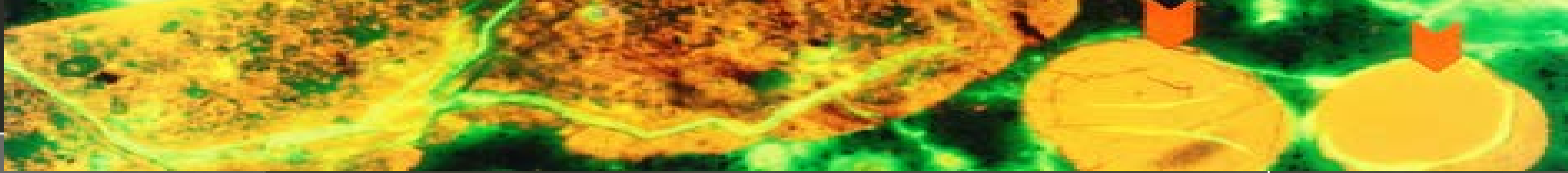


# Future of AAR Testing

## *Miniature Concrete Prism Test*

**(AASHTO TP 111)**


**Prasad Rangaraju**

***Clemson University, SC***


**National Concrete Consortium Meeting**

**Jacksonville, FL**

**April 24, 2014**

# 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 – Acc. Mortar Bar Test**
- **ASTM C 1293 – Conc. Prism Test (ASR)**

**ACR**

- **ASTM C 295 – Petrographic Examination**
- **ASTM C 586 – Rock Cylinder Test (ACR)**
- **ASTM C 1105 – Conc. Prism Test (ACR)**

# Existing Test Methods for ASR Mitigation in ASTM

- **ASTM C 441 – ASR Mitigation**
- **ASTM C 1567 – ASR Mitigation**
- **ASTM C 1293 – ASR Mitigation**
- **CRD-C-662 – ASR Mitigation (Lithium)**

# Deficiencies of Existing Methods

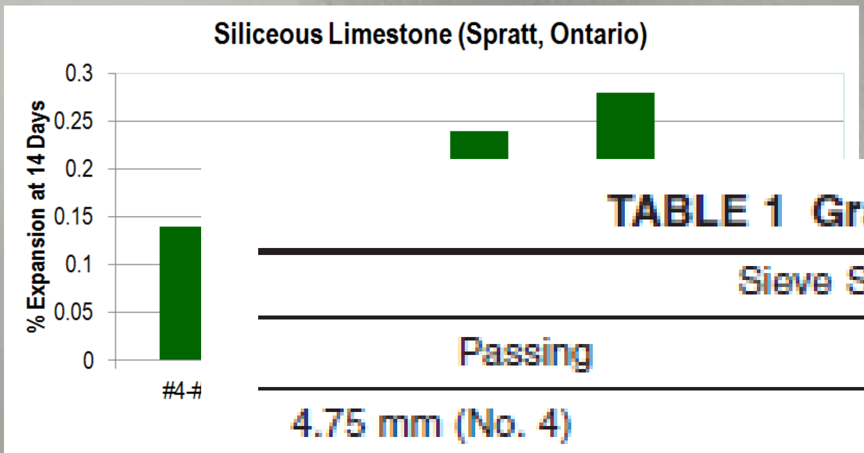
**ASTM C1260 (Accelerated Mortar Bar Test)**

- Severity of Test Conditions
  - High Test Temperature
  - Crushing/Sieving
- Inability to Identify Certain Slowly Reactive Aggregates
- Excessive False Positives
- Deleterious False Negatives
- Inability to Evaluate Job Mixtures

**ASTM C1293 (Concrete Prism Test)**

- Length of the Test Methods
- Leaching of Alkalis
- Inability to Evaluate Job Mixtures

# Influence of Aggregate Size on Expansion in ASTM C1260



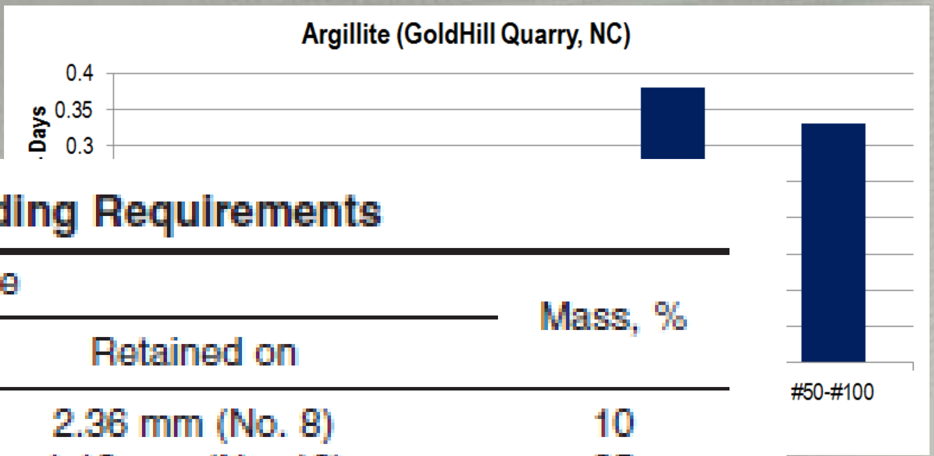
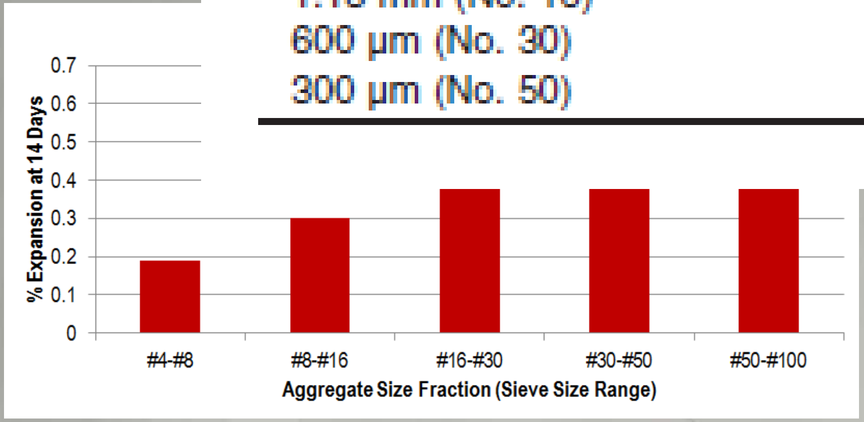
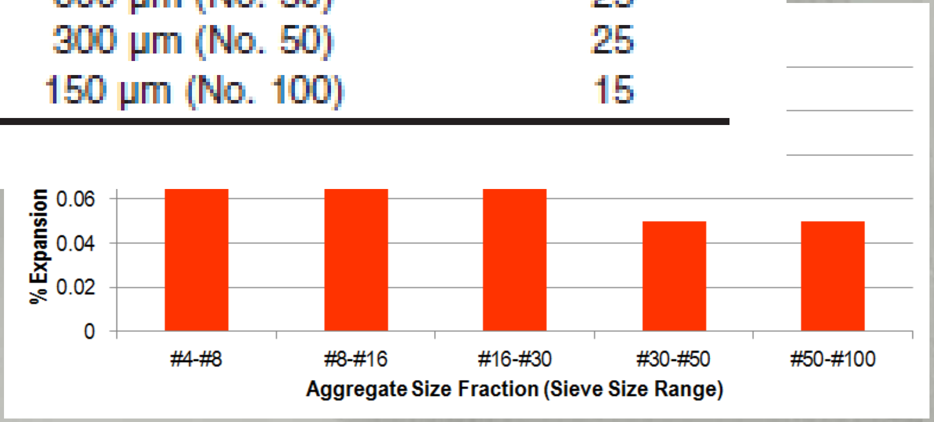



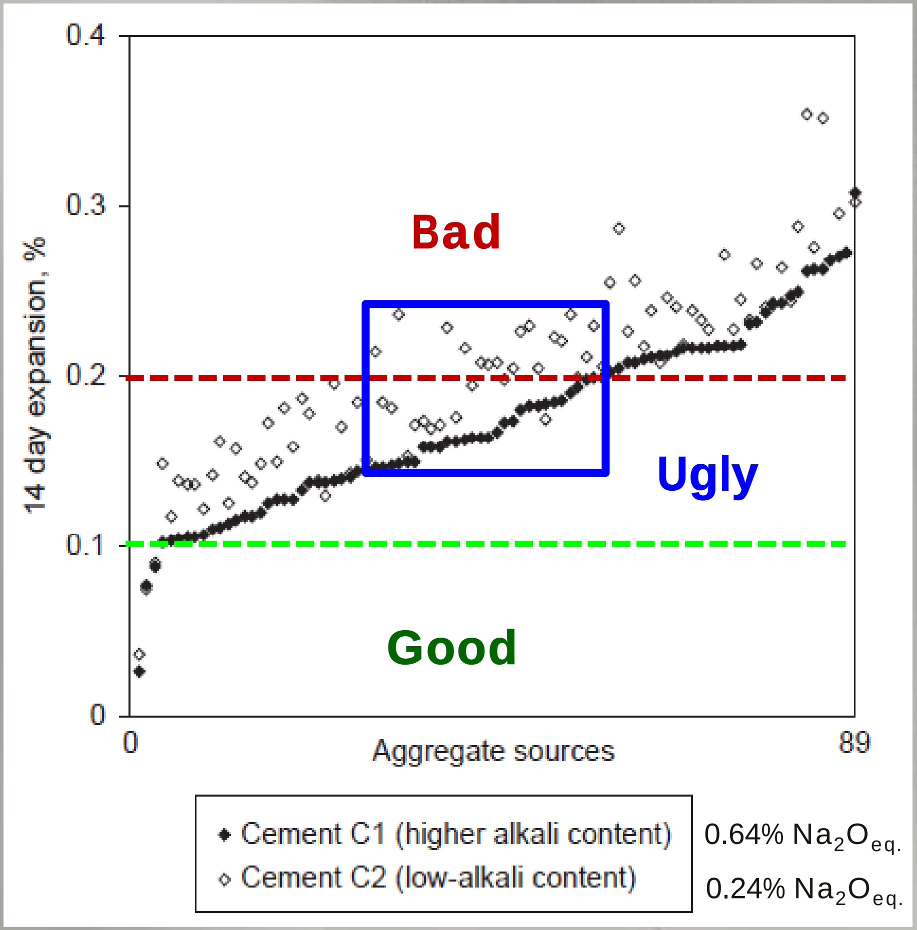

**TABLE 1 Grading Requirements**

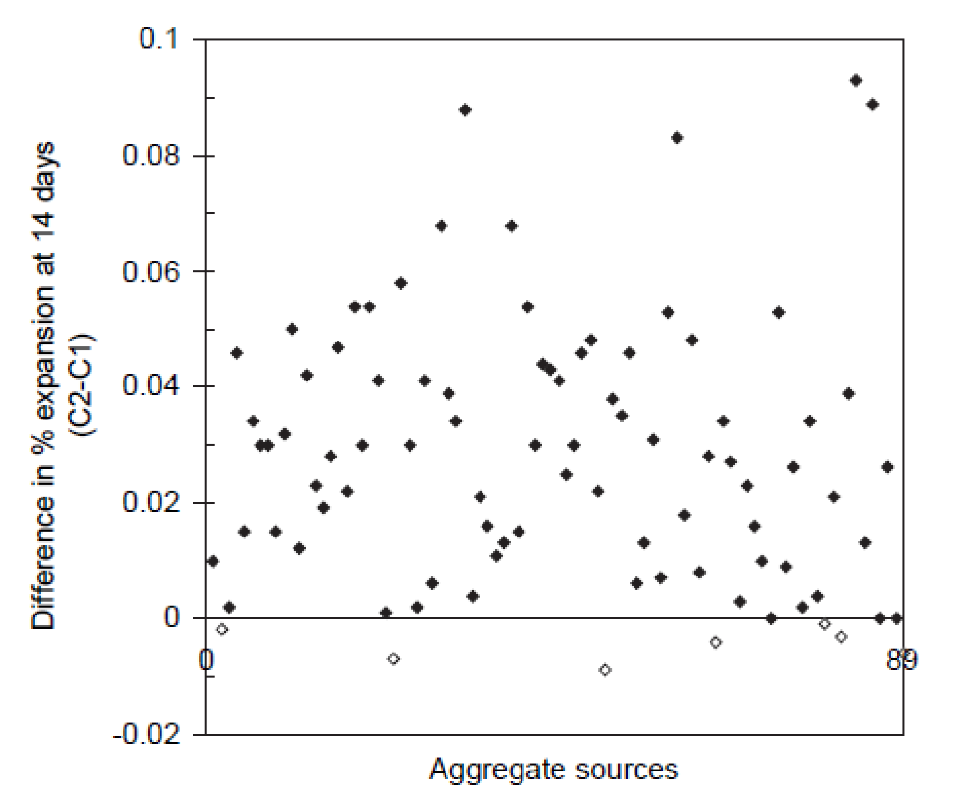
| Sieve Size | | Mass, % |
|---|---|---|
| Passing | Retained on | |
| 4.75 mm (No. 4) | 2.36 mm (No. 8) | 10 |
| 2.36 mm (No. 8) | 1.18 mm (No. 16) | 25 |
| 1.18 mm (No. 16) | 600 µm (No. 30) | 25 |
| 600 µm (No. 30) | 300 µm (No. 50) | 25 |
| 300 µm (No. 50) | 150 µm (No. 100) | 15 |



# Variability in ASTM C 1260 Test Results (MN Sources)



# Concerns with CPT & Accelerated CPT

- Length of the test method (1 year or 2 years)

- Significant alkali leaching (~ 35-40%) observed in test specimens and its impact on expansion  is questioned?

- The results are sensitive to the choice of non-reactive aggregate used in the concrete ?

# Miniature Concrete Prism Test

- This method is based on the research conducted for FHWA to develop a rapid and a reliable test method to evaluate:
  - ASR Potential of Aggregates
  - Effectiveness of ASR Mitigation Measures
  - ASR Potential in Job Concrete Mixtures

- 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 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

- Concrete Prisms = 2 in. x 2 in. x 11.25 in.
- Coarse Agg. Size Range = No. 4 – 1/2 in.
- Coarse Agg. Vol Fraction (Dry-Rod) = 0.65
- Coarse Agg. Grading Requirement

| Sieve Size, mm | | Mass, % |
|---|---|---|
| Passing | Retained | |
| 12.5 | 9.5 | 57.5 |
| 9.5 | 4.75 | 42.5 |

- 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
- Storage Environment* = 1N NaOH Solution (Soak)
- Storage Temperature = 60$^0$C

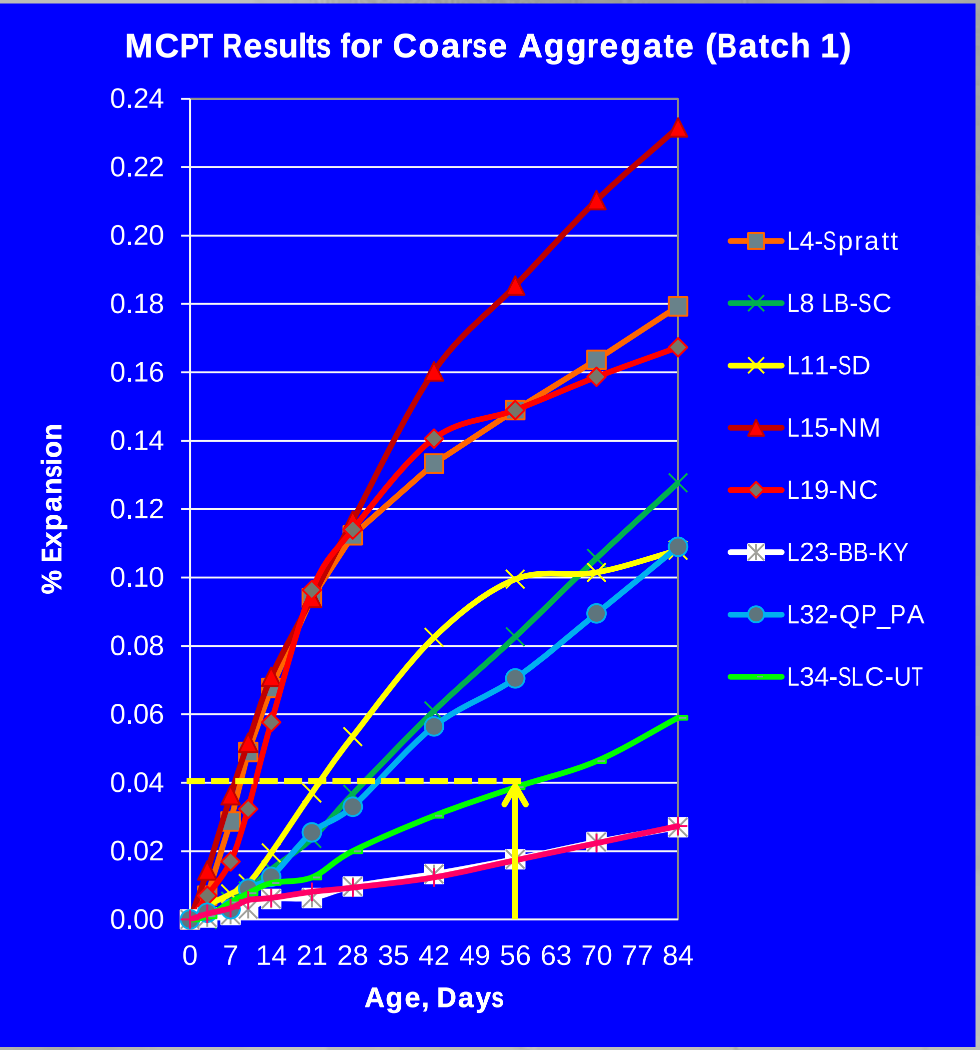
# MCPT Measurements

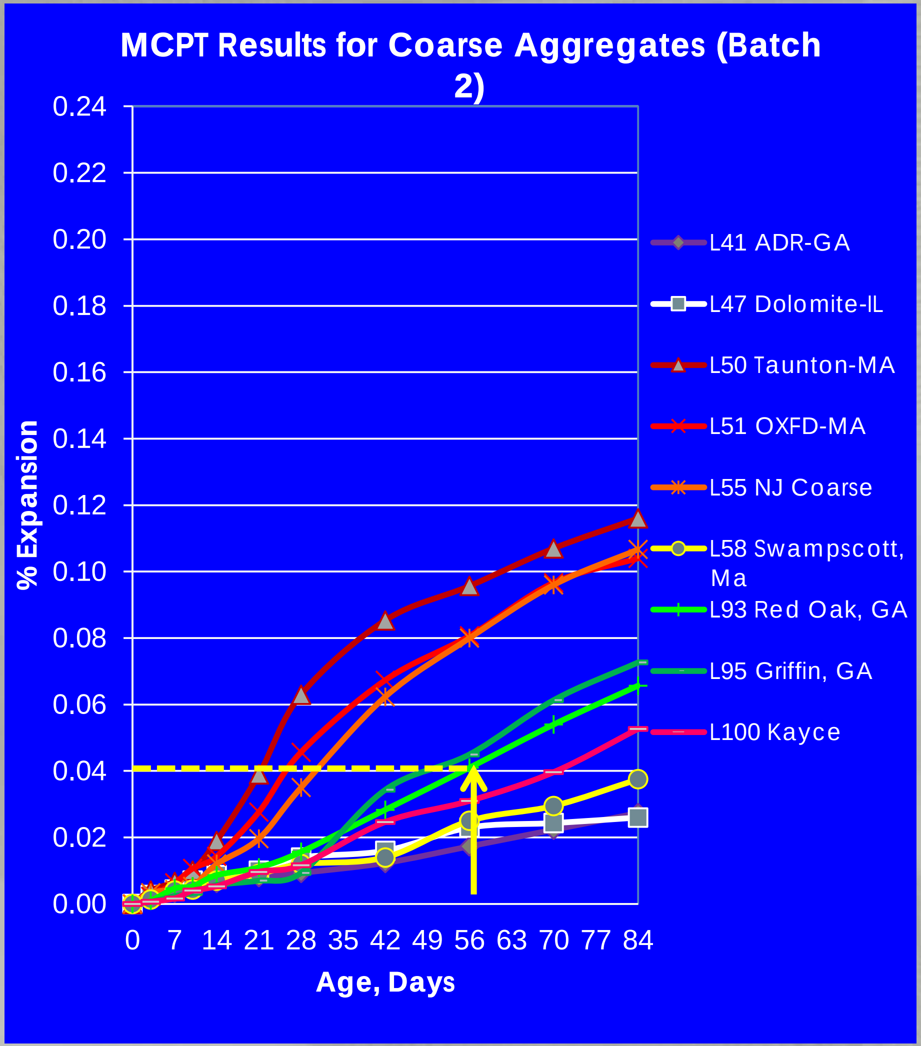
- **1st Day** **= Curing in 60 $^0$C in Water**
- **Subsequent Storage** **= 1N NaOH @ 60$^0$C**
- **Length Change Measurement** **= 1, 3, 7, 10, 14, 21, 28, 42, 56, 70, 84 days**
- **Non-reactive sand is used with reactive coarse agg, and vice-versa.**

# MCPT Validation

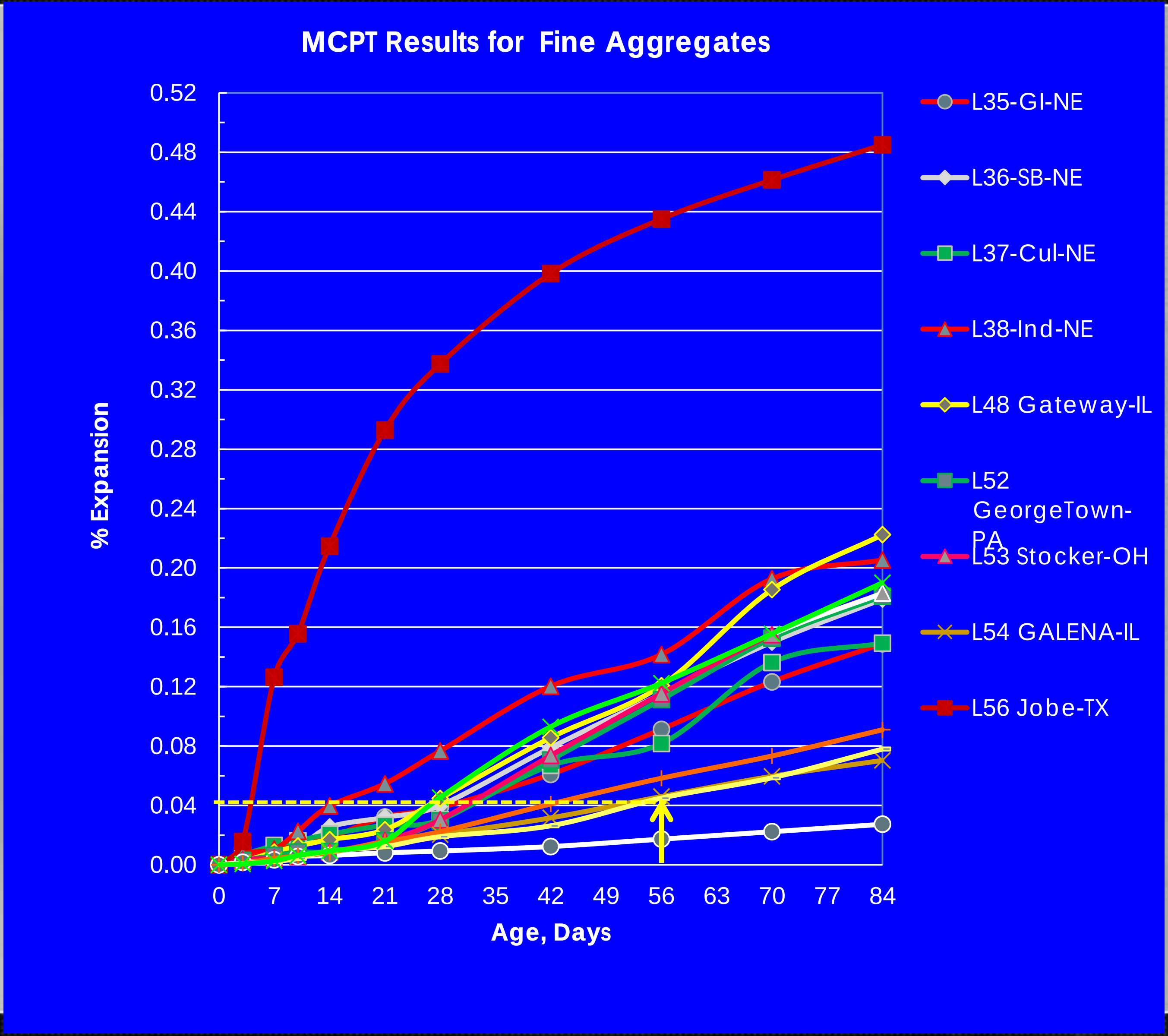
- **Evaluated 33 aggregates with known field performance**
- **Limited set of 12 aggregates were tested in MCPT, CPT and AMBT for correlations**
- **Evaluated 9 different fly ashes with different chemical composition**
- **Evaluated Slag, Meta Kaolin, Silica Fume, Lithium Admixtures**

# Coarse Aggregates in MCPT

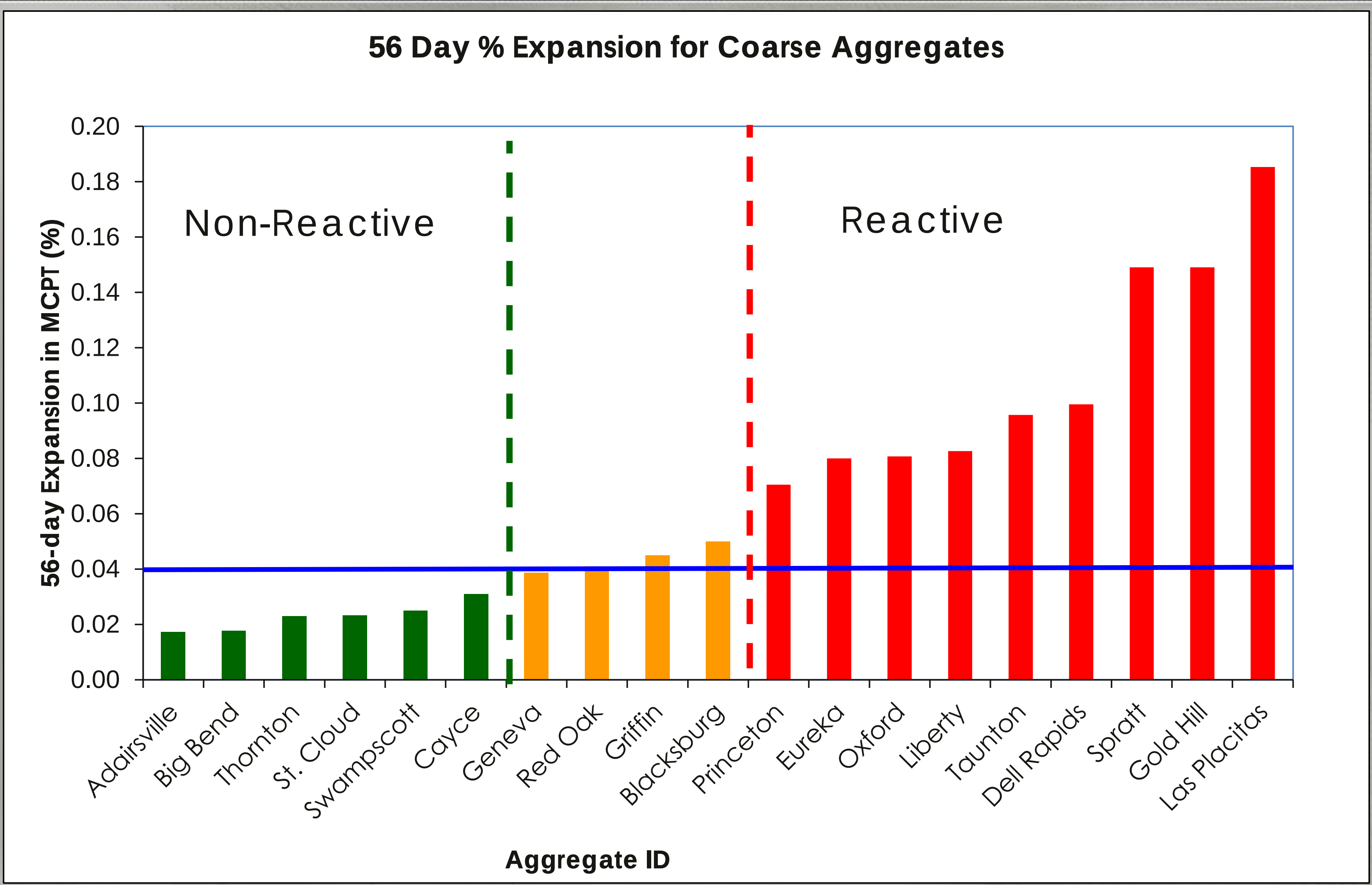


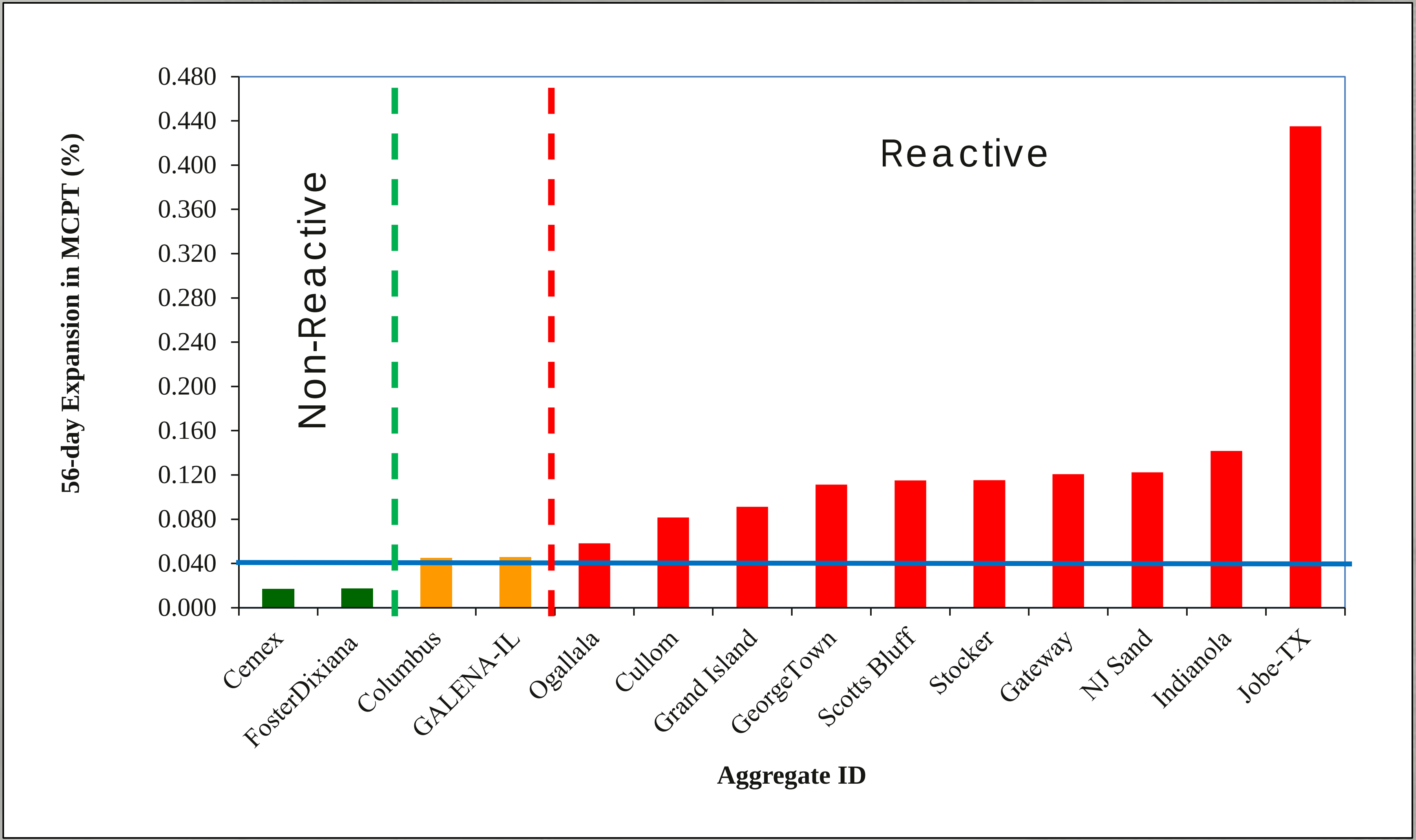
# Fine Aggregates in MCPT



# MCPT 56-expansions for coarse aggregates



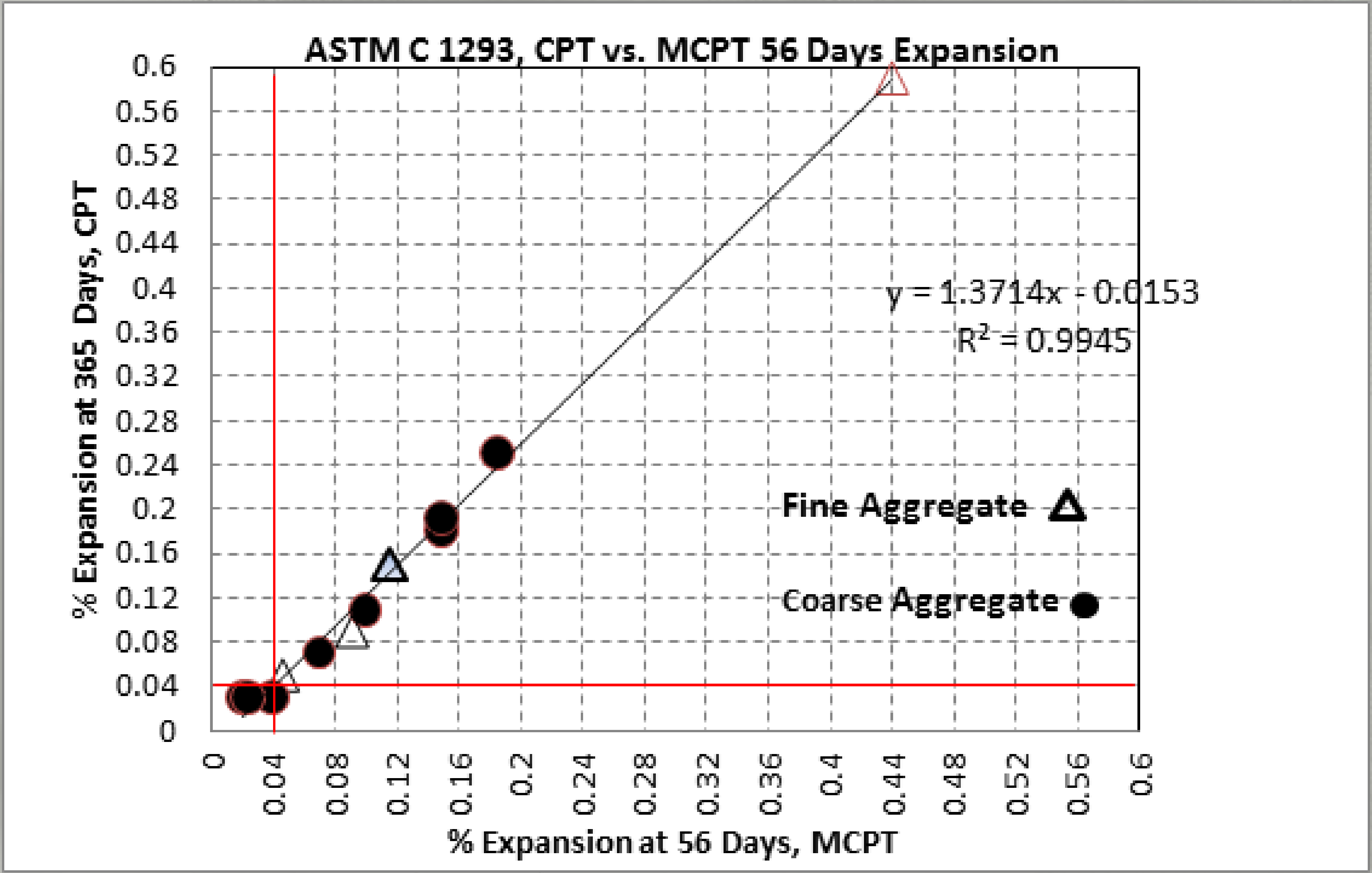
# MCPT 56-expansions for fine aggregates



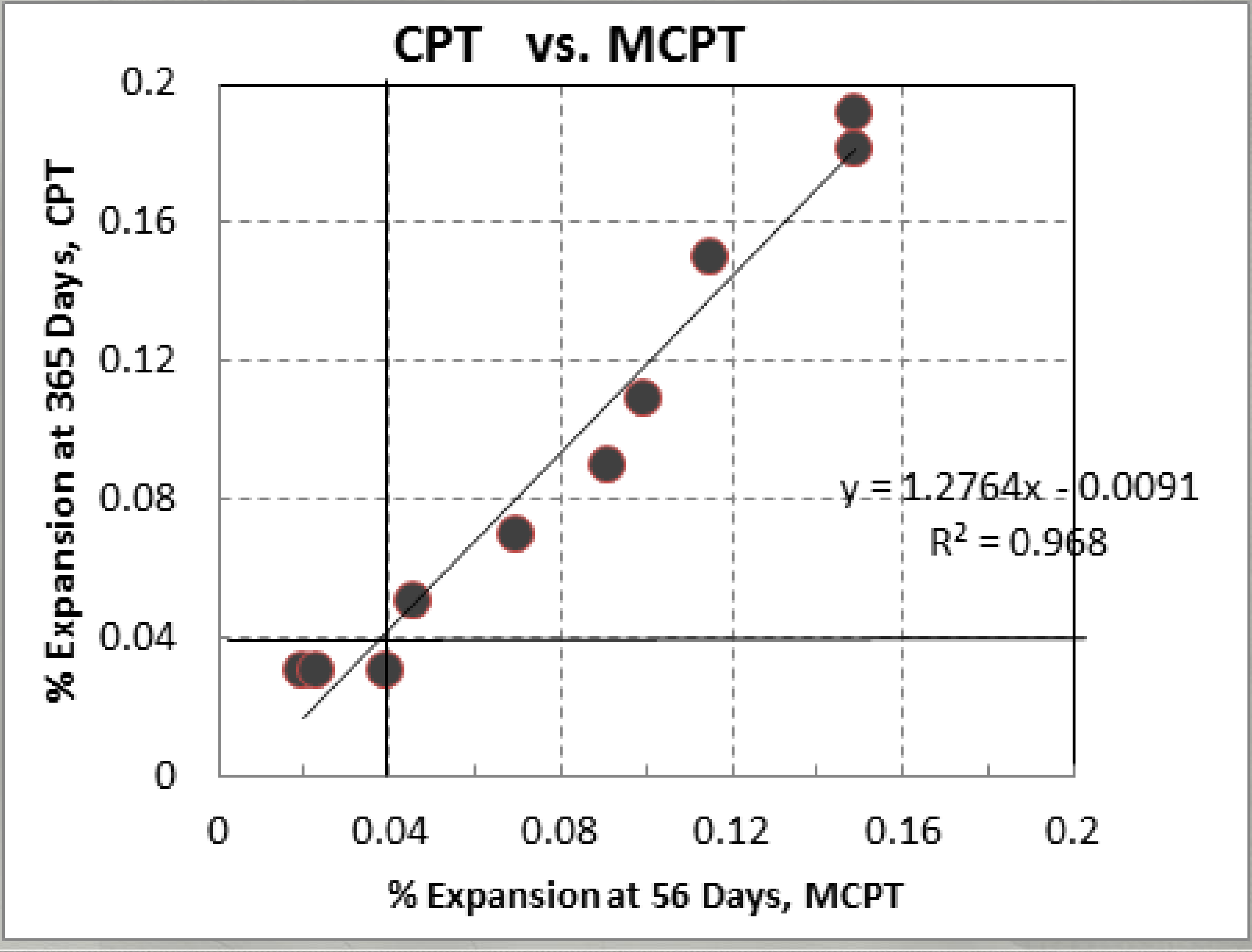
# Comparison of MCPT Results with CPT and AMBT

| Aggregate Identity | % Expansion | | | Average % Rate of Expansion (8-12 wks) | Field Experience |
|---|---|---|---|---|---|
| | MCPT, 56 Days (CV %) | ASTM C 1293, 365 days | ASTM C 1260, 14 days | | |
| L4-SP | 0.149 (4.08) | 0.181 | 0.350 | 0.0152 | Reactive |
| L11-SD | 0.099 (4.97) | 0.109 | 0.220 | 0.0043 | Reactive |
| L15-NM | 0.185(3.43) | 0.251 | 0.900 | 0.0231 | Reactive |
| L19-NC | 0.149 (1.16) | 0.192 | 0.530 | 0.0092 | Reactive |
| L23-BB | 0.017 (8.81) | 0.032 | 0.042 | 0.0047 | Innocuous |
| L54-GLN | 0.046 (4.34) | 0.050 | 0.235 | 0.0122 | Reactive |
| L32-QP | 0.070 (3.01) | 0.070 | 0.080 | 0.0193 | Reactive |
| L34-SLC | 0.039 (8.31) | 0.030 | 0.190 | 0.0102 | Low reactive |
| L59-MSP | 0.023 (2.47) | 0.030 | 0.100 | 0.0070 | Innocuous |
| L56-TX | 0.440 (4.21) | 0.590 | 0.640 | 0.0250 | Reactive |
| L35-GI | 0.091 (9.93) | 0.090 | 0.260 | 0.0288 | Reactive |
| L36-SB | 0.115 (9.83) | 0.150 | 0.460 | 0.0320 | Reactive |

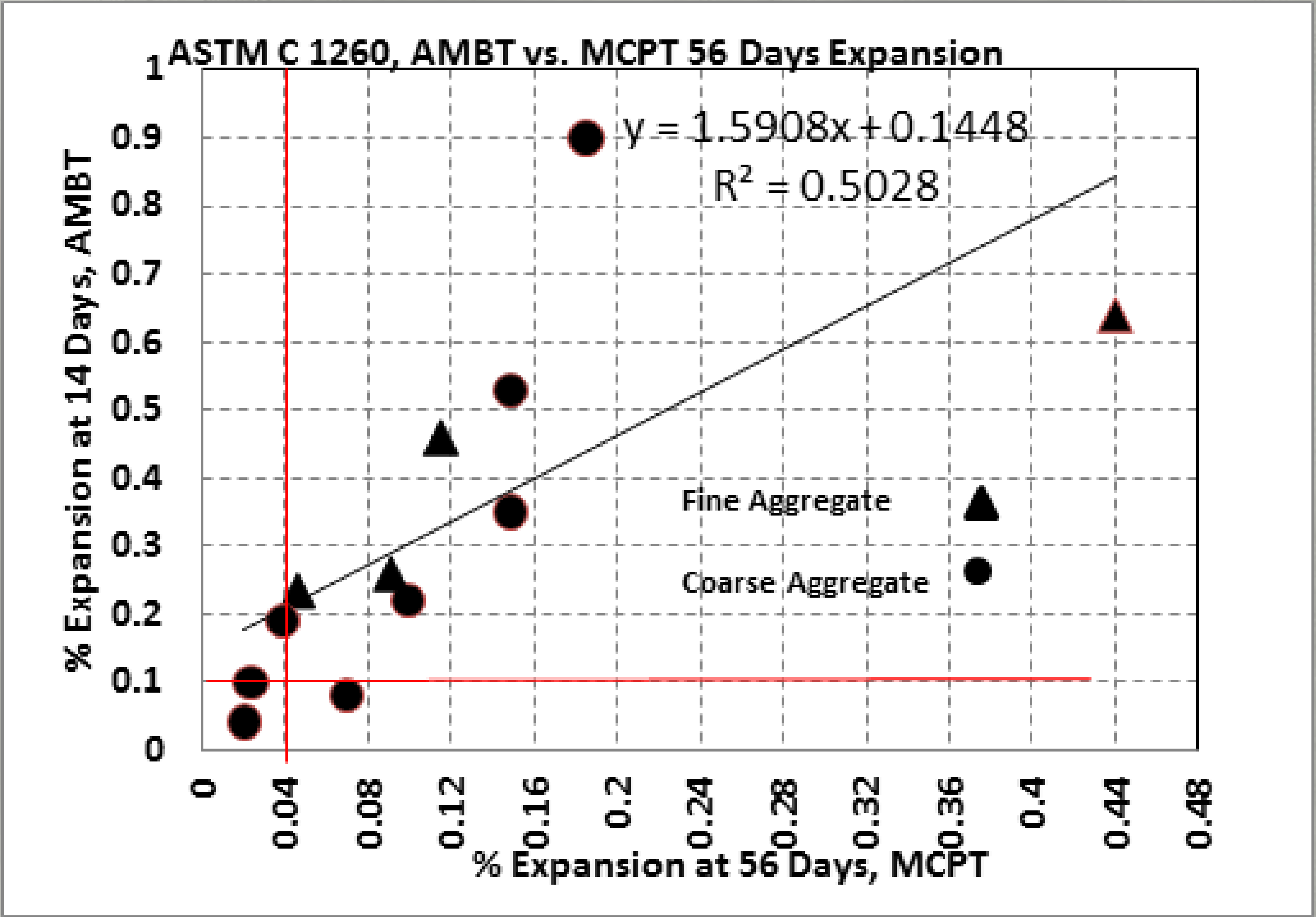
# MCPT-56 day versus CPT – 365 day



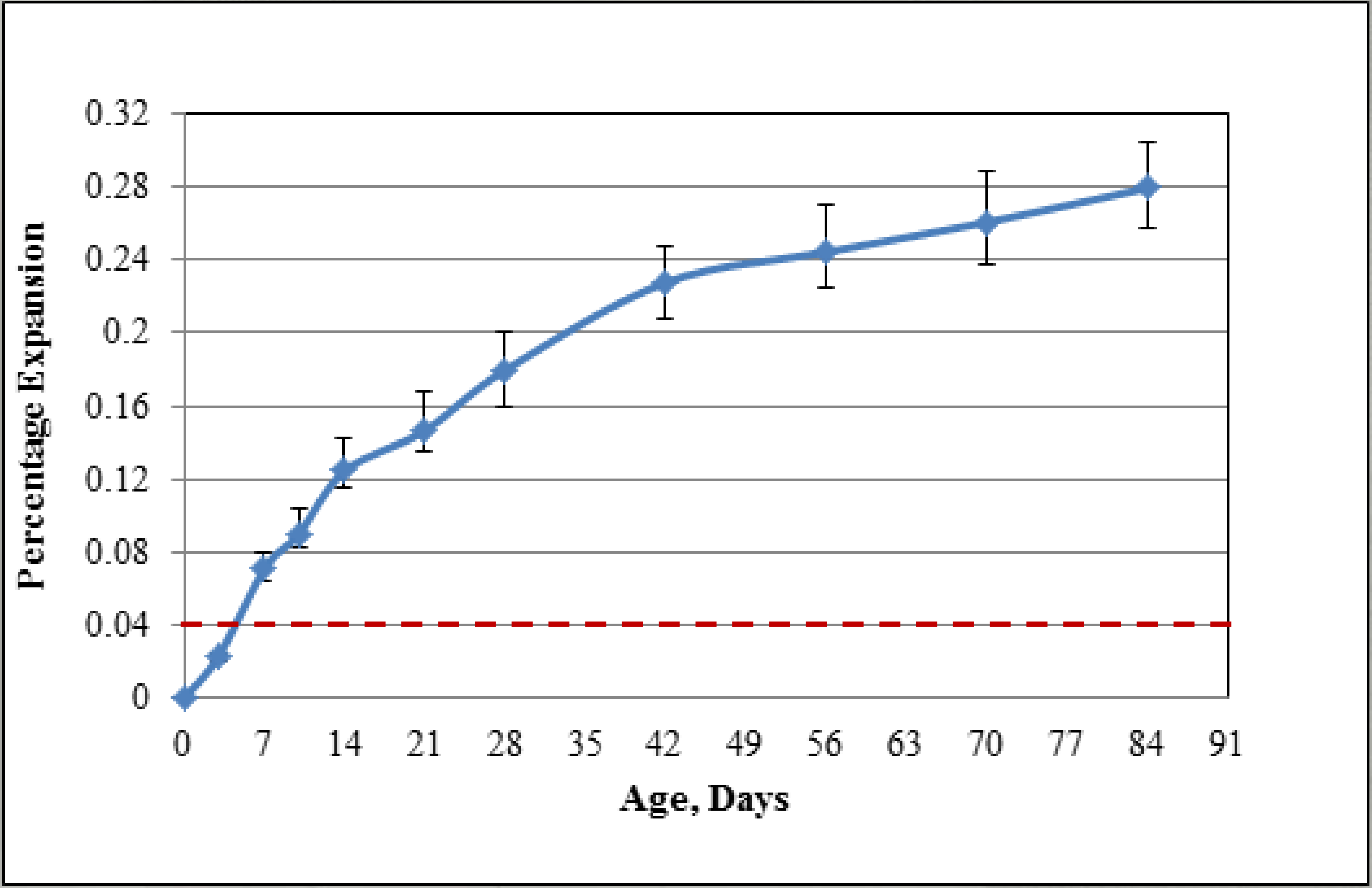
# MCPT 56 day versus CPT 365 day



# MCPT-56 day *versus* AMBT – 14 day



# ACR Prone Kingston Dolomitic Aggregate from Ontario in MCPT



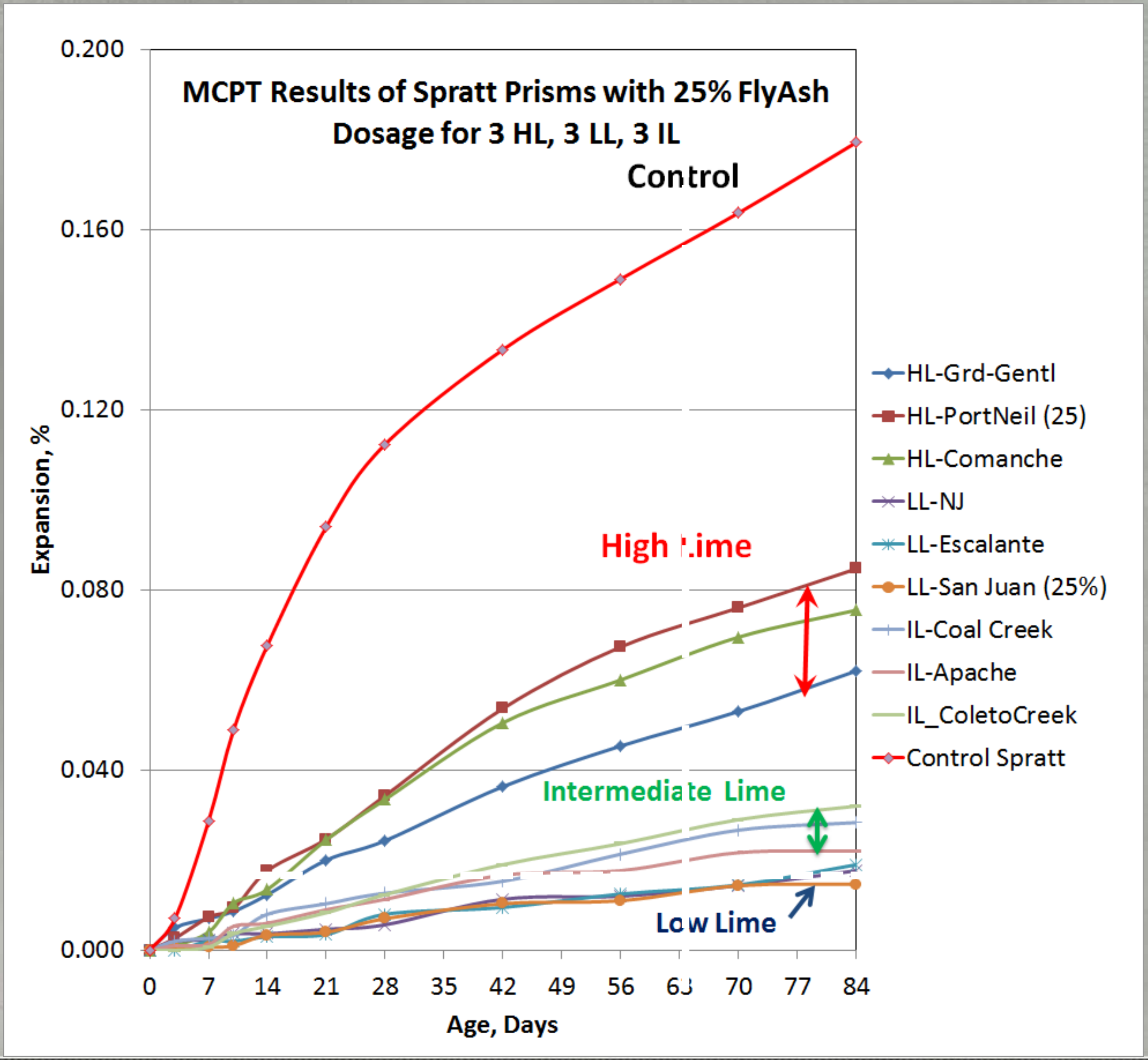
# Proposed criteria for characterizing aggregate reactivity in MCPT Method

| Degree of Reactivity | % Expansion at 56 Days (8 Weeks) | Average Rate of Expansion from 8 to 12 weeks |
|---|---|---|
| Non-reactive | | |
| Low/Slow Reactive | | |
| Moderate Reactive | 0.041% – 0.120% | N/A* |
| High Reactive | > 0.121%-0.240% | N/A* |
| Very Highly Reactive | ≥ 0.241% | N/A* |

* N/A – Not Applicable

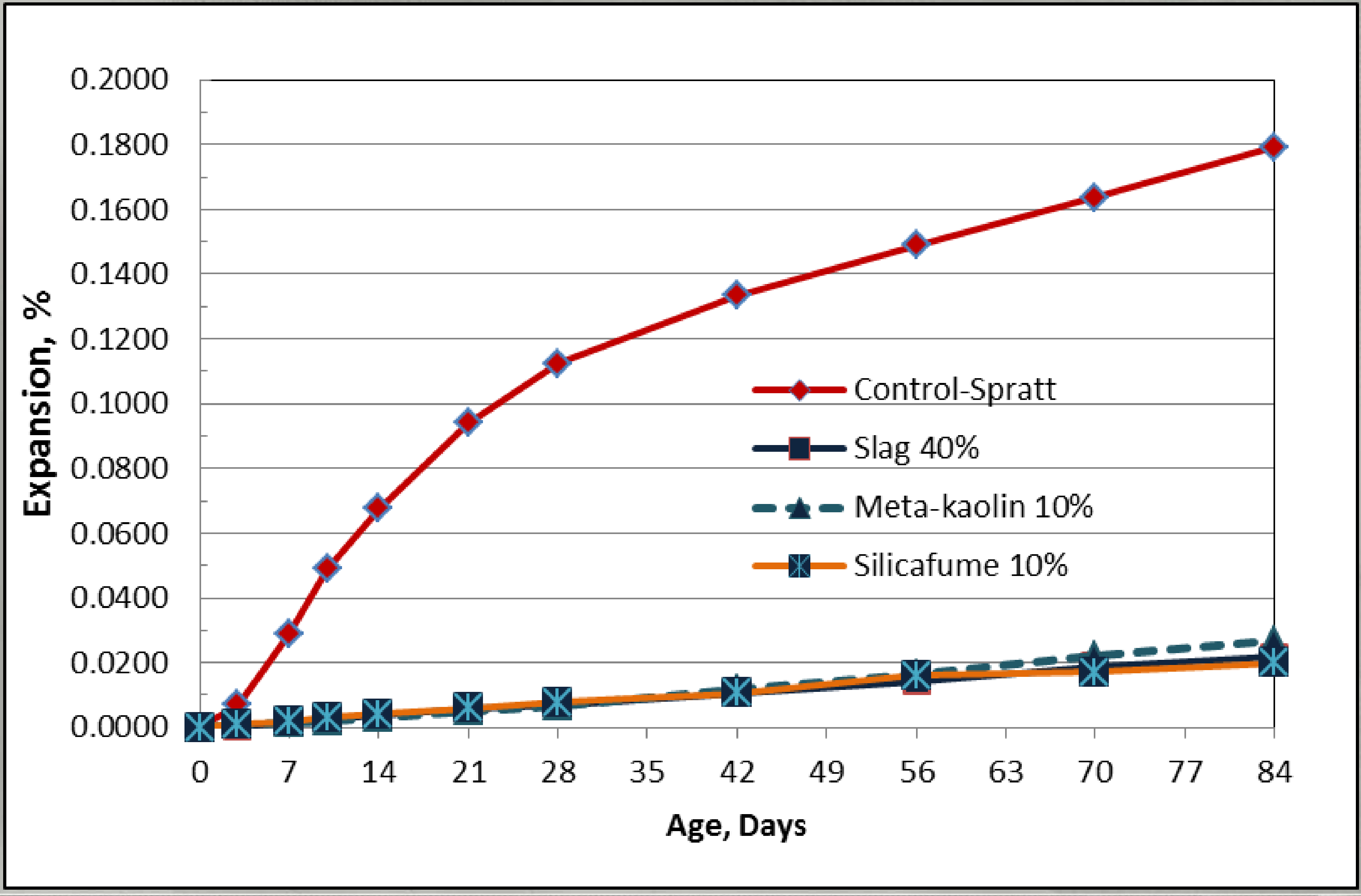
# Evaluation of Fly Ashes in MCPT

## *Effect of Fly Ash Composition*

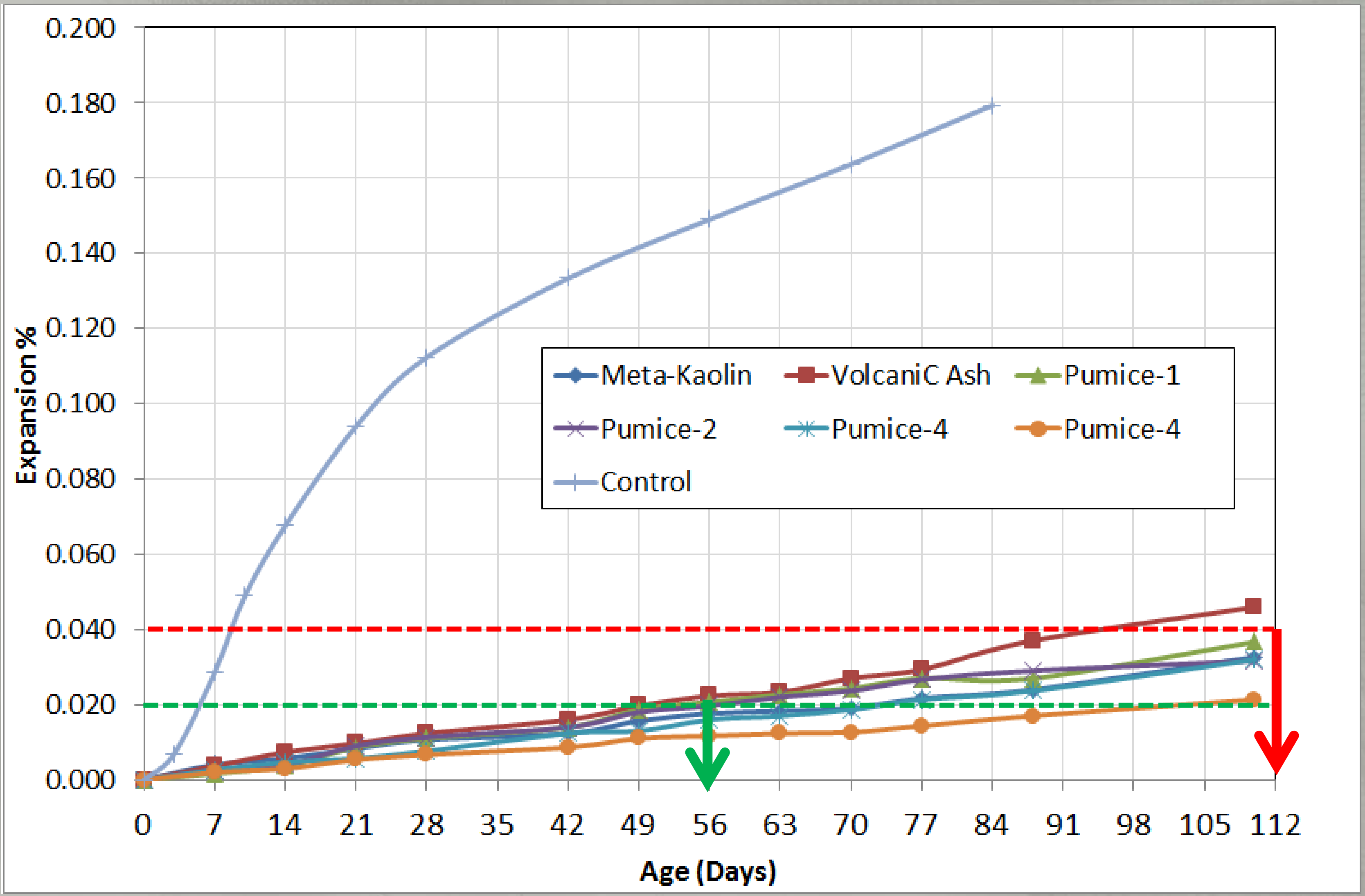


# Evaluation of Other SCMs in MCPT

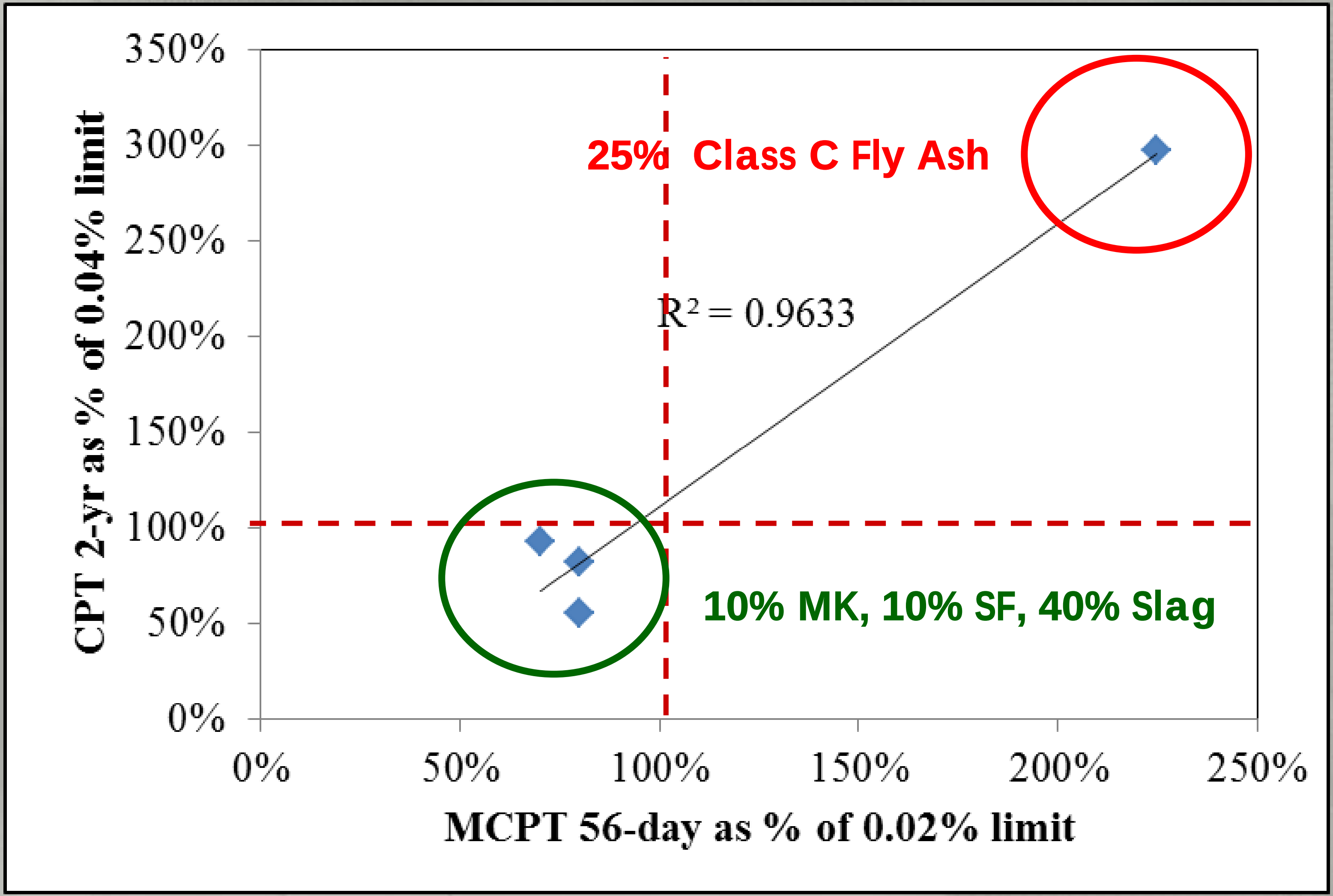
*Spratt Limestone Aggregate*



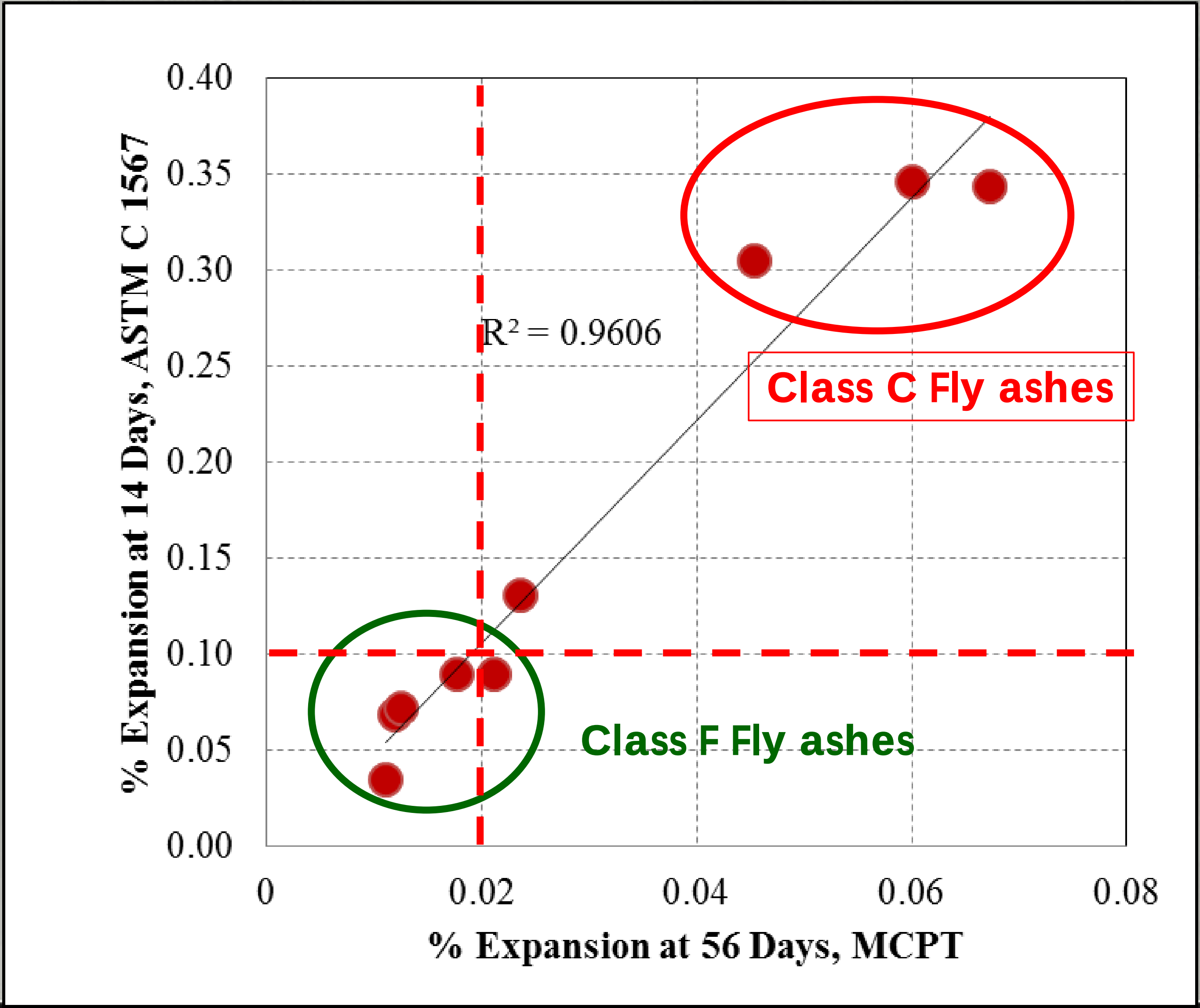
# Performance of Natural Pozzolans in MCPT



# Correlation between 56-day MCPT and 2-Yr CPT



# Correlation between AMBT and MCPT

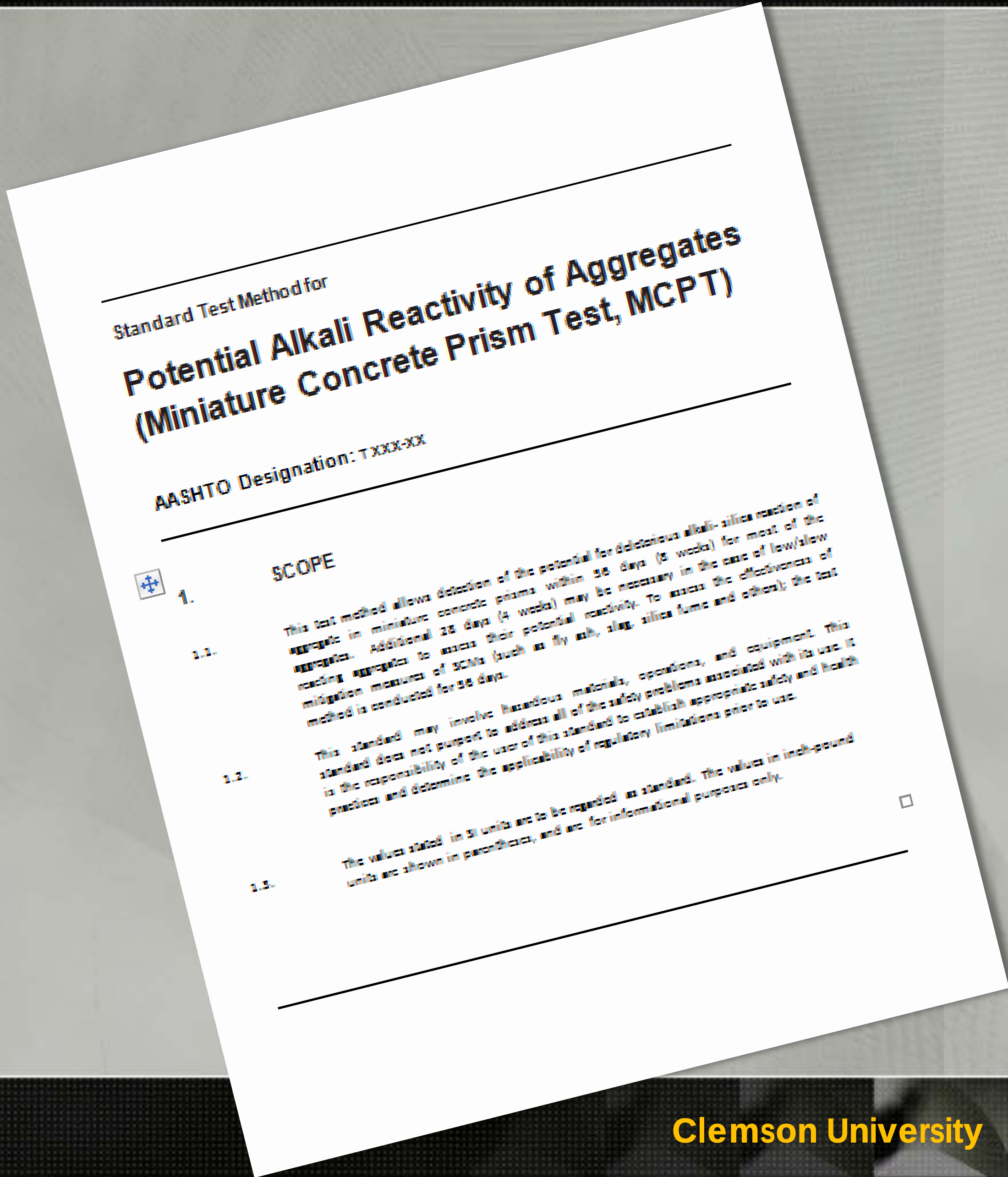


# Proposed Criteria for Evaluation of SCMs

| 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% |

# MCPT - AASHTO Test Method

- **AASHTO has approved this method as a provisional standard AASHTO TP 111**



# Multi-Lab Variability in Results of MCPT

- **Four different aggregates were used:**
  - **Spratt Siliceous Limestone (R-CA)**
  - **Adairsville Limestone (NR – CA)**
  - **McCombs Sand (R-FA) (formerly Jobe Sand)**
  - **Glasscock Quartz sand (NR – FA)**

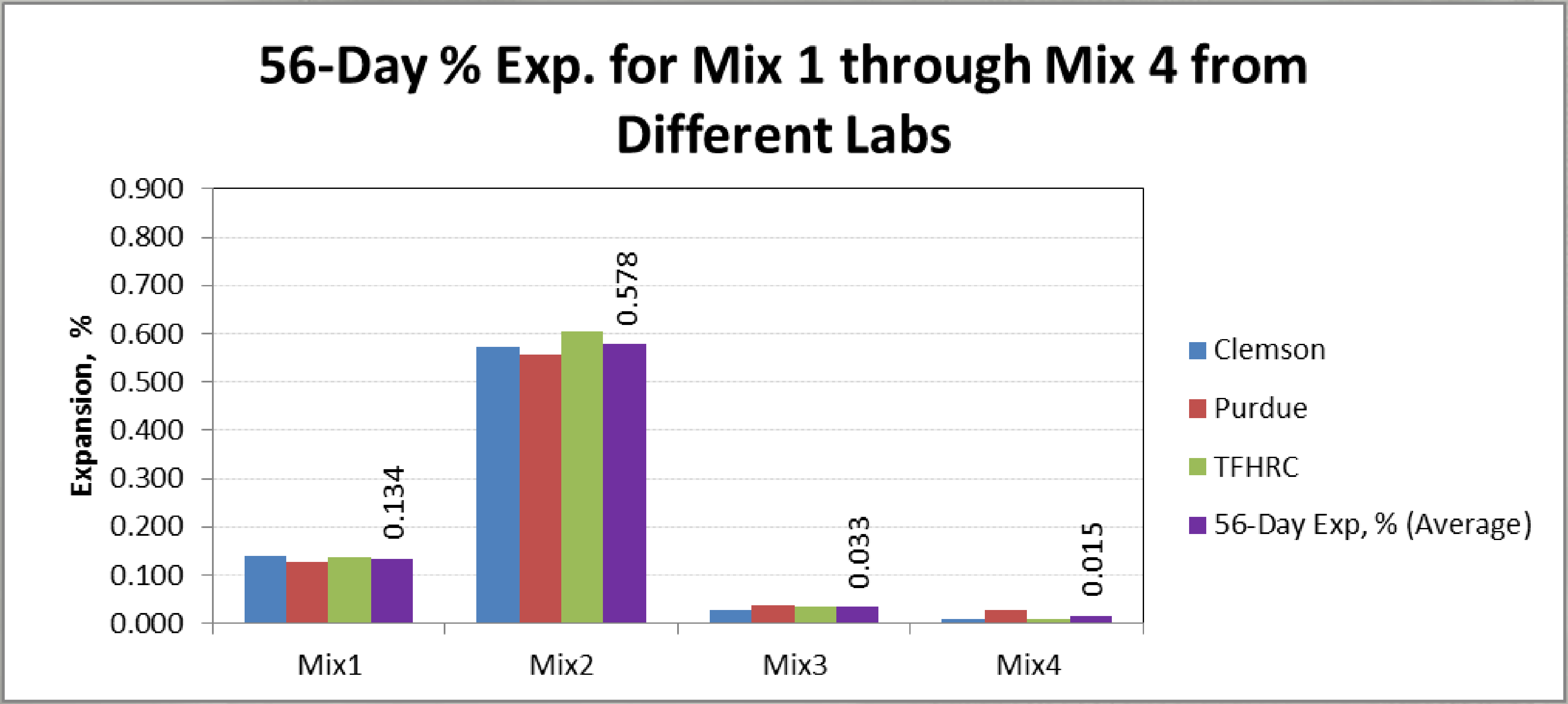
- **Six different labs were involved in this study**
  - **Turner-Fairbank Highway Research Center**
  - **Nebraska Dept. of Roads**
  - **Delaware Dept. of Transportation**
  - **Bowser-Morner, Inc.**
  - **Purdue University**
  - **Clemson University**

# Test Matrix for Multi-Lab Variability in MCPT

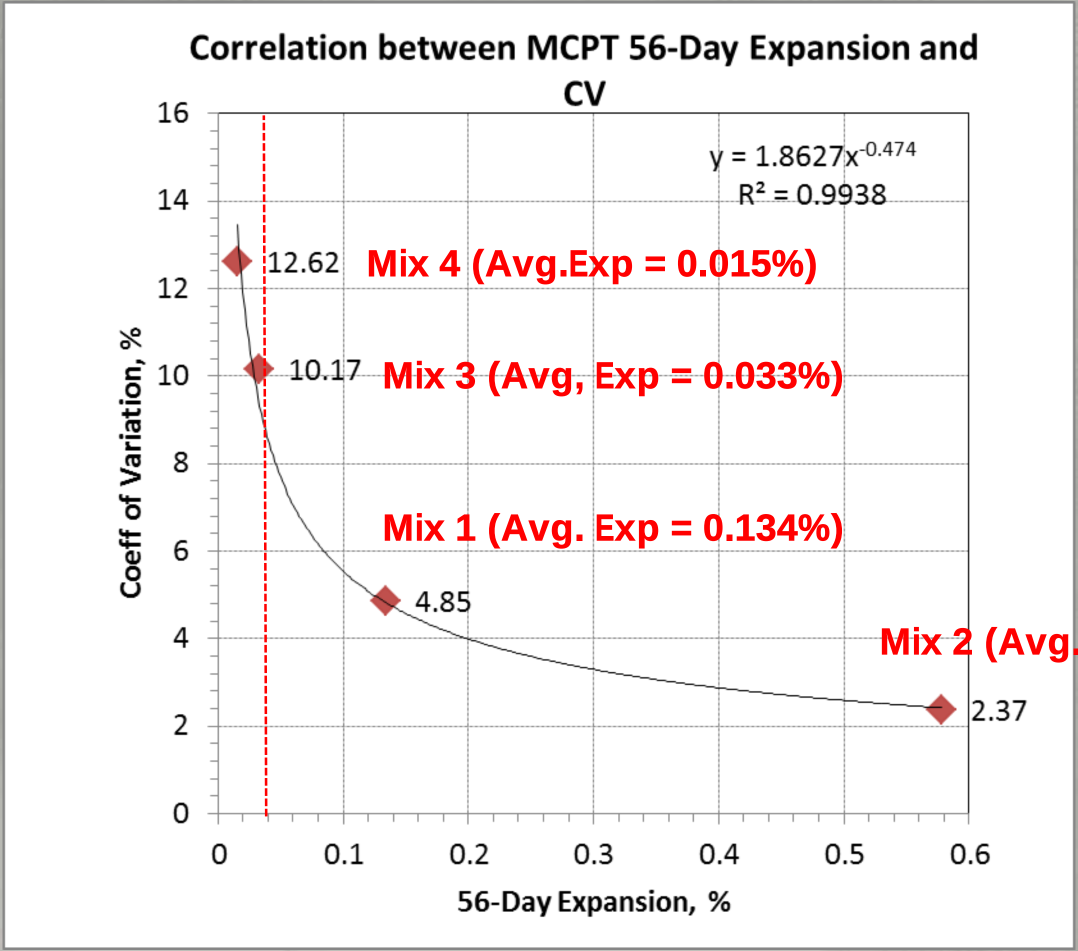
| Mix # | Coarse Aggregate | Fine Aggregate | SCM |
|---|---|---|---|
| 1 | Spratt Limestone (Reactive) | Glasscock Sand (Non-Reactive) | -- |
| 2 | Adairsville Limestone (Non-Reactive) | McCombs Sand (Reactive) | -- |
| 3 | Adairsville Limestone (Non-Reactive) | Glasscock Sand (Non-Reactive) | -- |
| 4 | Spratt Limestone (Reactive) | Glasscock Sand (Non-Reactive) | 25% Class F Fly Ash (CaO content = 1.24%) (S+A+F content = 84.8%) |

1. Turner-Fairbank Highway Research Center
2. Nebraska Dept. of Roads
3. Delaware Dept. of Transportation
4. Bowser-Morner, Inc.
5. Purdue University
6. Clemson University

# Round-robin Test Results



# Correlation between 56-Day % Exp. and COV



# Where do we stand with MCPT now?

# MCPT Status

- AASHTO approved this method as provisional standard – AASHTO TP 111
- Excellent correlation between 56-day MCPT Expansion and 365-Day CPT Expansion
- Ability to distinguish slow/low reactivity aggregates
- Ability to identify both ASR and ACR prone aggregates
- In short, MCPT provides a reliable alternative to AMBT and a rapid alternative to CPT

# Future Direction

- **Need to coordinate a multi-regional and multi-state effort to conduct a round-robin test to develop precision and bias statements for this method**

- **Need to develop a robust correlation between MCPT and field performance (Regional outdoor exposure sites)**

- **Need to explore the possibility to evaluate ASR potential of job concrete mixtures.**

- **Need to study the effect of companion non-reactive aggregates as well as of cement composition on test results.**

# Request for States

- To participate in a pooled-fund study to develop MCPT method into a more comprehensive tool to deal with AAR issues in concrete
- Primary research needs are:
  - Round-robin study to establish robustness, precision & bias statements
  - Correlation with field performance on a more broader basis (outdoor exposure sites, False +ve and False -ve aggregates)
  - Develop a framework to evaluate AAR potential of job concrete mixtures (with emphasis on pessimum behavior)

# Influence of Job Mix Parameters on ASR

- **Typical job mix parameters that differ from the standard MCPT method are:**
  - **w/c and 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**

- **Influence of regional temperature and moisture variations on ASR progression/mitigation in concrete**

# Cancer in Concrete (ASR)


**Questions?**

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