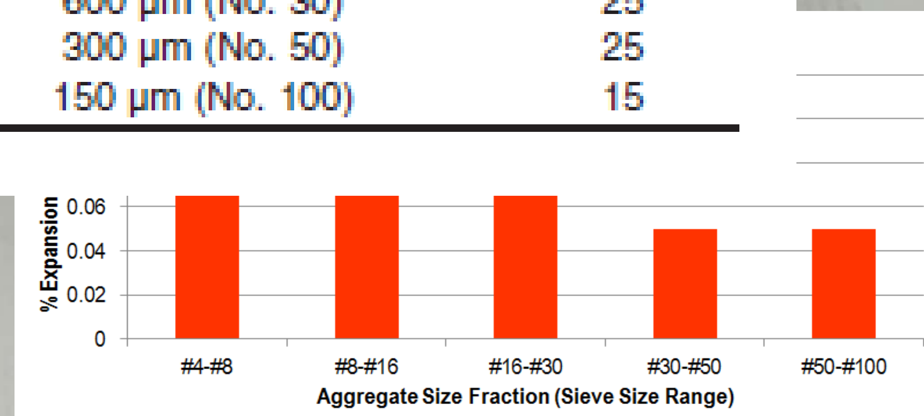


TABLE 1 Grading Requirements

Sieve Size		Mass, %
Passing	Retained on	
4.75 mm (No. 4)	2.36 mm (No. 8)	10
2.36 mm (No. 8)	1.18 mm (No. 16)	25
1.18 mm (No. 16)	600 µm (No. 30)	25
600 µm (No. 30)	300 µm (No. 50)	25
300 µm (No. 50)	150 µm (No. 100)	15



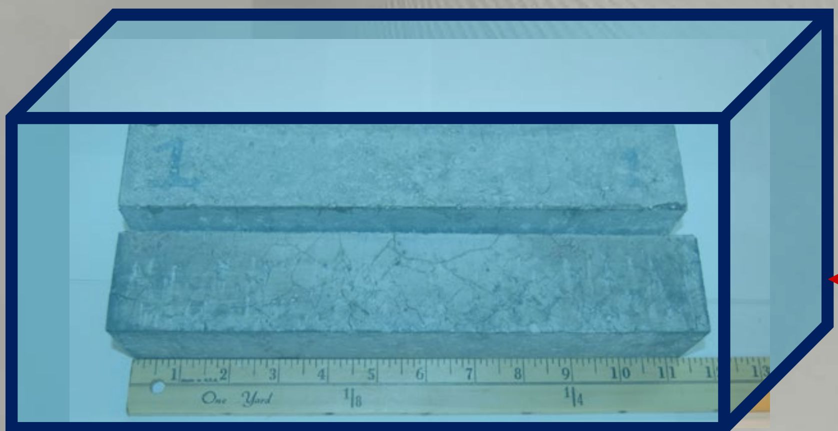


Miniature Concrete Prism Test – AASHTO TP110

- **No significant aggregate crushing is involved**
- **No alkali leaching**
- **Short test duration of 56 days (8 Weeks) for majority of aggregates**
- **For slow reacting aggregates 84 days (12 weeks)**
- **Can detect both ASR and ACR**
- **Can evaluate both aggregate and SCMs**
- **Potential to evaluate job concrete mixtures ??**

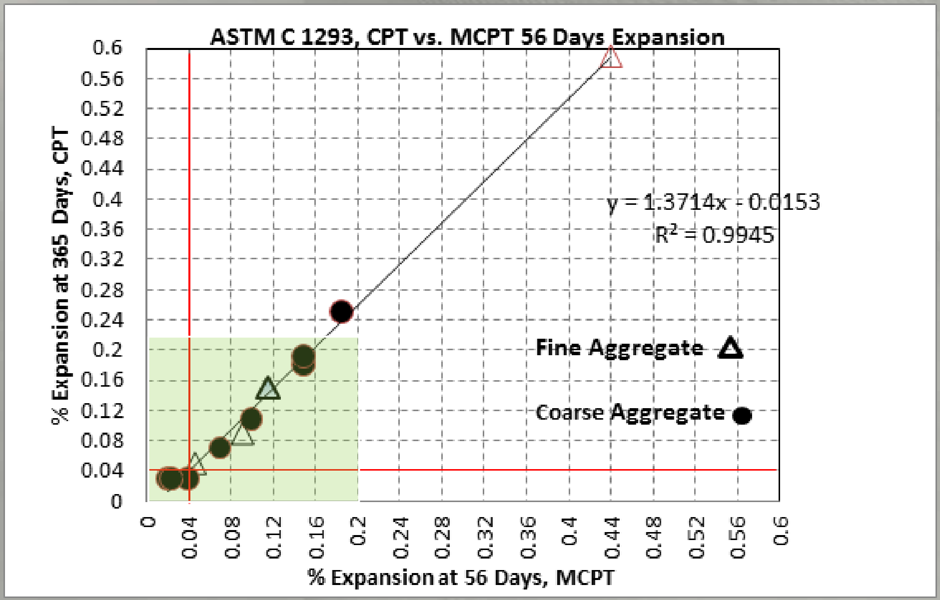
MCPT Method (AASHTO TP 110)

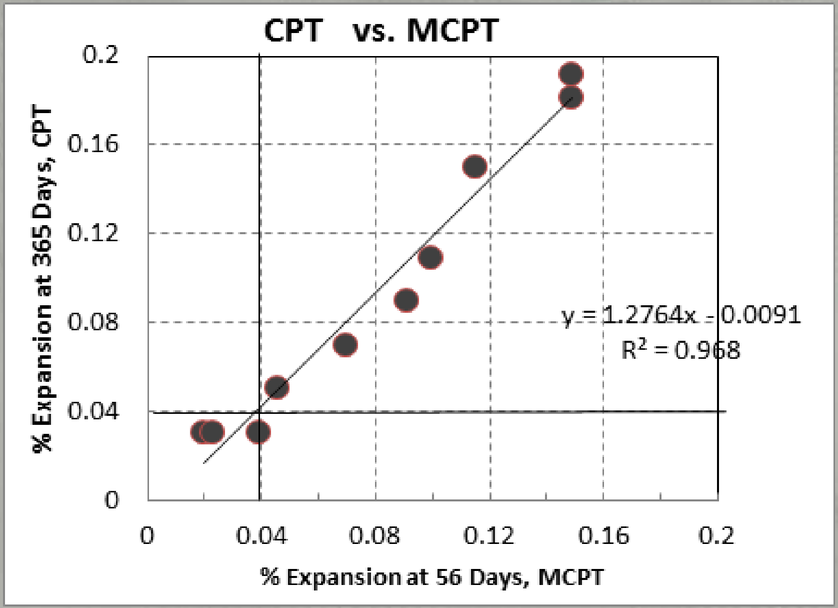
- **Cement Content** = **708 lb/yd^3 (420 kg/m^3)**
- **Cement Alkali Content** = **0.9% ± 0.1% $Na_2O_{eq.}$**
- **Alkali Boost, (Total Alkali Content)** = **1.25% $Na_2O_{eq.}$**
- **Water-to-cement ratio (fixed)** = **0.45**
- **Coarse Agg. Dry-Rodded Vol. Frac.** = **0.65 (MSA: ½ in.)**
- **Storage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



1 N NaOH @ 60ºC

MCPT-56 day versus CPT – 365 day

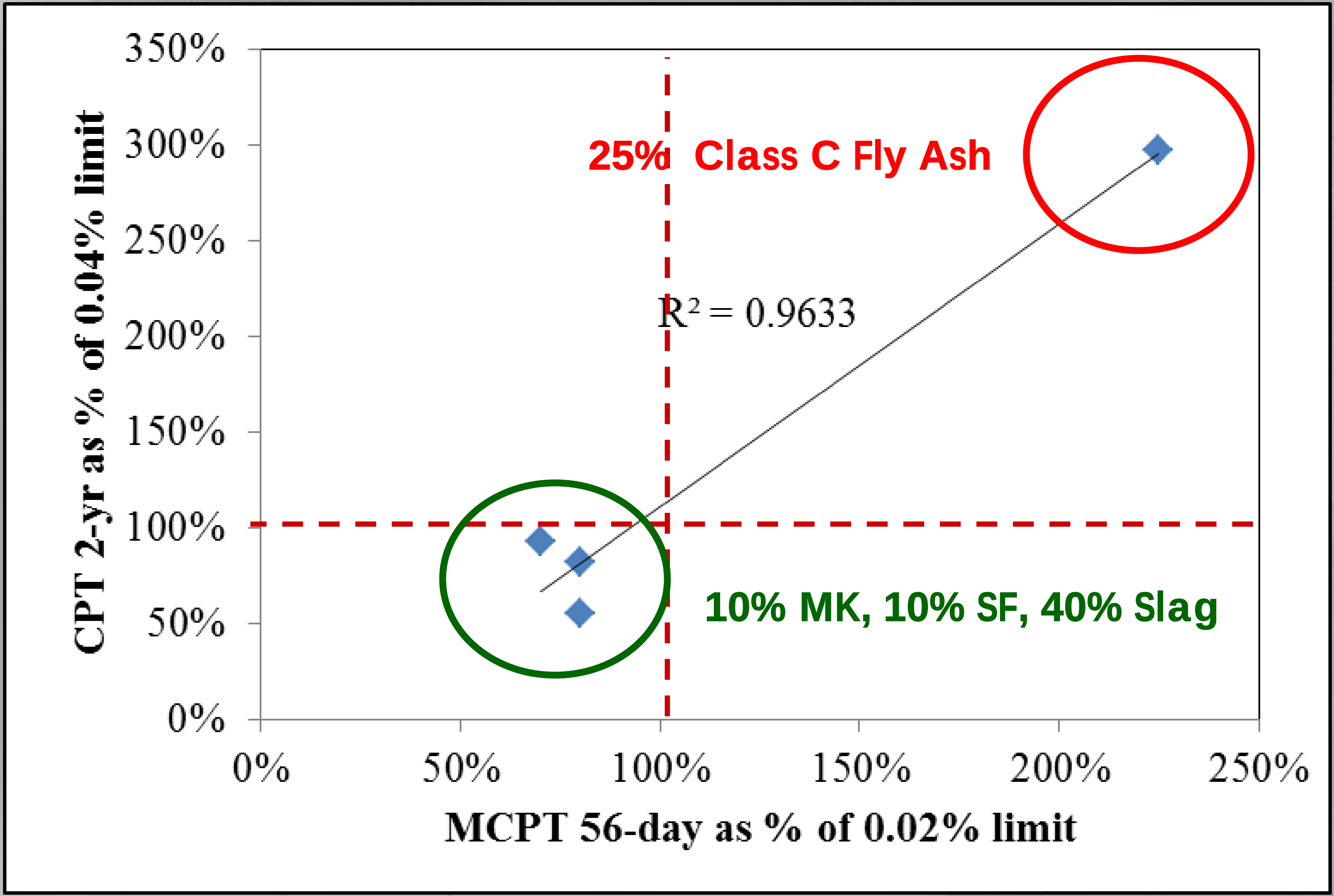




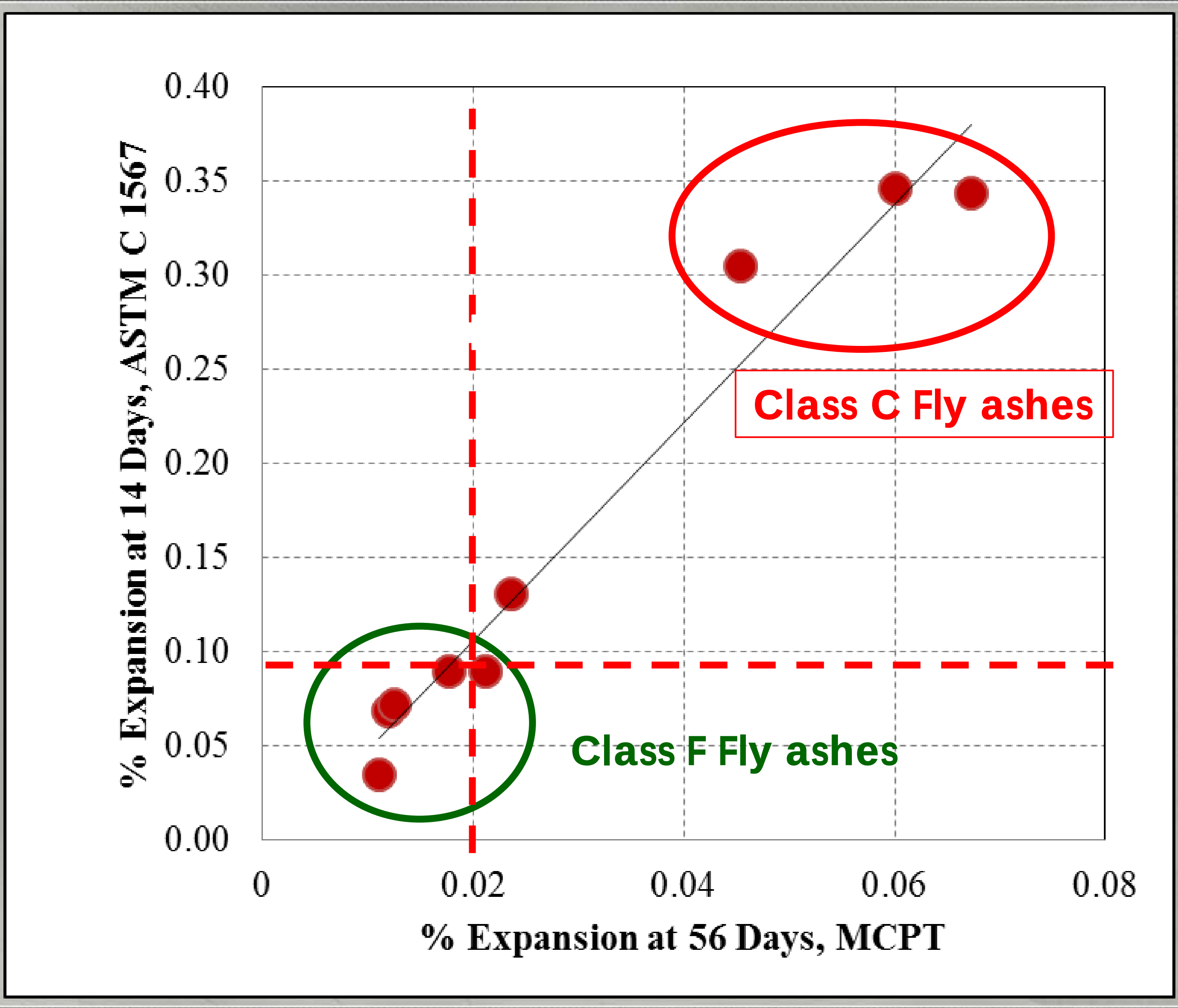
Proposed criteria for characterizing aggregate reactivity in MCPT Method

Degree of Reactivity	% Expansion at 56 Days (8 Weeks)	
Non-reactive (R0)	≤ 0.030 %	
Low/Slow Reactive (R0??)	0.031% – 0.040%	
Moderate Reactive (R1)	0.041% – 0.120%	
High Reactive (R2)	> 0.121%-0.240%	
Very Highly Reactive (R3)	≥ 0.241%	

Correlation between 56-day MCPT and 2-Yr CPT



Correlation between AMBT and MCPT



Proposed Criteria for Evaluation of SCMs

Efficiency of Mitigation	% Expansion at 56 Days (8 Weeks)	% Expansion at 112 Days (16 Weeks)
Effective	< 0.020%	≤ 0.040%
Uncertain*	0.020% – 0.025%	--
Not Effective	> 0.025%	> 0.040%

Research Need

- **AASHTO approved this method as provisional standard – AASHTO TP 110**

Gaps in Knowledge

- **TASK 1 - Correlation between MCPT and CPT for evaluating mitigation measures.**
- **TASK 2 - Correlation between MCPT and field performance, particularly with border-line aggregates.**
- **TASK 3 - Need to study the effect of starting cement alkali level and the "companion non-reactive aggregate" on test results.**
- **TASK 4 - Collaborate with states that already developed a correlation between field performance and 1- or 2-year CPT results and see how 56-day MCPT results correlate.**

MCPT & AASHTO PP65

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56-Day MCPT will provide a more reliable input than AMBT in the AASHTO PP 65 approach

So what does this all mean for Job Concrete Mixtures?

- **All the testing is focused on screening out the ingredients:**
  - **Fine Aggregate**
  - **Coarse Aggregate**
  - **SCMs – Quality and Dosage**

- **Shortcomings of standard test methods:**

  - **Pessimum effect of aggregate reactivity is not captured, particularly at proportions used in job mixtures.**

  - **Effect of w/c ratio, cement content, cement alkali content is not captured**

- **WE ARE NOT EVALUATING JOB MIXTURES.**

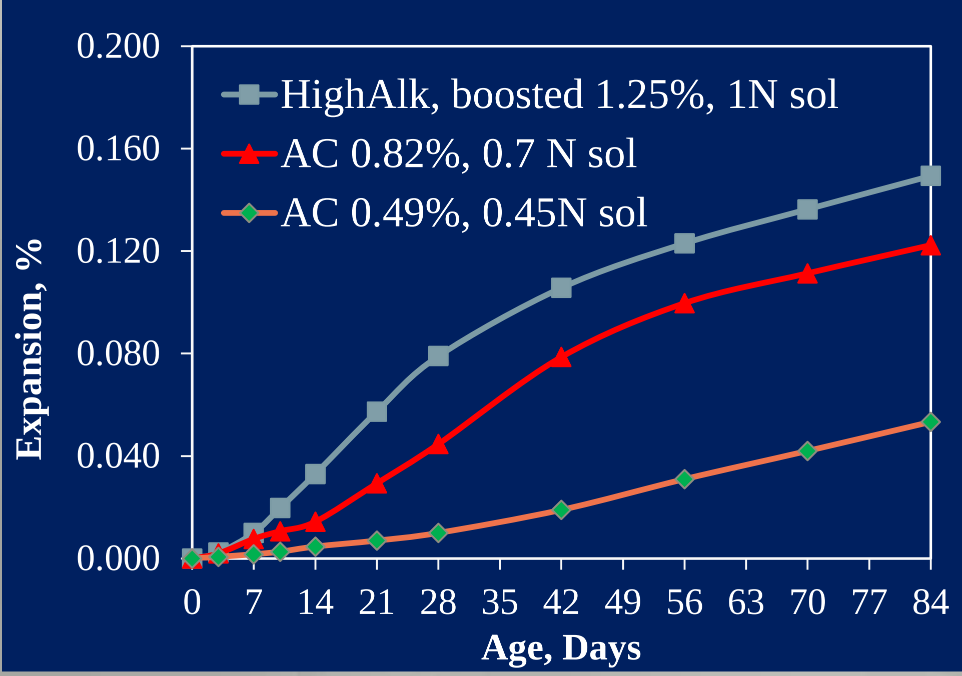
Influence of Job Mix Parameters on ASR

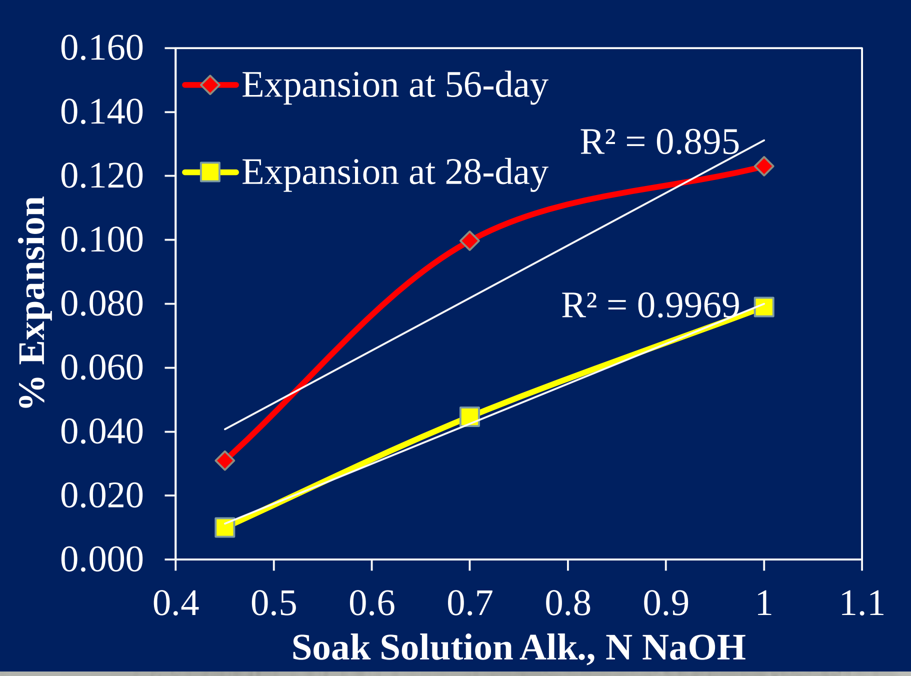
- **Typical job mix parameters that differ from the standard MCPT method are:**
  - **w/cm ratios**
  - **Total cement content**
  - **Total alkali loading in concrete**
  - **Dosage of SCMs**
  - **Vol. fraction of aggregates in concrete**
  - **Presence of blended aggregates with competing reactivity**

Preliminary Evaluation of Factors that Affect ASR Potential of Job Mixtures

Effect of pore solution conc. on the % expansion in the MPCT

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

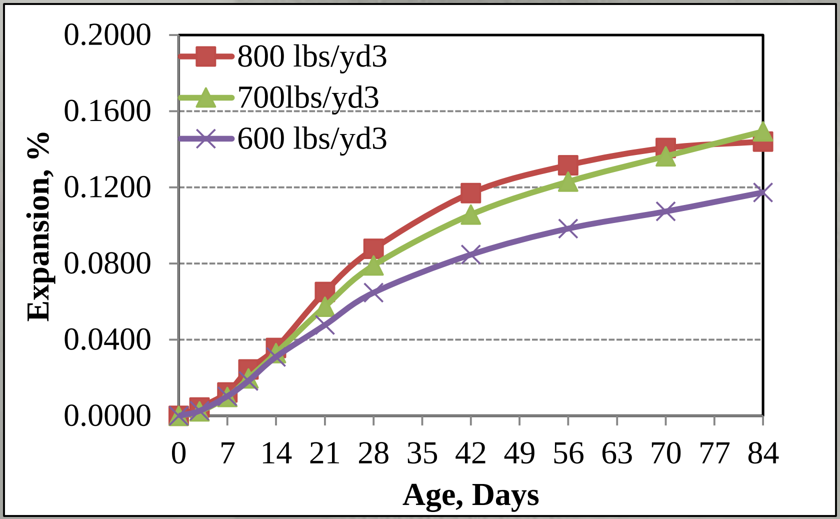




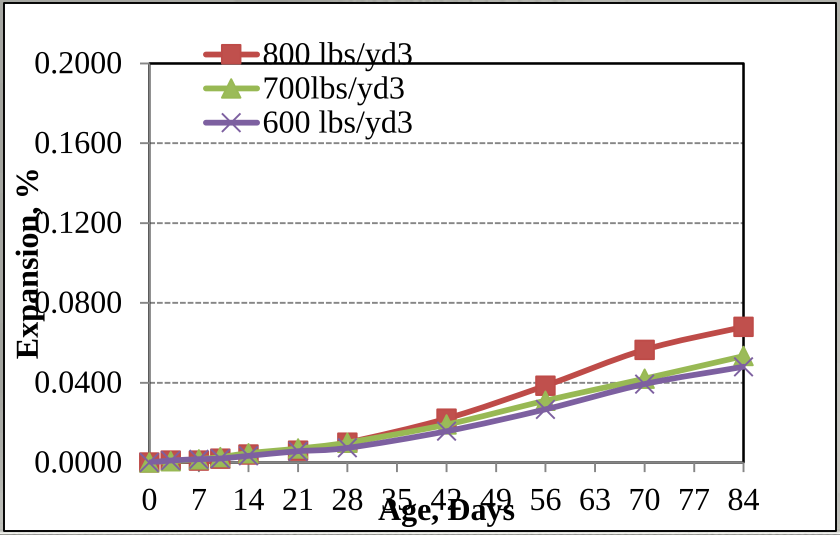
Effect of cement content on expansion in MCPT with High and Low Alkali Cement

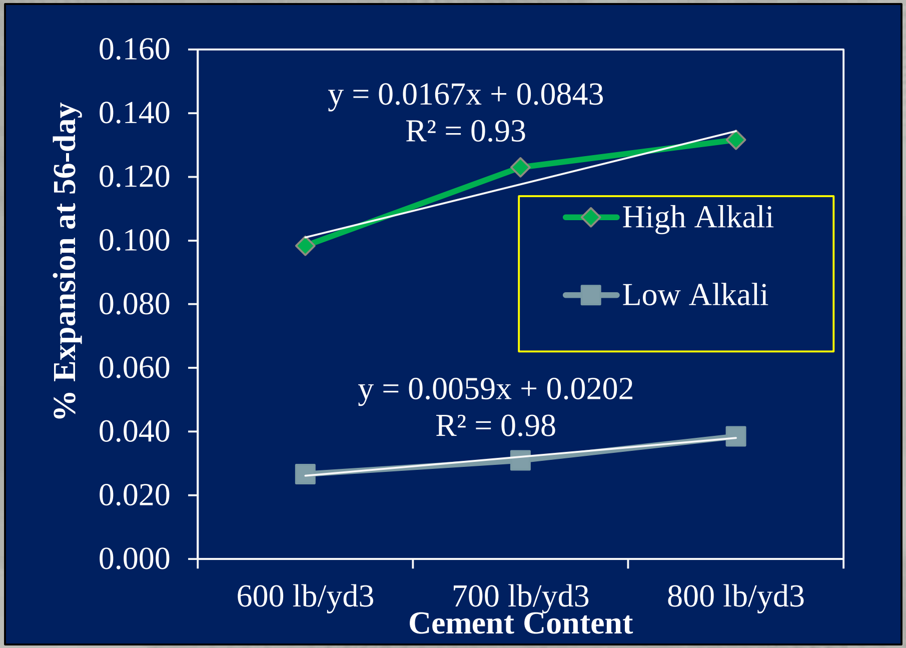
w/c =0.45

HA

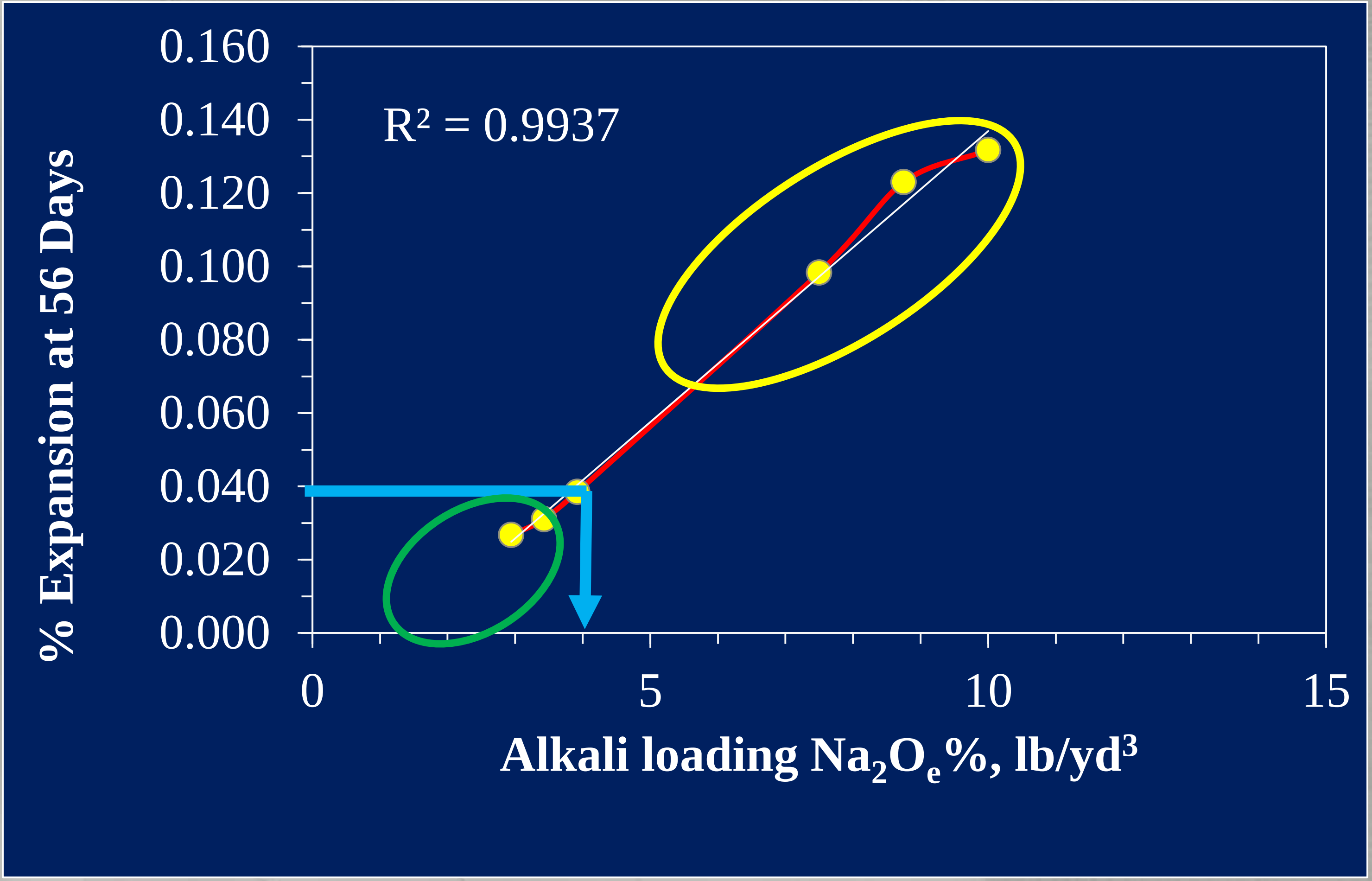


LA





Effect of Alkali Loading in Concrete on Expansion in MCPT



Potential Pooled Fund Study

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- **TASK 4 - Collaborate with states that already developed a correlation between field performance and 1- or 2-year CPT results and see how 56-day MCPT results correlate.**
- **TASK 5 – Development of precision and bias statement**
- **TASK 6 – Develop MCPT to evaluate ASR potential of JOB CONCRETE MIXTURES**

Integration of MCPT into Performance-Based Specifications

Questions?

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