ASR Research in Texas

Brian D. Merrill, P.E.

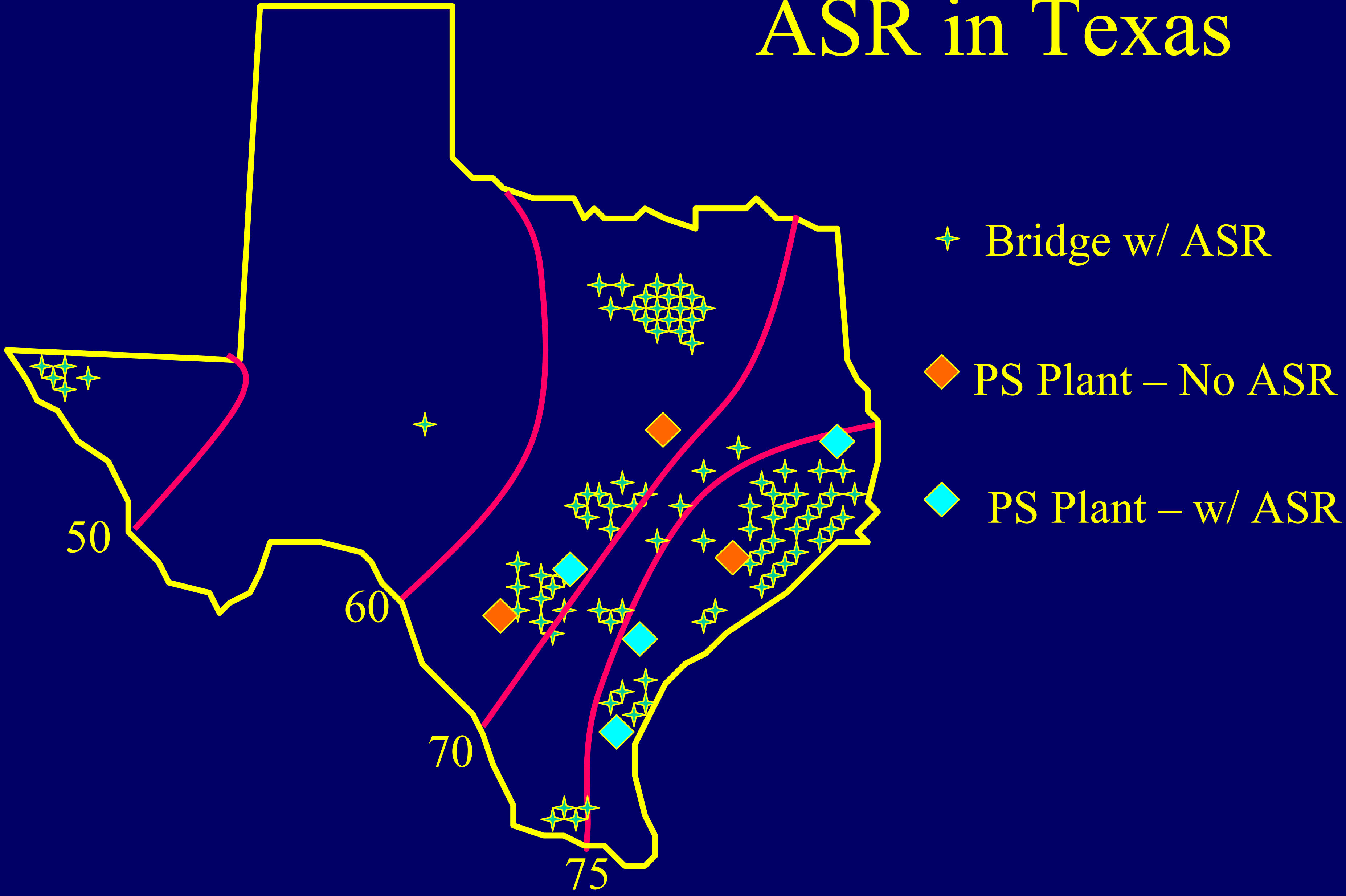
State Bridge Construction & Maintenance Engineer

Where is ASR Found in TX?

- Mainly in bridge structures
- A few isolated pavements

- 1st Showed up in 1994 (girders cast in 1988)
- Initial confusion over cause: ASR vs DEF
- Referred to as Premature Concrete Deterioration (PCD)
- Except for ELP, started with concrete from 1986

ASR in Texas



Fundamental Questions on ASR

1. What does it do to a structure?
   a. Have we lost capacity? How much?
2. If we have ASR, what can we do about it?
   a. Can we keep it from getting worse?
   b. Can we stop further cracking?
3. Can we prevent ASR in new concrete?

TxDOT ASR Research Projects

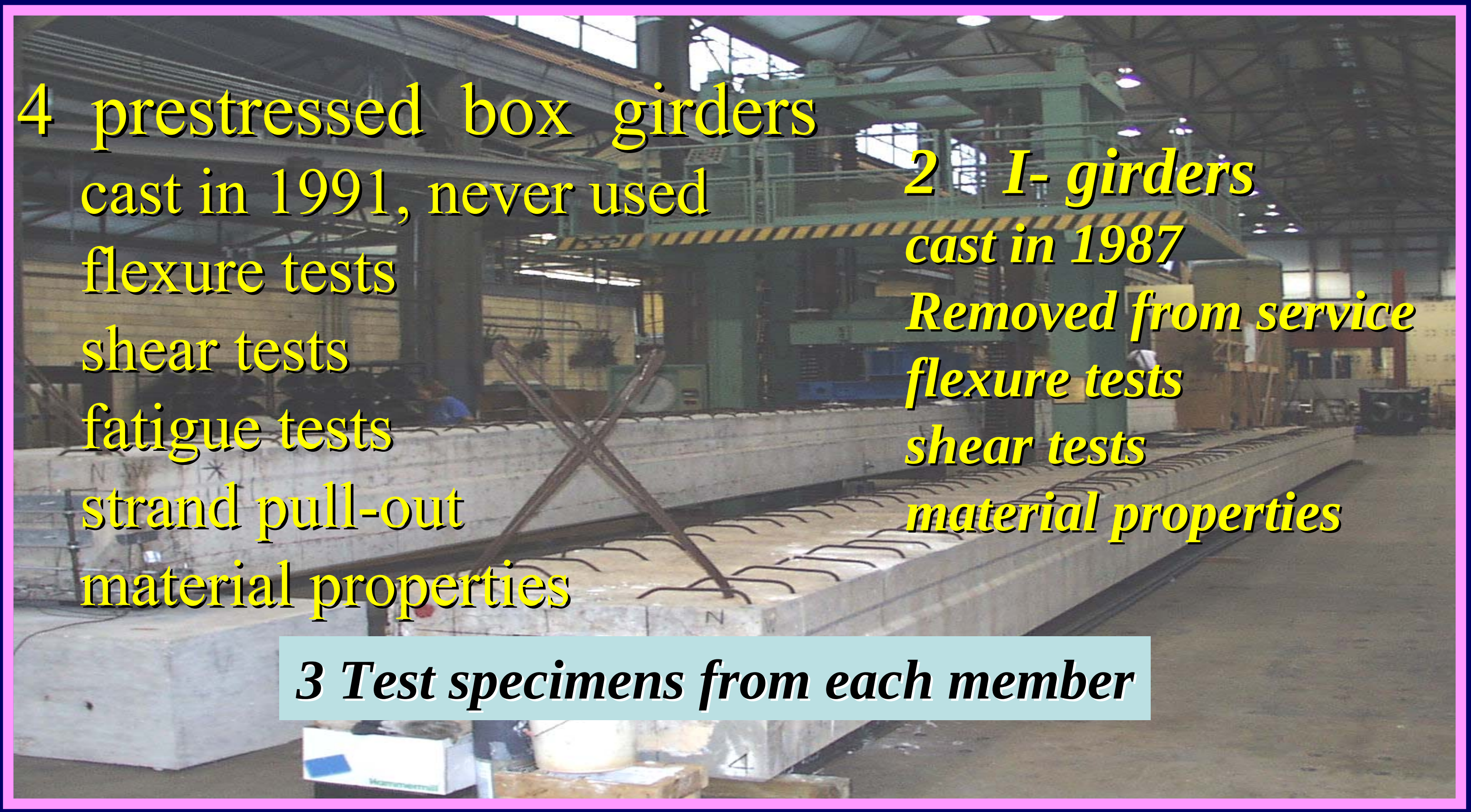
- 0-1857: Structural Assessment of In-Service Bridges
- 0-4069: Mitigation Techniques for In-Service Bridges
- 1521: Lithium Field Trials
- 0-4085: Prevention of ASR in New Concrete
- 0-4183: Improved Test Procedures for ASR
- 0-5218: Large/Unusual Structures – Protocol

TxDOT ASR Research Projects

- 0-5722: Lap Splice & Dev Length
- 0-5997: “D” Region Assessment
- HOU-CTR IAC: Shear Strength of Caps with ASR
- HOU-CTR IAC: Trap Girders
- In-House Testing on ASR in new girders
- *0-6491: NDE for ASR/DEF (field Investigation)*
- *0-6436: Effect of ASR on Rebar Stress*

0-1857: Structural Assessment of In-Service Bridges with Premature Concrete Deterioration (PCD)

Univ. of Texas: Klingner et al



Conclusions

- Flexure: Damage did not affect flexural strength, ultimate deflection, or strand slip
- Shear: Damage caused a loss of shear strength, increase in ultimate deflection, and more strand slip
- Fatigue: Reliable performance under large overload
  - 28,000 cycles to failure at 0.75 Vn
  - > 3 million cycles to failure at 0.50 Vn
- Deterioration can be monitored using crack index:

$\Sigma\ l\, w^2$ in a defined area

Study 0-4069: Effectiveness of Methods to Mitigate Premature Concrete Deterioration

Univ. of Texas: Klingner et al

Objectives

1. Identify or develop test methods for evaluating the effectiveness of treatments
2. Check the reliability of the test method
3. Use the test method to compare the effectiveness of proposed mitigation techniques
4. Based on that comparison , recommend particular mitigation techniques

Mitigation Treatments

	Mitigation Treatment	Abbreviation
M1	TxDOT Surface Treatment –Silane , plus TxDOT Appearance Coat Paint	Sil + 742h
M2	TxDOT Surface Treatment – Silane	Silane
M3	TxDOT Surface Treatment – Silane , plus Class B Type II Latex paint	Sil + latex
M4	TxDOT Surface Treatment – Silane , plus Opaque Concrete Sealer	Sil + opq
M5	Lithium Nitrate , followed by TxDOT Surface Treatment – Silane	Li NO_3 + Sil
M6	Penetrating Epoxy	Epoxy
M7	Control ; no mitigation treatment	Control

Practical Implications of Life Extension due to Mitigation Treatments

- Mitigation Treatment M1 is the most effective mitigation treatment at 0.5 - in. depth
  - Exposure - Time Ratio = 0.64
  - Extended life ≈ Original Life / 0.64 = 1.5
- Mitigation Treatments M1 & M4 are the most effective mitigation treatments at 1.5 - in. depth
  - Exposure - Time Ratio = 0.75
  - Extended life ≈ Original Life / 0.75 = 1.3

Conclusions of Study 4069

- Mitigation Treatment M1 (current TxDOT recommendation) is the most effective mitigation treatment
- Based on laboratory testing of Study 4069 , Mitigation Treatment M1 extends life of treated structures by a factor of 1.3 to 1.5
- *What we don't know is how much life is "lost" due to ASR*

1521 - Lithium Field Implementation Trials

Treating Existing Concrete Exhibiting Distress due to Alkali Silica Reactivity

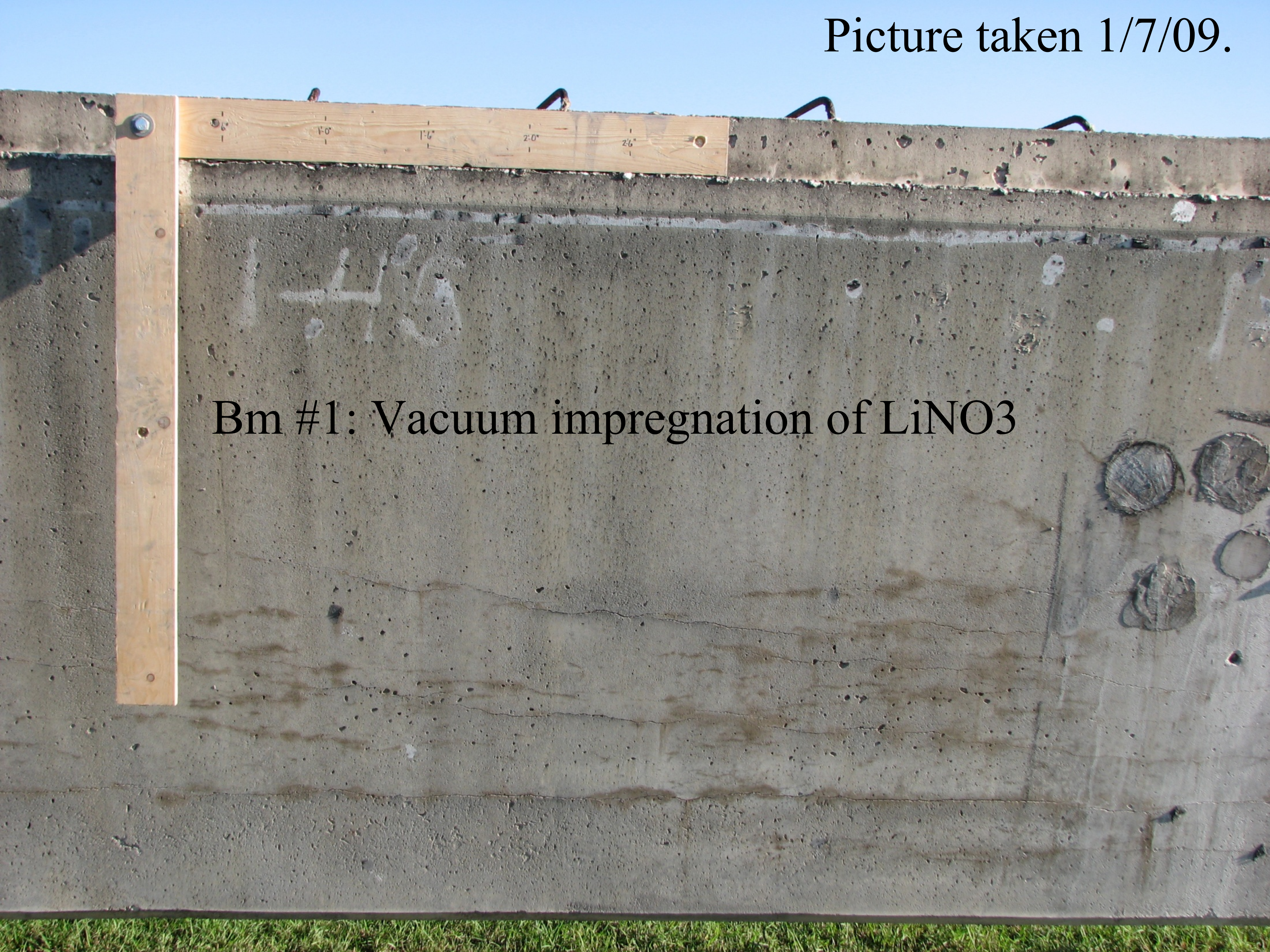
Texas Department of Transportation

Jennifer Moore, P.E.

Treatments

- Beam 1 – Single vacuum application of $LiNO_3$
- Beam 2 – Untreated control.
- Beam 3 – Surface treatment with silane and caulking all open cracks.
- Beam 4 – Surface treatment with silane, caulking all open cracks, and opaque concrete sealer
- Beam 5 – Spray on application of $LiNO_3$ at four separate times.

Picture taken 9/16/04.


Picture taken 1/7/09.
Bm #1: Vacuum impregnation of LiNO3


Picture taken 10/5/04.
1'
1'-6"
2'
2'-6"
3'
5-28
Bm #5: Topical (4x) application of $LiNO_3$


Picture taken 1/7/09.
5-28
Bm #5: Topical (4x) application of LiNO3

Treatments

- Beam 1 – Vacuum application of $LiNO_3$ 2.5
- Beam 2 – Untreated control.
- Beam 3 – Silane and caulking open cracks. 2
- Beam 4 – Silane, caulking cracks, and opaque concrete sealer 2
- Beam 5 – Spray appl (4x) of $LiNO_3$ 4

1 = very effective

5 = ineffective

Project 0-4183
Development of Improved Alkali-Silica Reactivity Test Procedures and Criteria”

TxDOT In-House Project

Project Objectives

- Develop test method that will give reliable results faster than ASTM C 1293
- Generate database of material information for prestressed concrete bridge members

Improved Test Method?

- Modified ASTM C 1293
  - Storage condition temperature increased to 140°F
  - Initial results of these test did not show any good correlations
  - No further work was done by TxDOT.
  - UT started to investigate test method in project 4085

Project 4085 – Preventing ASR/DEF in New Concrete

- Understand relationship between ASR & DEF
- Evaluated existing testing protocols
- Developed guidelines for new specifications
- ID’d and tested mitigation strategies using SCM’s (graveyard)
- Evaluate potential for further ASR/DEF
- Done at UT by Folliard w/ Thomas & Fournier,….

Concrete "Graveyard"

ASR Spec Options

1. Replace 25-35% cement with F flyash
2. Replace 35-50% cement with GGBFS or MFFA
3. Replace 35-50% of cement with F flyash, GGBFS, MFFA, UFFA, metakaolin, or silica fume. Flyash must be < 35% and SF must be < 10%
4. Use Type IP or IS cements (up to 10% repl. with F ash, GGBFS or SF)

ASR Spec Options

5. Replace 35-50% cement with C ash plus >6% SF, UFFA or metakaolin, but C ash < 35% and SF < 10%
6. LiNO3 at 0.55 gal (30% sol’n) per pound of alkalis
7. Straight cement if total alkali content < 4.00 lbs per cy
8. “Out” option. Can test any mix using C1567. All aggregates must have <0.10% expansion. Can’t use certain listed aggregates

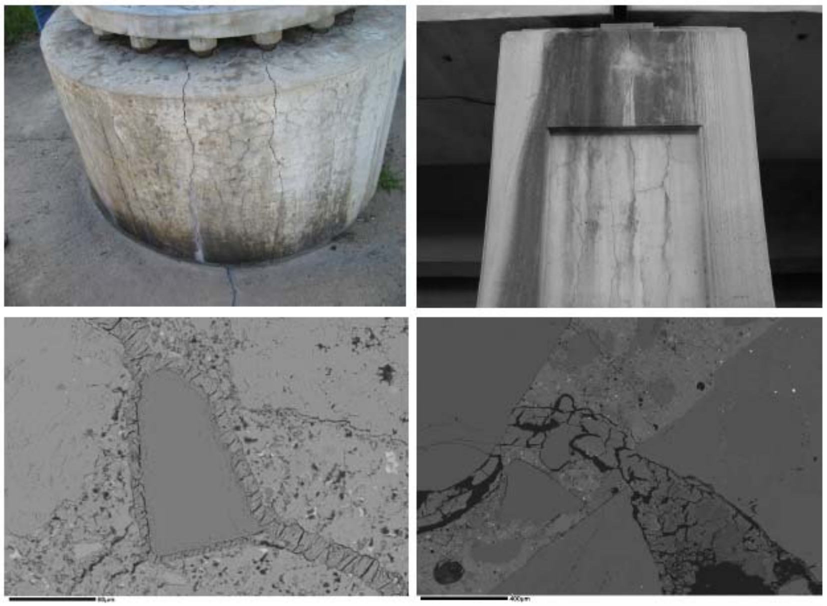
TxDOT Project 5218

Extending the Service Life of Large or Unusual Structures Affected by Premature Concrete Deterioration

Project Objectives

- Develop and implement materials protocol for evaluating structures affected by ASR and/or DEF
- Evaluate and quantify stresses generated by DEF (w/ and w/o ASR)
- Evaluate structural impact of ASR and/or DEF on selected elements from San Antonio Y (SAY)
- Evaluate potential for using lithium nitrate to reduce ASR-induced expansion in field structures.

PROTOCOL
FOR THE DIAGNOSIS AND PROGNOSIS OF CONCRETE STRUCTURES AFFECTED BY ALKALI-SILICA REACTION AND/OR DELAYED ETTRINGITE FORMATION



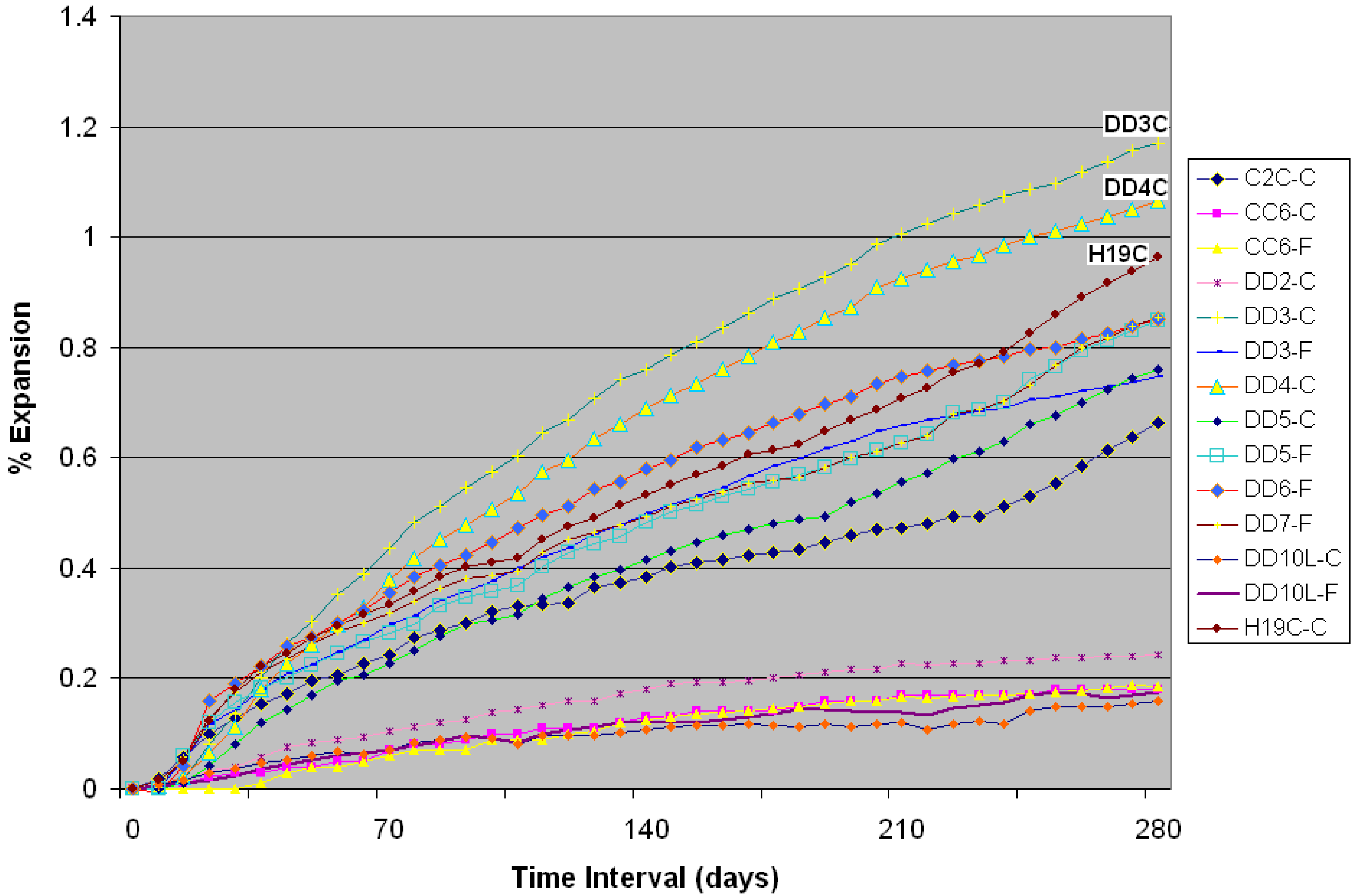
Developed by:
Kevin J. Folliard, Michael D.A. Thomas, and Benoit Fournier

Developed for:
Texas Department of Transportation
TxDOT Project 5218: "Extending the Service Life of Large or Unusual Structures Affected by Premature Concrete Deterioration"

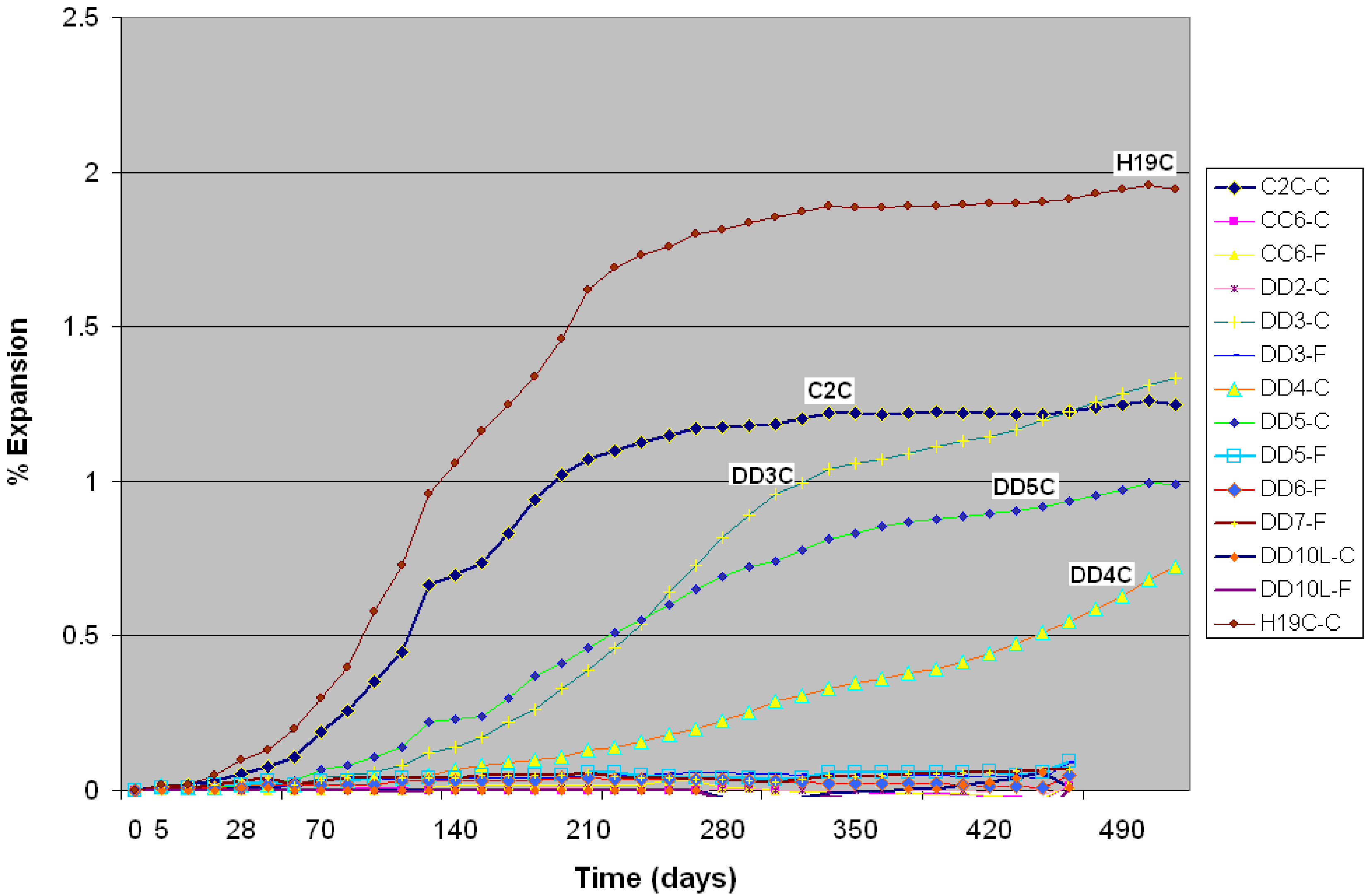
October 2007

1. Determine cause/extent of damage to date.
2. Estimate future potential for expansion

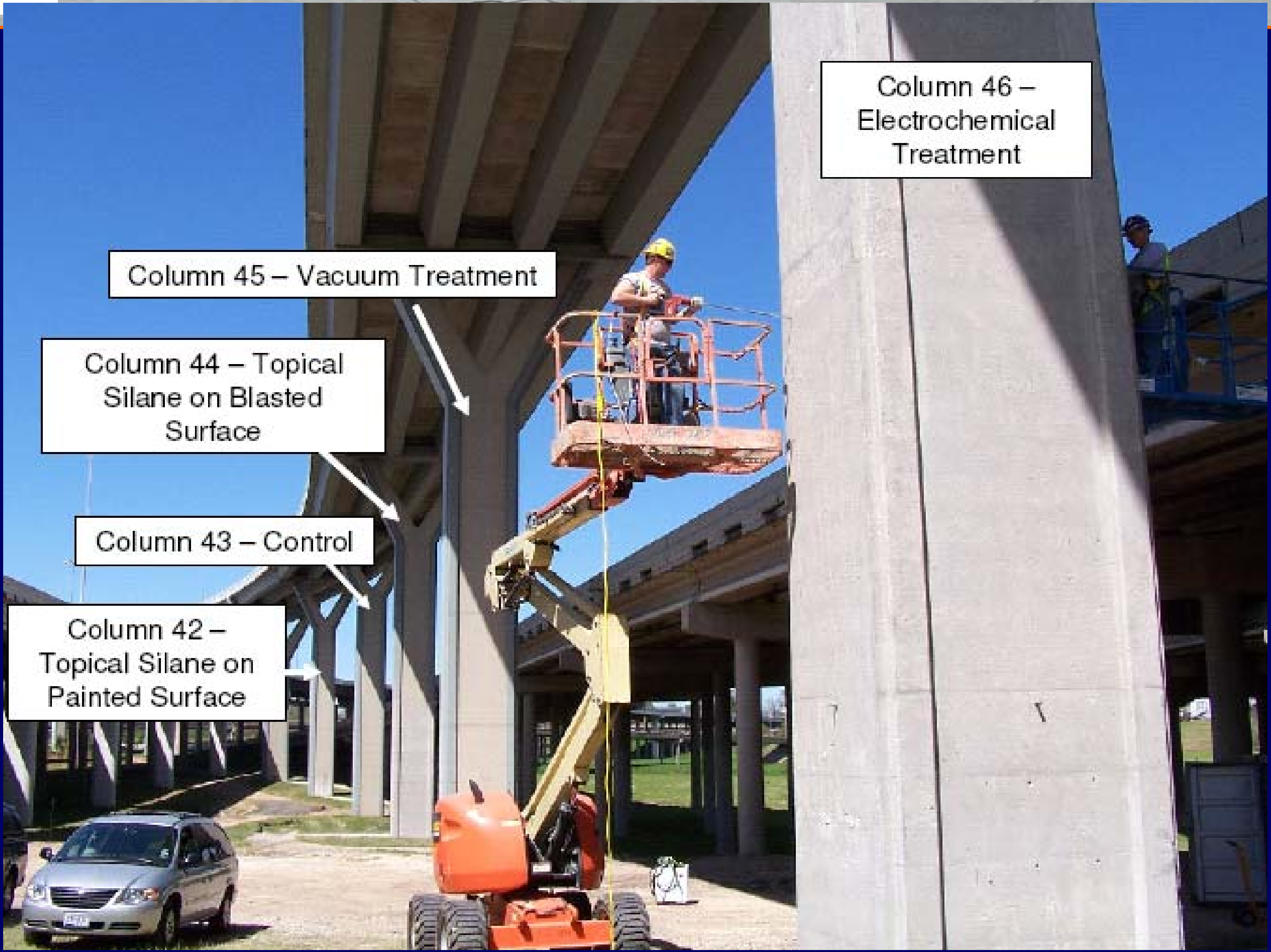
Residual Expansion due to ASR



Residual Expansion due to DEF



Houston columns – field trial



Electrochemical

Vacuum

Only limited penetration of lithium penetration beyond ½” to 1”

Summary

- Most important product from this project will be Materials Protocol – already being used in TX and in other states.
- Progress made on evaluating stresses due to DEF – confinement of 600 psi or less seems to be efficient in suppressing DEF.
- $LiNO_3$ did not penetrate well into concrete

TxDOT 5722
Lap Splice and Development Length Performance of ASR and/or DEF Damaged Concrete Elements

PD: Ricardo Gonzalez
RS: David Trejo
co-RS: Joseph Bracci
Staff: Paolo Gardoni, Stefan Hurlebaus

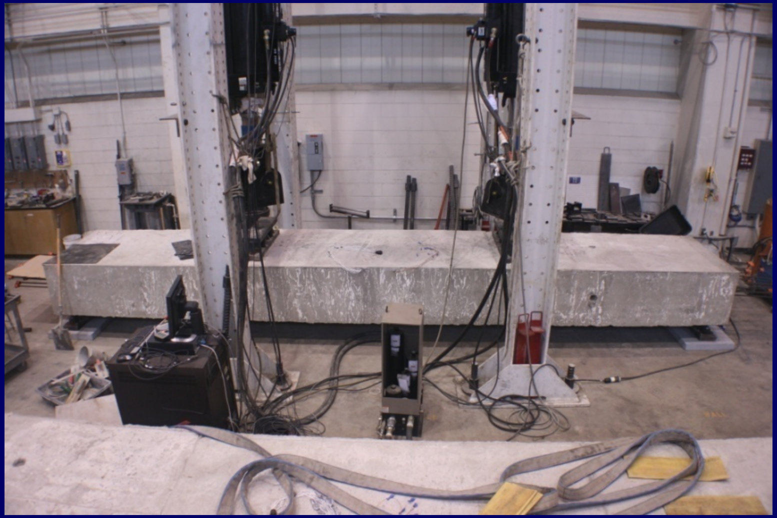
Texas Transportation Institute

What we are doing

- Determine the performance of critical lap splices in bridge columns with varying degrees of cracking due to ASR/DEF
- Determine the need and effectiveness of rehabilitation techniques for damaged lap splice regions

Research Progress

- Casted 16 column specimens
  - 2 control specimens
  - 14 specimens for field exposure and ASR/DEF degradation mechanisms
- Provoke ASR/DEF
  - DEF
    - Control concrete temperature to above 160° F for first 2 days of curing by electrical heating elements
  - ASR
    - High Alkali - Type III Cement
    - Reactive Siliceous Aggregates
    - Sodium Hydroxide Supplement



TxDOT 5997
Structural Assessment of "D" Regions affected by Premature Concrete Deterioration

PD: Dingyi Yang
RS: Joseph Bracci
Researchers: John Mander, Zachary Grasley, Stefan Hurlebaus

Texas Transportation Institute

Nature of the problem

- There is a significant portion of the TxDOT infrastructure that has experienced premature concrete deterioration due to ASR and/or DEF. This research project is to determine the performance of critical D-regions with varying degrees of cracking due to ASR/DEF using large-scale specimens and analytical methods.

Research Progress

- 4 C-shaped beam-column specimens (2 D-regions)
  - 1 control specimen (casted)
  - 3 specimens for field exposure and ASR/DEF degradation mechanisms (cast in Jan-Feb 09)
- Provoke ASR/DEF
  - DEF
    - Control concrete temperature to above 160° F for the first 2 days of curing by electrical heating elements
  - ASR
    - High Alkali - Type III Cement
    - Reactive Siliceous Aggregates
    - Sodium Hydroxide Supplement

Research Progress

Structural Testing

- 1 control specimen
  - Testing in late winter/early spring 2009
- 3 deteriorated specimens subjected to wet/dry cycles
  - Testing at phase 1 cracking (~fall 2009)
  - Testing at phase II cracking (~fall 2010)
  - Testing at phase III cracking (~summer 2011)
  - Specimens are ideal candidates for NDT and NDE studies

Houston Dist contract with Univ of Texas

Shear Strength of ASR/DEF Affected Bridge Bent Caps

Project Overview

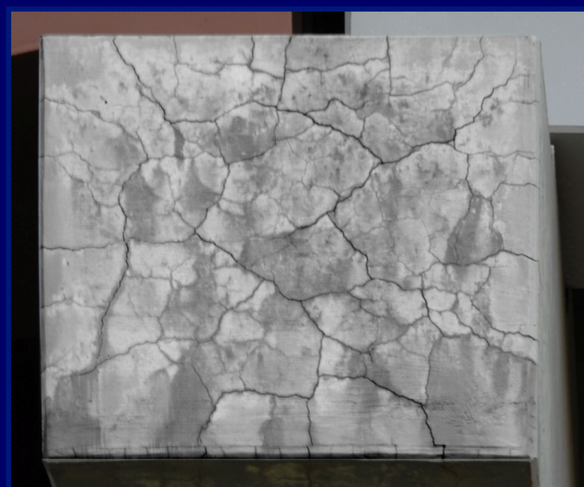
Dean Deschenes

Oguzhan Bayrak

January 2009

Motivation

Signs of premature concrete deterioration due to alkali-silica reaction and/or delayed ettringite formation identified on several bridge bent caps in Houston, Texas.



US 59 & I-10 Interchange

US 59 & I-10 Interchange

Objectives

- Fabricate large-scale specimens that are representative of in-service bents
- Use materials and techniques to produce field-representative ASR/DEF damage
- Evaluate shear capacity of bents with ASR/DEF damage

Investigation of Trap Beams

Houston Dist contract with Univ of Texas

- Cast in 1995 at Contractor's casting yard
- A few were rejected (several 100's put into service)
- Possible ASR throughout girders
- DEF in end regions


7-26-95
07/07/2004

Girders in service

Alkali Silica Reaction in Texas: Recent Discoveries

In-house study

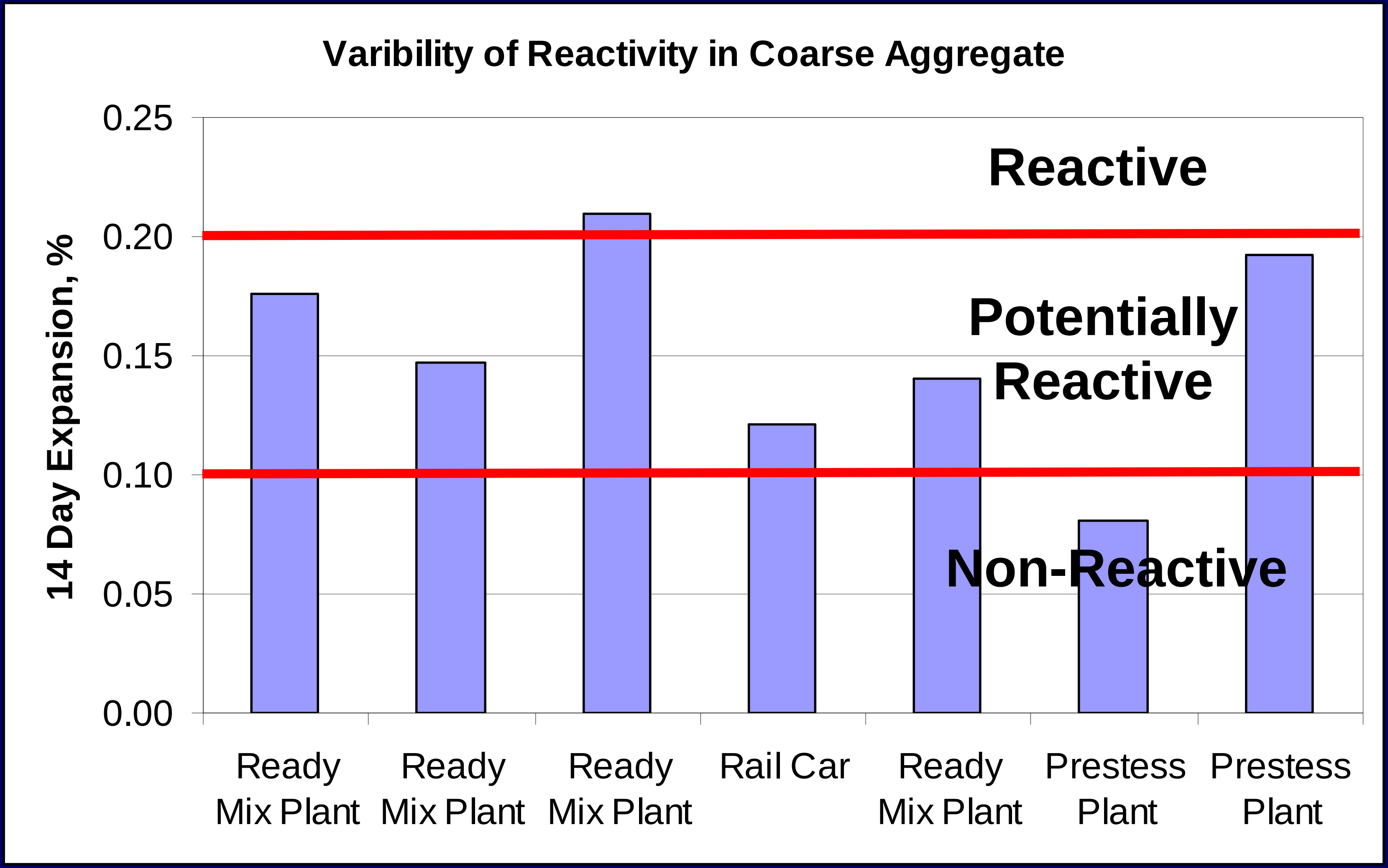
Background

- Early 2008 TxDOT inspectors noted cracking of new prestressed concrete girders that were still in storage.
- These girders were fabricated 2002-2006 for various projects and all used similar concrete mix designs
- The mix designs met the ASR specs

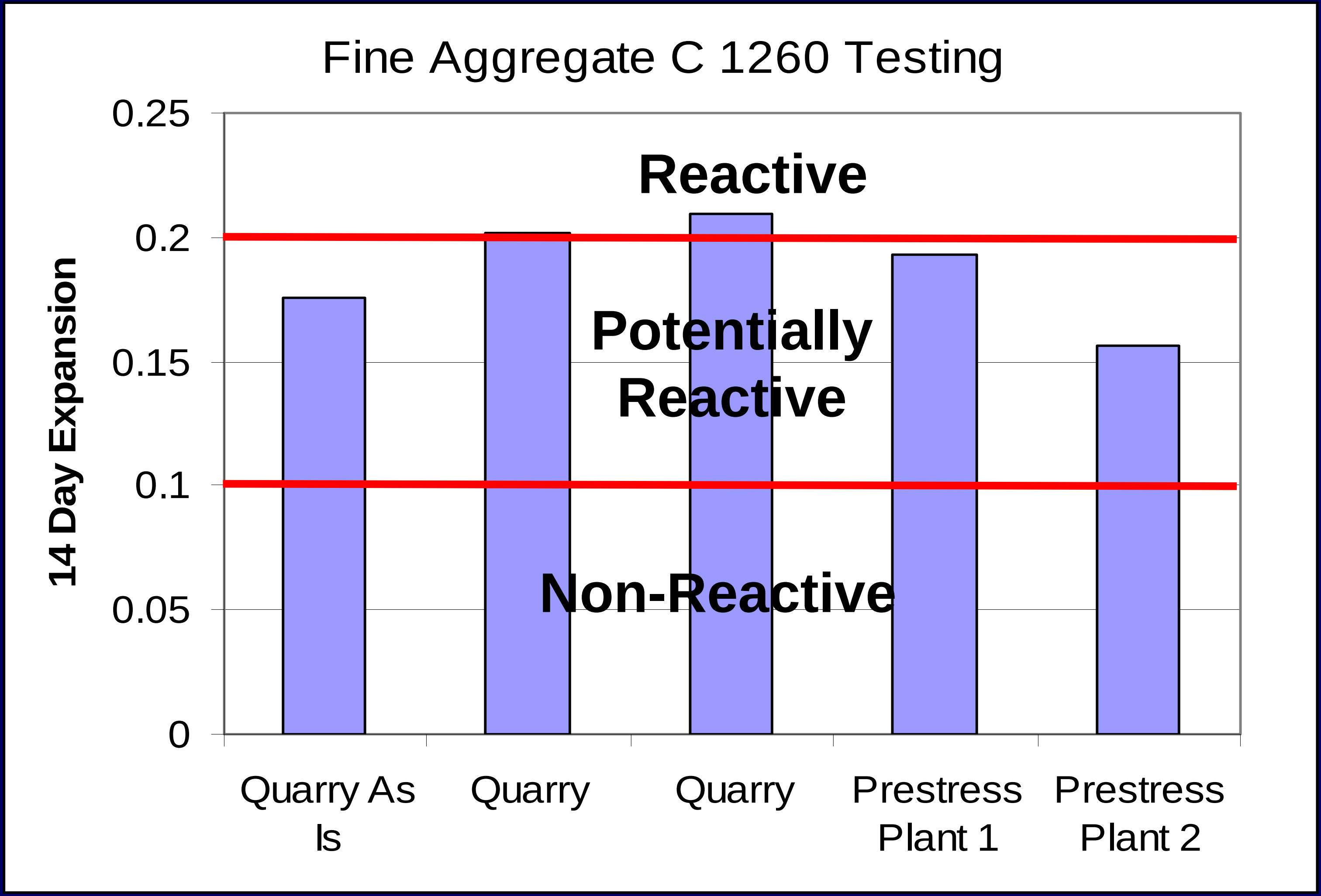
Two Options in Question in Item 421

- Option 1. Replace 20 to 35% of the cement with Class F fly ash.
- Option 7. When using hydraulic cement only, ensure that the total alkali contribution from the cement in the concrete does not exceed 4.00 lb. per cubic yard of concrete.

ASTM C 1260 Testing
Limestone Coarse Aggregate



ASTM C 1260 Testing
Fine Aggregate



Conclusions

- Evidence of ASR gel was confirmed in the girders.
- Alkali content appears to be below 4.0 pcy in two cases.
- 20% Class F Fly Ash may not always provide enough mitigation.

Outcome

- Changes to Item 424 (Prestressed Fabrication Spec) SP 424-001
  - Disallows the use of options 6, 7, & 8 for major prestressed members
  - Increased the minimum fly ash dosage to 25% for all major prestressed members
- Aggregate sources used in girders were added to Option 7 exclusion list
- Initiated a detailed investigation of other fine aggregates in the same region

0-6491: NDE of Bridges with PCD

New Project for FY2010

- No current methods for assessing in-situ quality of concrete
- Only have visual inspection followed by coring/petrography
- Project proposes to
  1. Evaluate existing methods
  2. Develop new method if existing don't work

#5: 0-6491: NDE of Bridges with PCD

Nondestructive Evaluation Methods

- Visual
- Ultrasonic Testing
- Impact – Echo
- Electromagnetic Methods
- Radiography
- Acoustic emission
- Others?

#4: 0-6436: Affect of ASR on Rebar Stress *New for FY2011*