

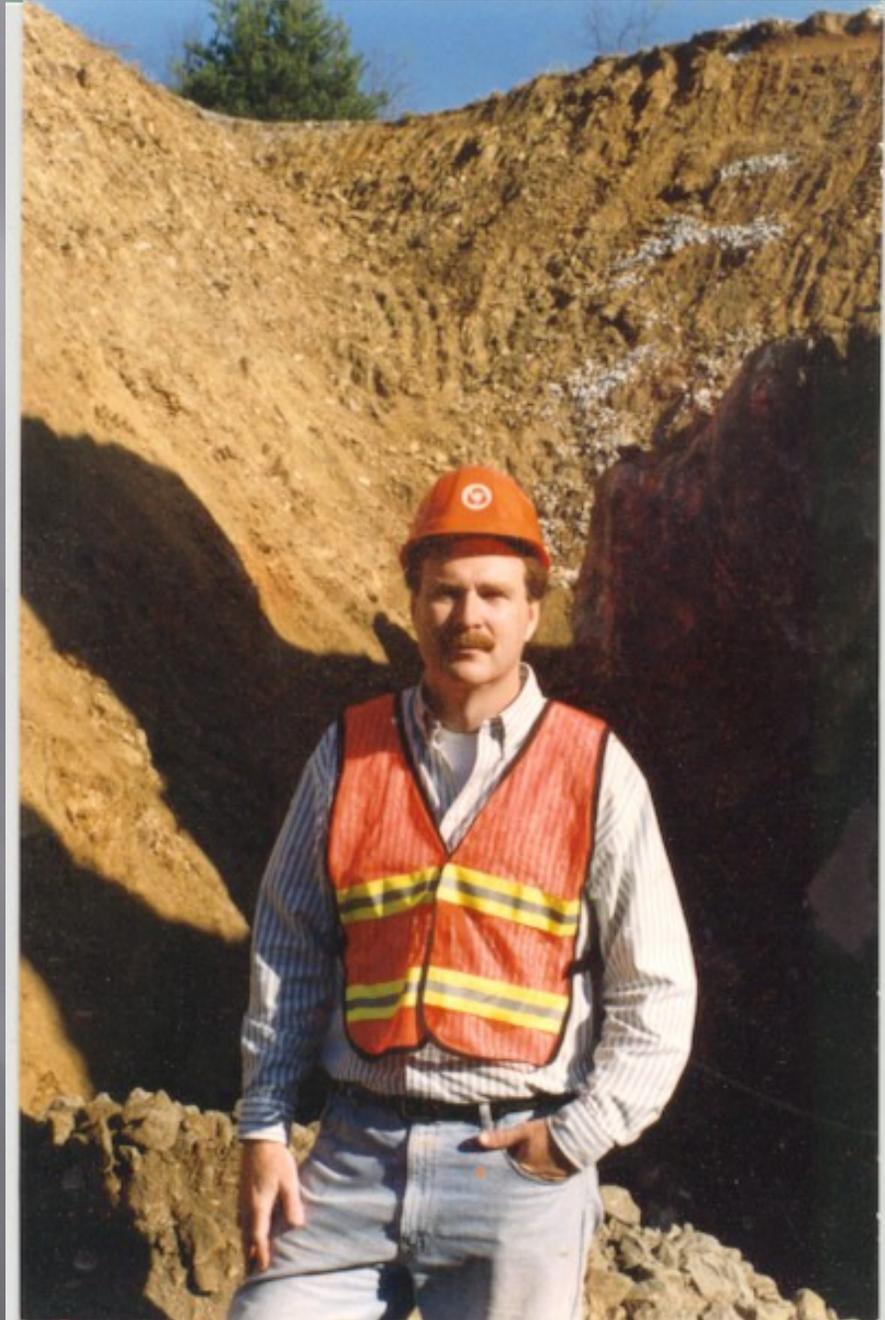
The logo for Alkali Silica Reaction (ASR) features the letters 'A', 'S', and 'R' in a bold, 3D, cyan font. The letters are set against a black rectangular background that is partially obscured by a white diagonal banner.The background of the slide is a photograph of a large concrete bridge with a series of arches and a railing, viewed from a low angle looking up. The sky is overcast with grey clouds.

Alkali Silica Reaction

Henry and Hank, P.E.'s

What is ASR?







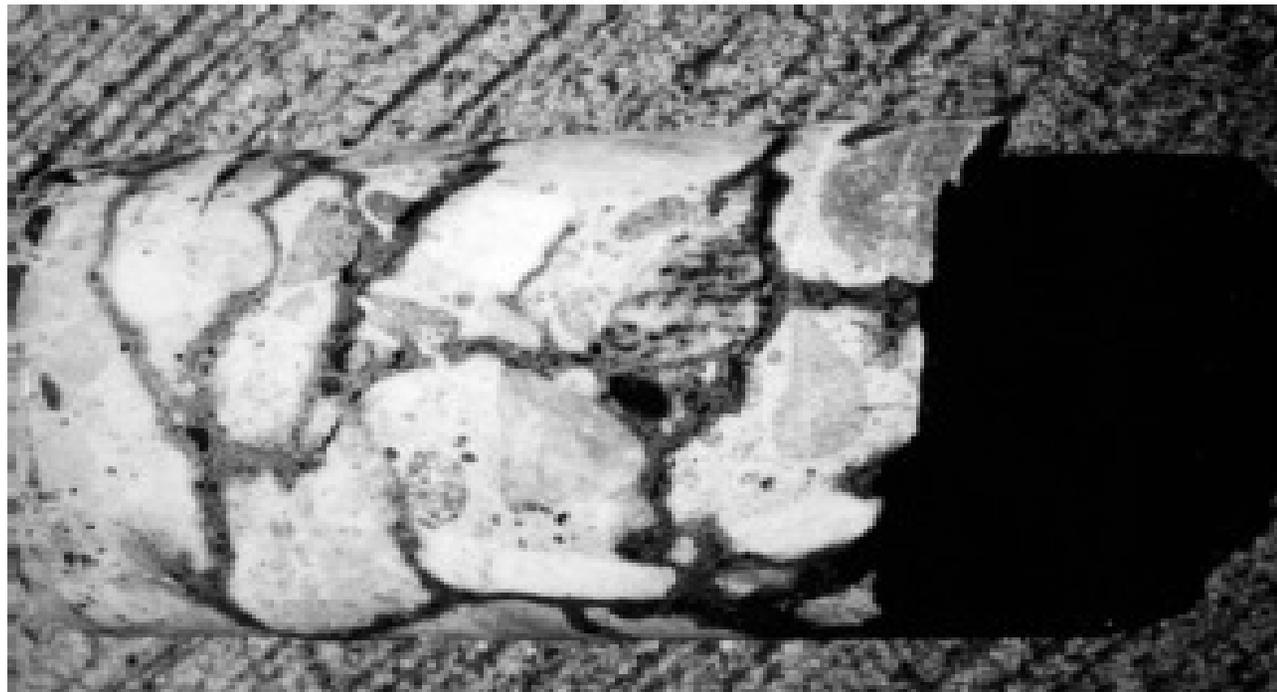
Bridge Deck U.S. Rt. 68 and MD Rt. 55



Courtesy of Maryland State Highway Administration

Cracking Mechanism

- ▣ Bridge deck core showing both the vertical and horizontal cracking due to ASR.





U.S. Rt. 50 and Rt. 301



Courtesy of Maryland State Highway Administration

U.S. Rt. 1 over Little Gunpowder Falls



Courtesy of Maryland State Highway Administration

MD Rt. 100 and Rt. 301



Courtesy of Maryland State Highway Administration

Transmission Pole U.S. 301, AA County



Courtesy of Maryland State Highway Administration

Transmission Pole Foundation



Courtesy of Maryland State Highway Administration

Sidewalk



Courtesy of Maryland State Highway Administration

ASR Challenges

ASR leaves concrete in such a weakened condition that normal stresses become fatal, stresses that otherwise would not destroy the concrete.

Concrete Products, April 1996



Strategic Highway Research Program, Washington, D.C. 1991

History



Thomas Stanton, California Department of Highways

ASR Process

Step One:

Silica in aggregates reacts with alkali in cement to produce a gel.

Step Two:

The gel absorbs water, causing expansion and hydraulic pressures sufficient to fracture and break apart the concrete.

Process Requirements:

Sufficient moisture (80% RH).
Reactive silica.
Source of alkali.



Strategic Highway Research Program, Washington, D.C. 1991

ASR Reactivity Factors

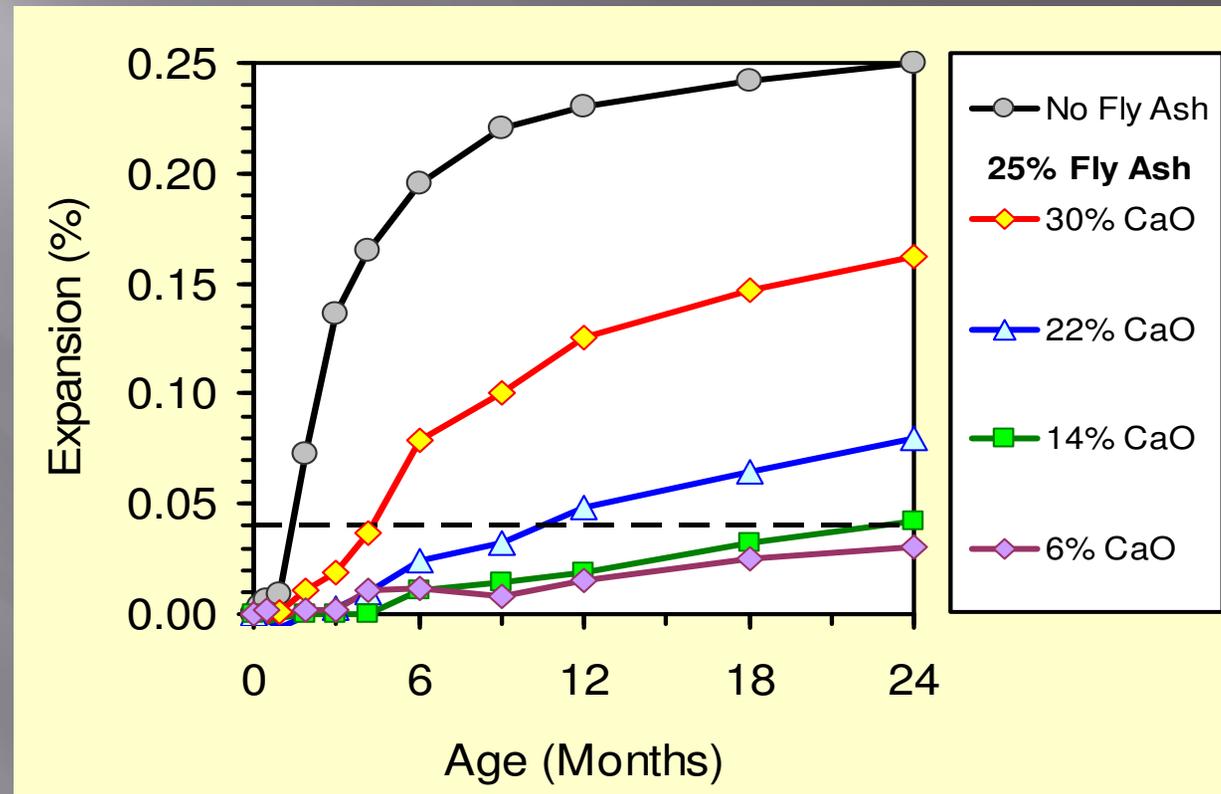
- ▣ Most vulnerable parts of a concrete structure are those exposed to a warm and humid environment.
 - Repeated drying and wetting cycles is more likely to develop excessive ASR than concrete stored at a uniform content
 - Excessive ASR occur in concrete embedded in moist soil, such as basis and foundations

Preventive Measures

There are four basic levers to control ASR in concrete:

- Use non-reactive aggregates
- Control the total alkalis in concrete
- Keep the concrete dry
- Use supplementary cementing materials

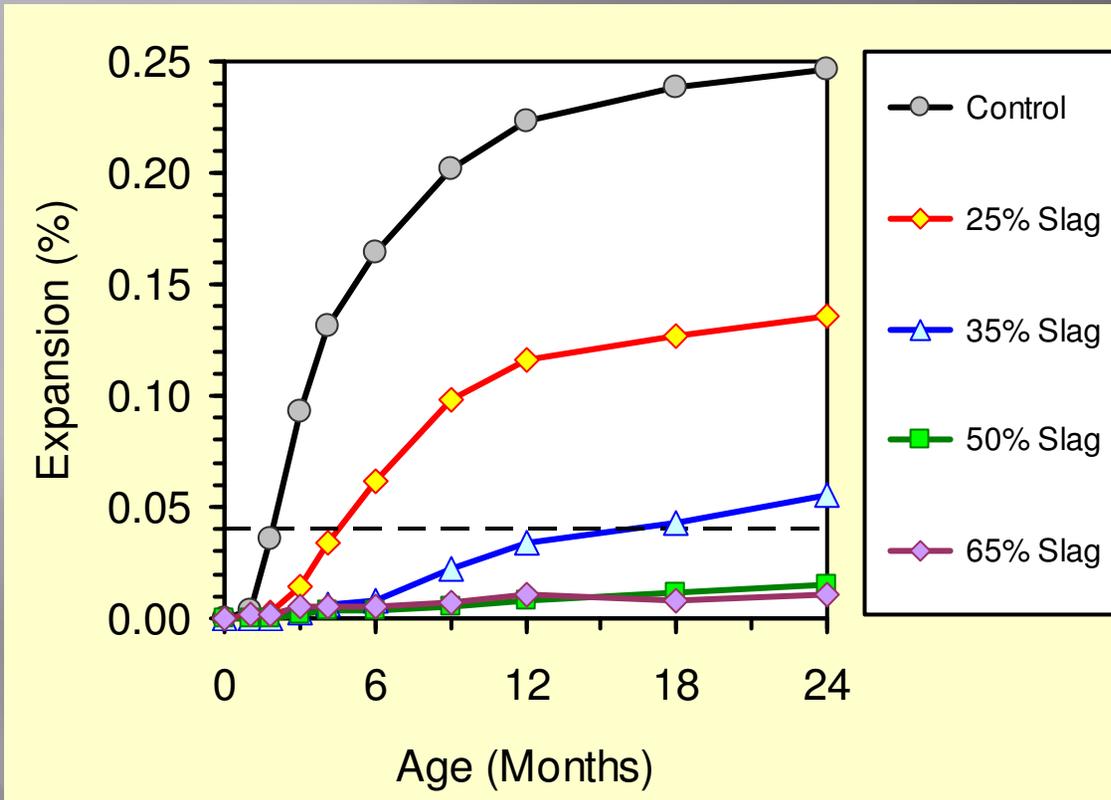
Effect of FA composition on ASR : calcium content



The efficiency of FA in controlling ASR tends to increase as :

- FA content increases (whatever the FA composition)
- calcium content of FA decreases

Effect of Slag content on ASR



Thomas & Innis, 1998

Limit (CSA): $\text{Exp} \leq 0.04\%$

The efficiency of Slag in controlling ASR increases as: Slag content increases

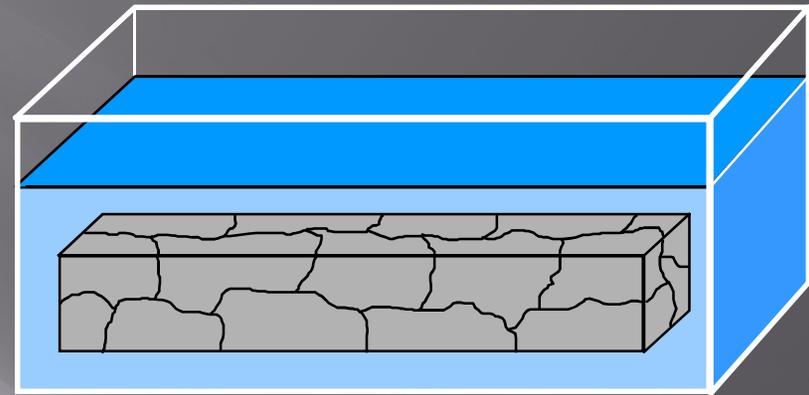
Current State Spec

- ▣ Test aggregates by ASTM C1260
- ▣ If aggregates are reactive:
 - Use low alkali cement
 - Use slag cement, fly ash or silica fume and test in accordance with ASTM C1567 (MSMT equivalent)
 - Switch to non reactive aggregates

Test Methods

Most test methods involve:

1. Manufacturing mortar bars or concrete prisms
2. Storing either in a moist room or in high alkali solutions
3. Storing at standard or high temperatures
4. Measuring expansion



Test Methods - ASTM C 227 Potential Reactivity of Cement Aggregate Combinations

- ▣ High alkali cement used to make mortar bars
- ▣ Length change tested at 3 and 6 months
(expansions of .05% and 0.10%, respectively)
- ▣ Not good for slowly reacting aggregates

Test Methods

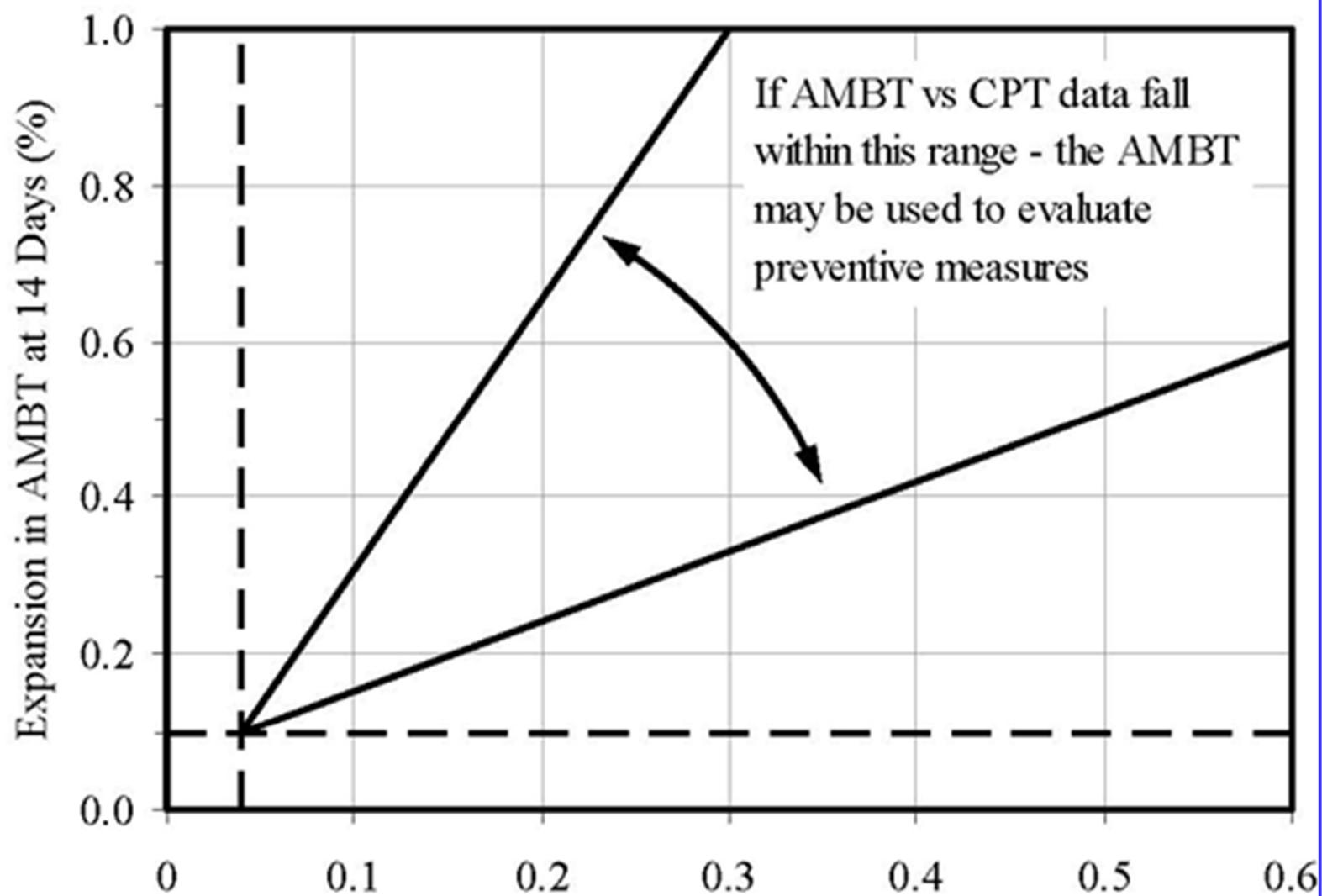
ASTM C 1260 - Potential Alkali Reactivity of Aggregates (Mortar Bar Method)

- ❑ Mortar bars stored in high alkali solution at high temperatures
- ❑ Length measurements taken over a period of 14 days
- ❑ Expansion less than 0.10% - Innocuous?
- ❑ Expansion between 0.10 and 0.20% - May or may not be a problem
- ❑ Expansion greater than 0.20% - Deleteriously reactive
- ❑ May give false positives and false negatives
- ❑ Some researchers feel that 0.08% is a better limit
- ❑ Does not take into account the alkalis of the cementitious materials

Test Methods

ASTM C 1567 - Test Method for Determining the Potential Alkali Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated mortar Bar Method)

- ❑ Mortar bars stored in high alkali solution at high temperatures
- ❑ Length measurements taken over a period of 14 days
- ❑ Expansion less than 0.10% - Innocuous?
- ❑ Expansion between 0.10 and 0.20% - May or may not be a problem
- ❑ Expansion greater than 0.20% - Deleteriously reactive
- ❑ May give false positives and false negatives
- ❑ Some researchers feel that 0.08% is a better limit
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Test Methods

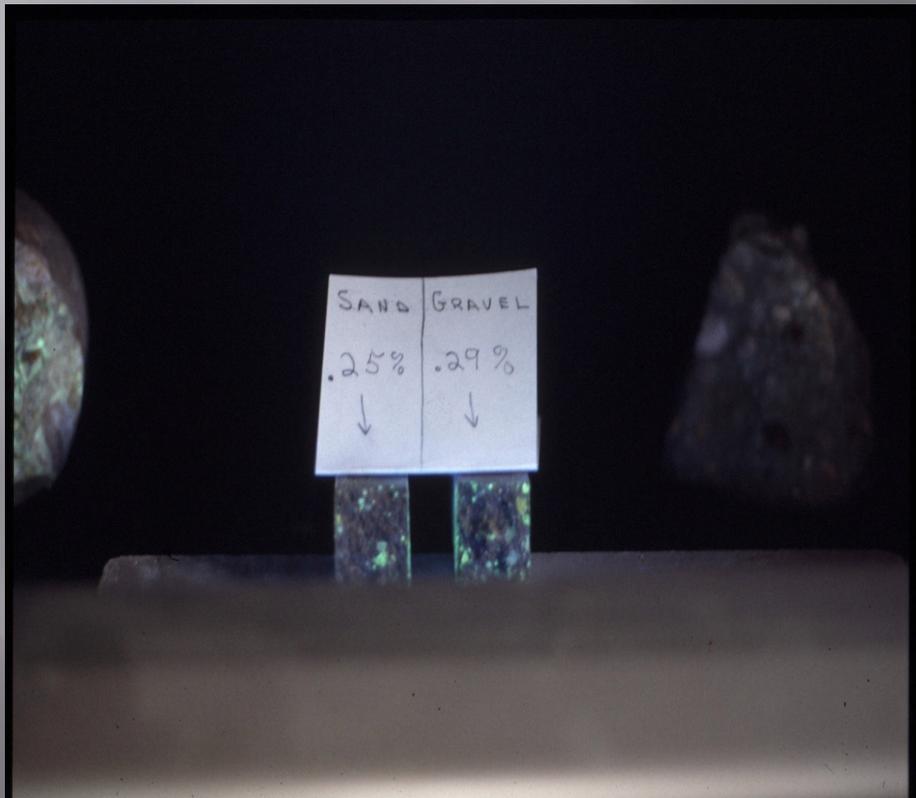
ASTM C 1293 - Test Method for Determination of Length Change of Concrete Due to Alkali Silica Reaction

- ▣ Concrete prisms cast and placed in high alkali solution
- ▣ Measurements made out to 1 year
- ▣ Expansion must be less than 0.04%
- ▣ Does not take into account alkalis of the cement

Test Methods

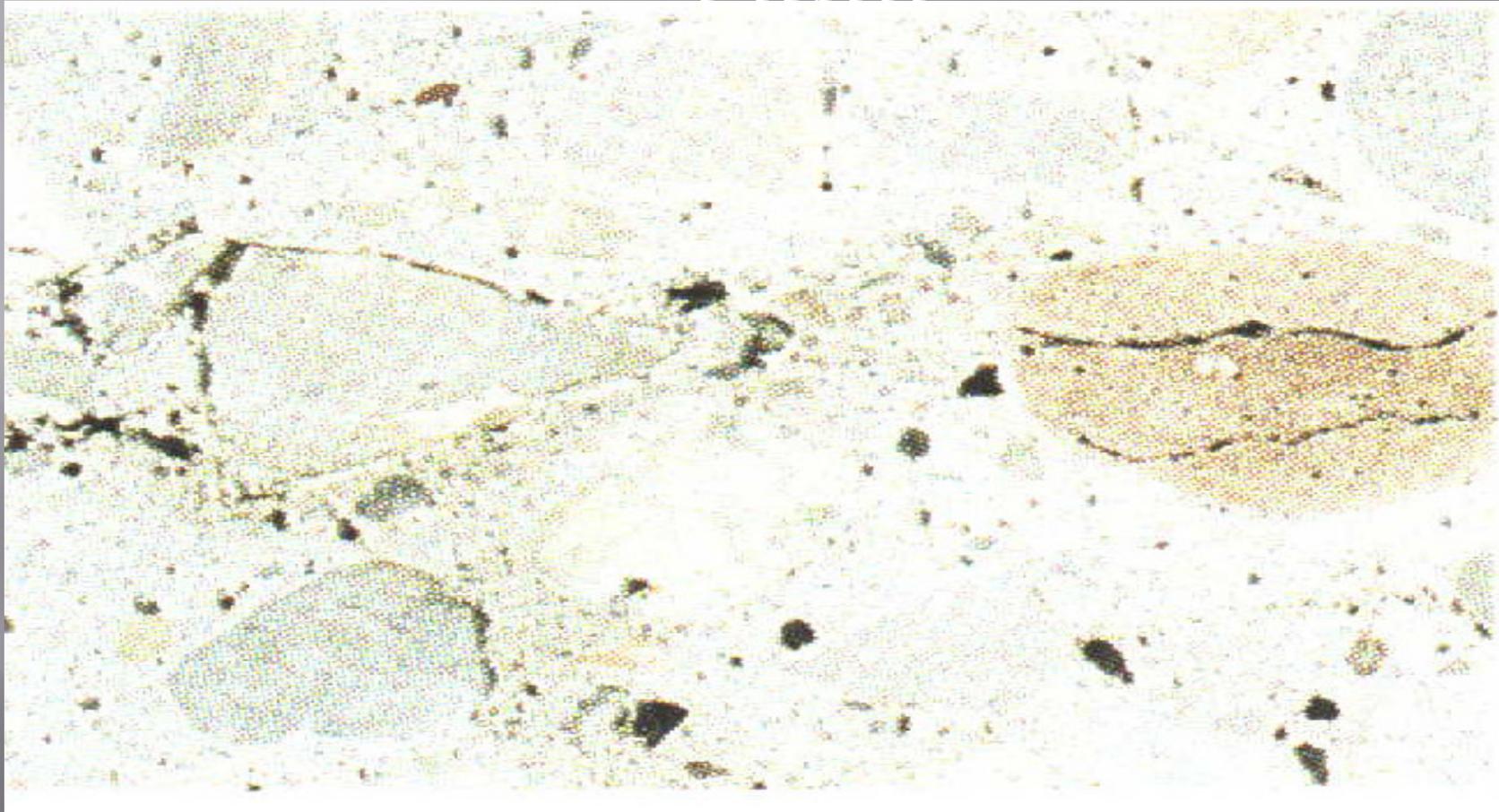
- ▣ ASTM C 295 - Petrographic Examination of Aggregate for Concrete
- ▣ Field Performance

Gel Fluorescence Test

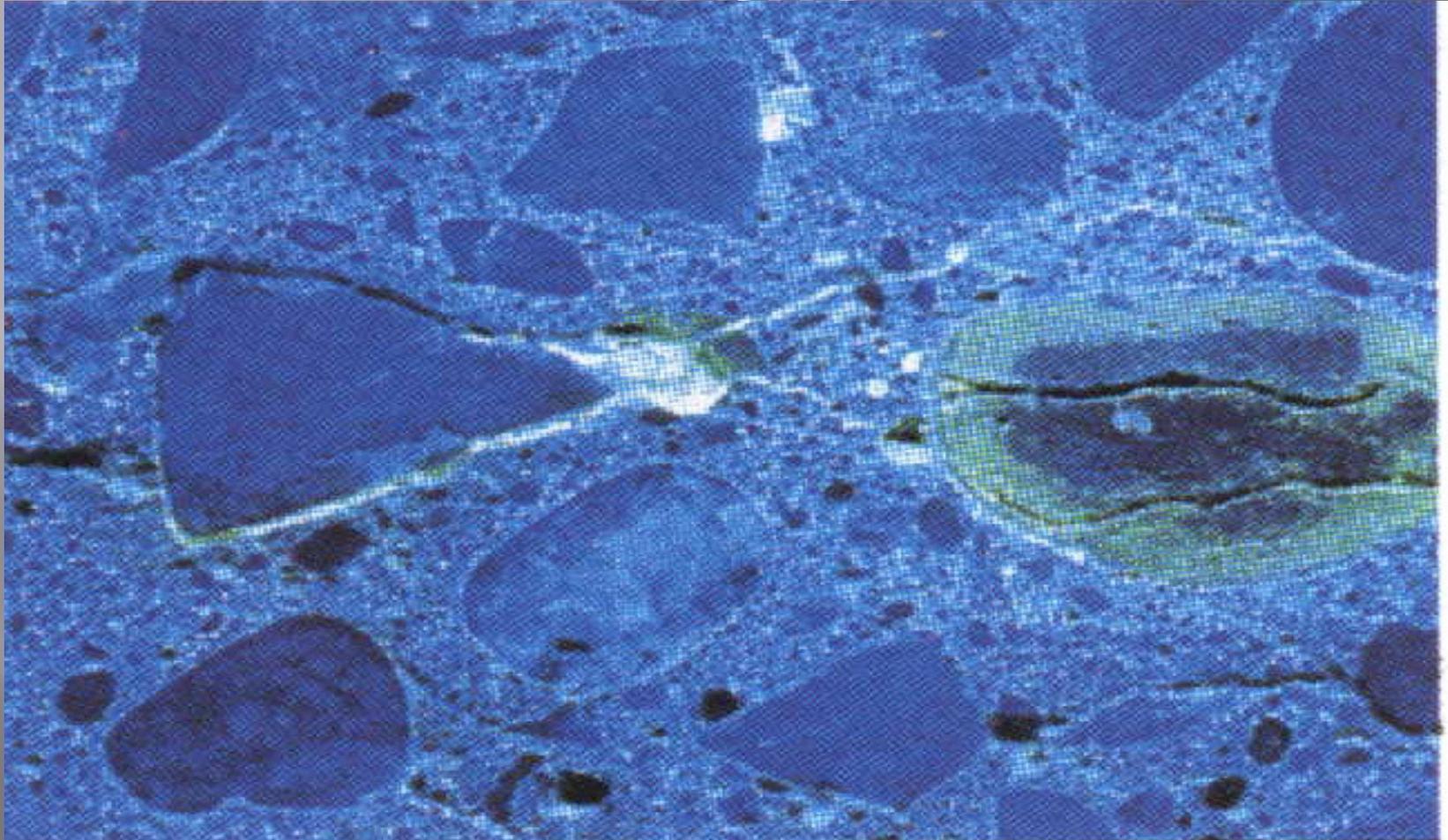


- Spray uranyl acetate solution on exposed surface
- View under ultraviolet illumination

Specimen Under Normal Light



Specimen under ultraviolet light



KILROY'S
of
Kathmandu
Restaurant & Bar



CURRENT STATE OF ASR MITIGATION AND MSHA NEW REQUIREMENTS

What's New in 20 Years?



**1995 - Motorola
Cell Phone**



iPhone 6 Plus

What's New in 20 Years?



2014 – MacBook Air

What's New in 20 Years?



2015 – Mustang GT

AASHTO PP65-11

Standard Practice for

**Determining the Reactivity of
Concrete Aggregates and Selecting
Appropriate Measures for
Preventing Deleterious Expansion
in New Concrete Construction**

AASHTO Designation: PP 65-11

AASHTO PP65-11

Technical Report Document

1. Report No. FHWA-HIF-09-001	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Report on Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction	7. Author(s) Michael D.A. Thomas, Benoit Fournier, and Kevin J. Folliard	5. Report Date April 2008
		6. Performing Organization Code
9. Performing Organization Name and Address The Transtec Group, Inc. 6111 Balcones Drive Austin, TX 78731	12. Sponsoring Agency Name and Address Office of Pavement Technology Federal Highway Administration 1200 New Jersey Avenue, DE Washington, DC 20590	8. Performing Organization Report Number
		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DTFH61-D-00035
		13. Type of Report and Period Covered Final Report April 2008
		14. Sponsoring Agency Code

AASHTO PP65-11

- ▣ Identify potentially reactive aggregates
- ▣ Select preventative measures to minimize risk

Identify Reactive

- ▣ Field Experience
 - Min 10 years, same cement and aggregate
 - Cores, petrographic analysis
- ▣ Aggregate Petrographic Analysis reactive?
- ▣ ASTM C1293 Concrete Prism Test (CPT)
 - Concrete prisms, 1 year results
 - Expansion under .04% = innocuous
 - PP65 recommends as most reliable aggregate test



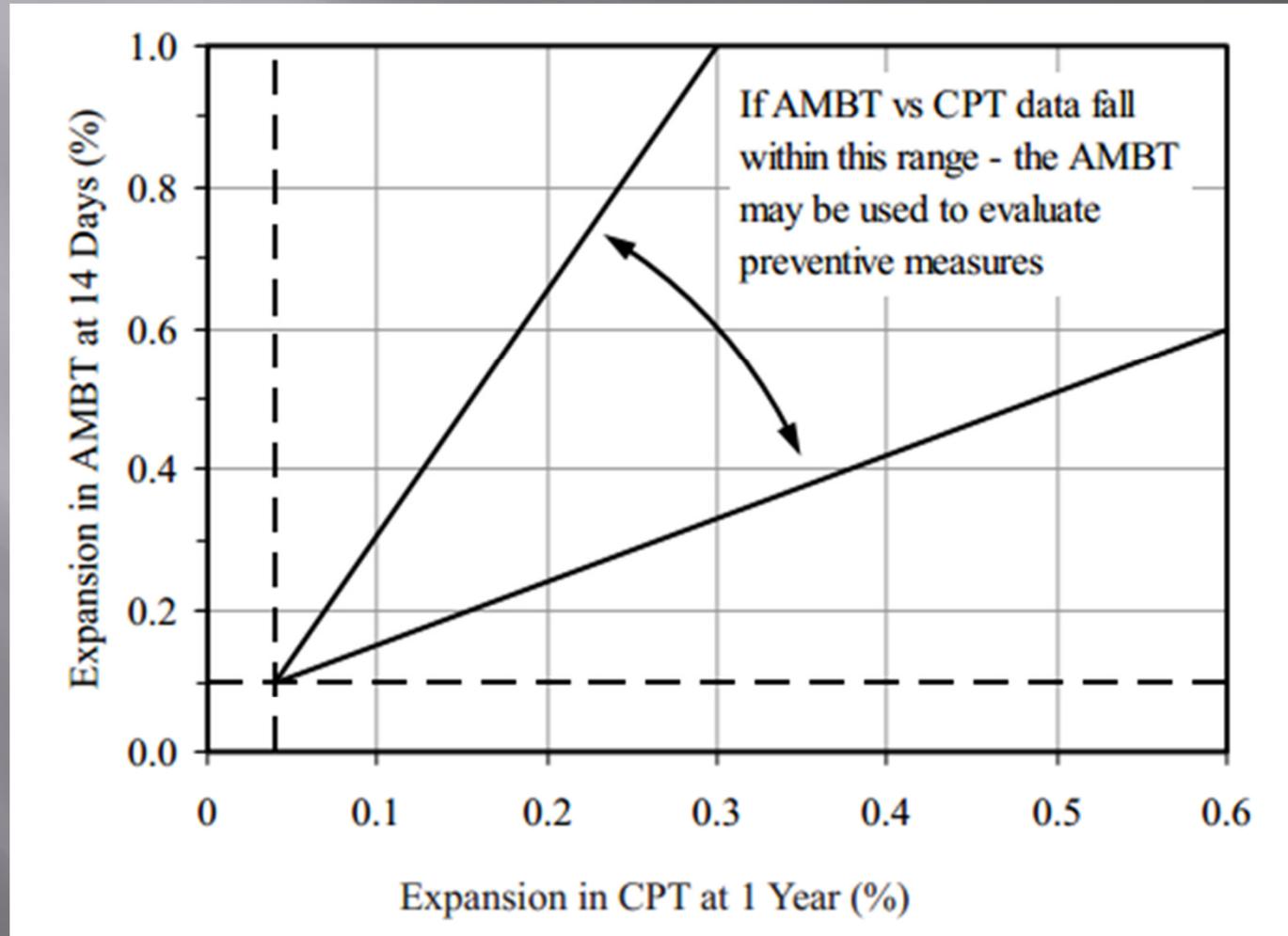
Preventative Measures

- ▣ Avoid Reactive Aggregates
- ▣ Performance: Use chemical or mineral admixtures (SCM's) and test for expansion
- ▣ Prescriptive: Limit amount of alkalis in mix design
- ▣ Prescriptive: Dosage of mineral admixtures (SCM's) based on aggregates, structure, etc.

Use SCM's or Chemical Admix

- ▣ Propose strategy: mix design with SCM or lithium dosage or low alkali cement
- ▣ Test with ASTM C1293 CPT
 - Acceptable if expansion less than 0.04% after **2 YEARS**
- ▣ Test with ASTM C1567, 14-day AMBT
 - Acceptable if expansion less than 0.10% , AND
 - Good correlation between AMBT and 1 year CPT

C1293 and C1260 Compared



Thomas, M.D.A., 2008

Limit Alkalies in Mix

- ▣ Low Alkali Cement: $\leq 0.60\%$ NaO_2equiv
- ▣ Better Approach: Calculate Mass of Alkalies per cubic yard

$$620 \text{ lb/cy cement} \times 0.64\% \text{ NaO}_2\text{eq} =$$

4 lb/cy

- ▣ Three levels: 5 lbs, 4 lbs, 3 lbs

Prescriptive SCM Dosages

- ▣ Reactivity of Aggregates- Moderate, Highly, Very Highly reactive
- ▣ Exposure conditions – Dry, Wet, Exposed to seawater or deicers
- ▣ Structure Class – S2 sidewalks; S4 major bridges and tunnels
- ▣ Prevention Levels: minimum dosage of fly ash, slag, and silica fume

NEW MSHA Specification

- ▣ Test Aggregates using 1-year CPT and 14-day C1260 (AMBT) every 3 years to determine Reactivity Class and reliability of C1260.

Reactivity Class	ASTM C 1293
R0	Expansion \leq 0.04
R1	0.04 < Expansion \leq 0.12
R2	0.12 < Expansion \leq 0.24

Mitigation Option 1

Prescriptive SCM Dosages

SCM Replacement	Cement equivalent alkalis ≤ 0.70		0.70 < Cement Equivalent alkalis ≤ 1.00	
	R1	R2	R1	R2
Class F Fly Ash	20	25	25	25*
Slag Cement	35	50	50	50*
Slag and F Ash	**	**	**	**

* The alkali content of the concrete shall be less than 3.0 lb/yd³

** Fractional combinations of SCM's used together must equal or exceed 1.

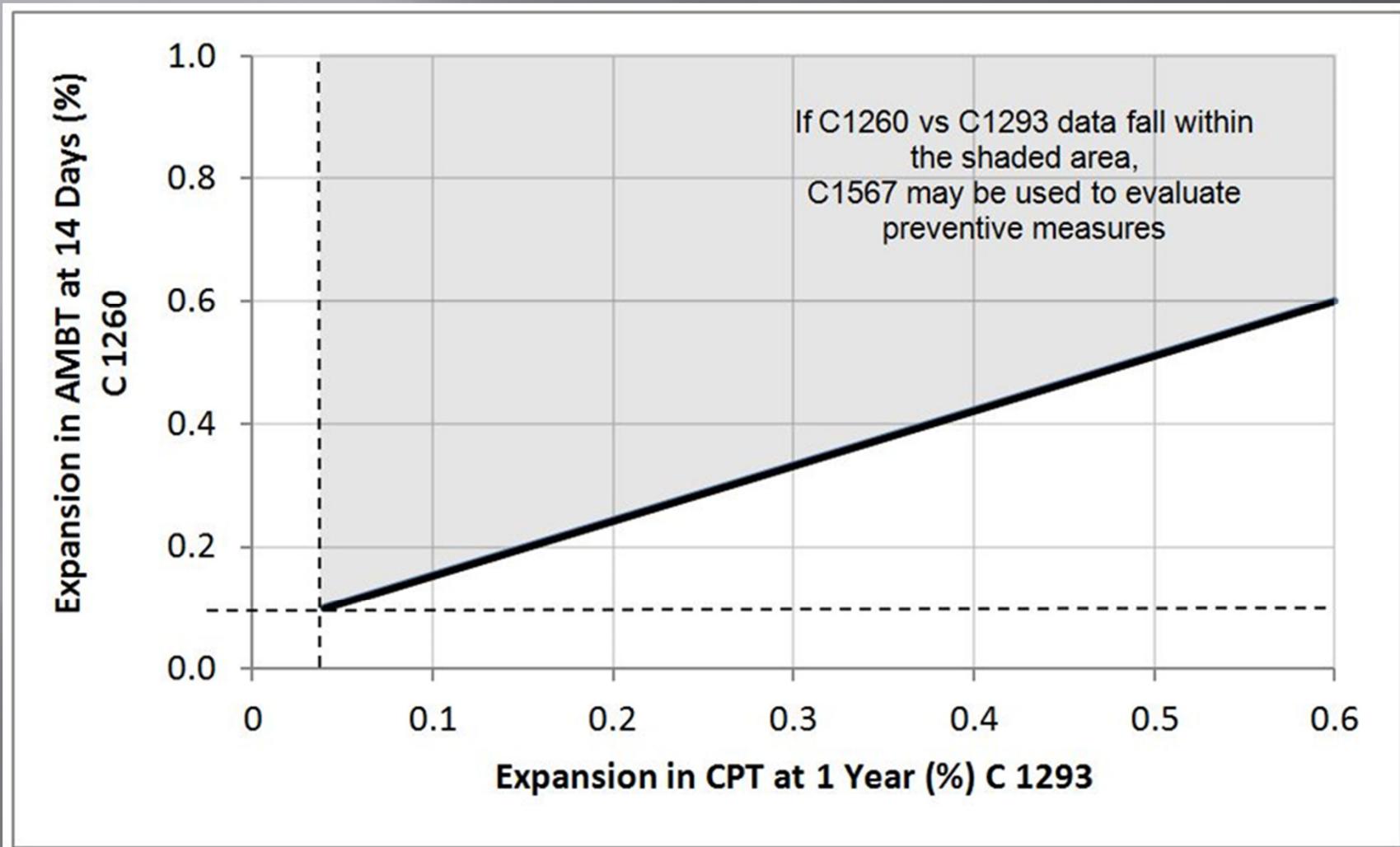
Mitigation Option 2

Prequalify Mix with Testing

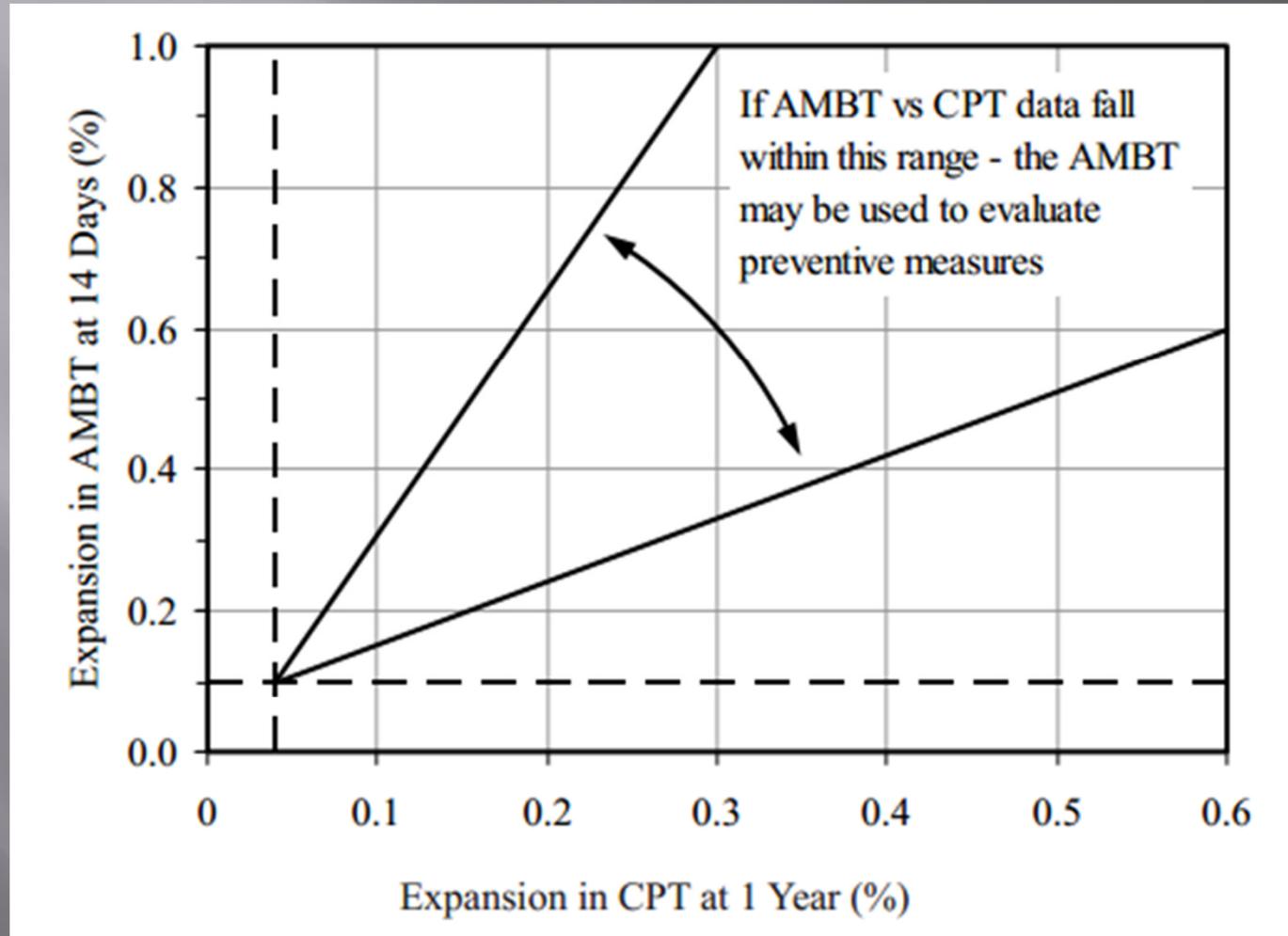
- ▣ Test proposed mixture using ASTM C1567.
- ▣ Acceptable if expansion is less than 0.10% at 14 days.
- ▣ Assumes good relationship between 1-year prism test (CPT) and 14-day C1260 test (AMBT).

Mitigation Option 2

Prequalify Mix with Testing



C1293 and C1260 Compared



Thomas, M.D.A., 2008

Mitigation Option 3

Prescriptive Alkali Limit

- ▣ For R1 aggregates only, limit mass of alkalis to 3 lbs per cubic yard.
- ▣ Only use cement alkalis
- ▣ Class F dosage range: 15% min to 25% max

Questions?

- ▣ Henry Prenger, P.E. – henry.prenger@lafargena.com
- ▣ Hank Keiper, P.E. – hkeiper@sefagroup.com