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TEXAS
The University of Texas at Austin

LONG-TERM LABORATORY TEST METHODS AND FIELD EXPOSURE BLOCKS FOR DELAYED ETTRINGITE FORMATION (DEF)

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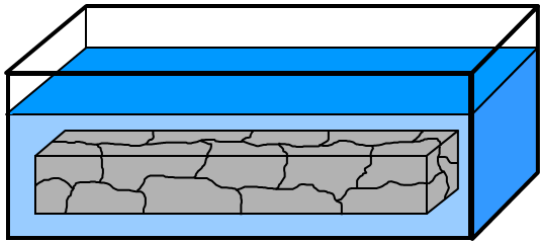
Presentation Outline

- Laboratory Testing
  - Materials
  - Temperature
  - Test Methods
  - Cements
  - Prevention
  - Aggregates
- Exposure Blocks
  - History
  - Cement Type
  - Admixture
  - Prevention
- DEF in Structures
  - Laboratory Evaluation
  - Case Study



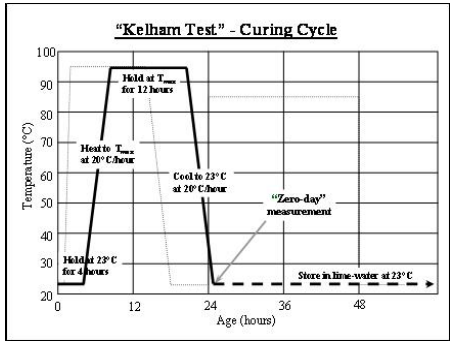
ASTM C150 Cements

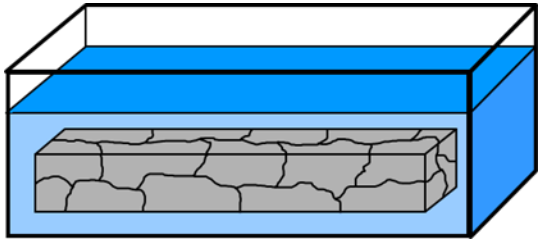
(%)	PC - AI	PC - AIII	PC - BI	PC - BIII	PC - CI	PC - V
SiO_2	21.50	20.62	20.10	20.10	19.80	21.80
Al_2O_3	4.10	4.89	5.30	5.10	5.50	4.10
Fe_2O_3	3.50	2.39	3.40	3.40	2.00	3.90
CaO	--	64.27	65.50	64.90	61.60	63.80
MgO	2.50	1.77	0.60	1.00	2.60	2.10
SO_3	2.78	3.83	3.30	3.70	4.20	1.90
C_3A	4.90	8.93	8.00	8.00	11.10	4.00
Alkali	0.56	0.62	0.67	0.50	0.95	0.59
Wagner (m^2/Kg)	218	--	200	244	--	203
Blaine (m^2/Kg)	--	526	367	537	399	323

Supplementary Cementitious Materials

(%)	FA (F)	FA (C)	SL	SF	MK	UFFA
SiO_2	50.79	35.80	35.91	93.17	51.00	50.65
Al_2O_3	24.25	21.40	11.98	--	40.00	26.64
Fe_2O_3	4.18	5.60	0.94	2.10	1.00	4.66
CaO	14.76	24.30	44.10	0.80	2.00	10.85
MgO	2.31	4.80	8.90	0.30	0.20	2.23
SO_3	0.57	1.20	1.63	0.20	--	1
Alkali	0.20	1.40	0.58	0.48	0.50	.41

- Heating Regimes
  - Kelham
  - Fu
  - Ferraro
  - Modified ASTM C227



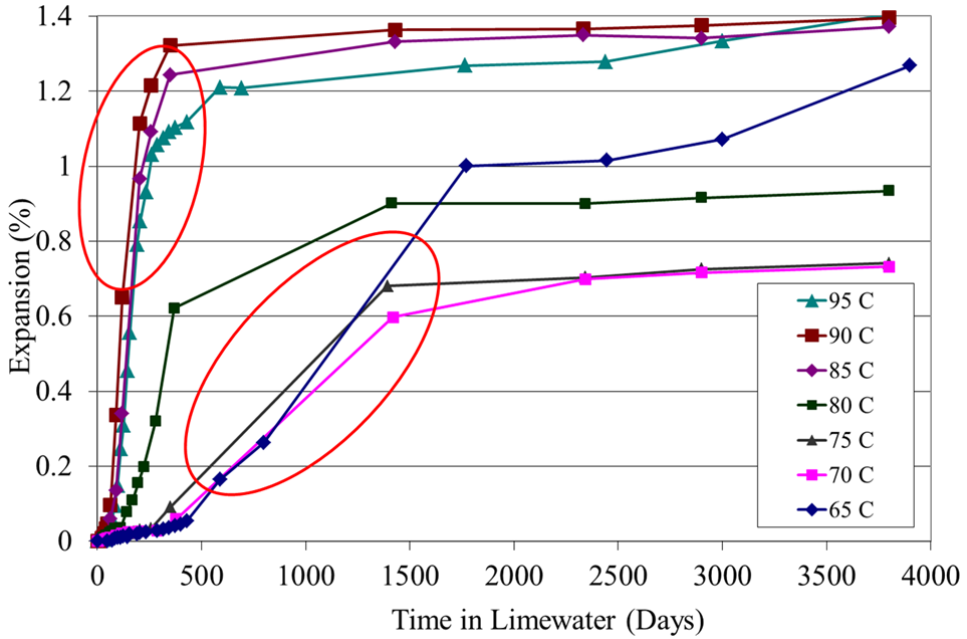


What is the critical temperature for DEF to occur? 70 ° C

- Kelham and Fu
- 3 Types of Cement
- 65 to 95 ° C at 5 degree increments

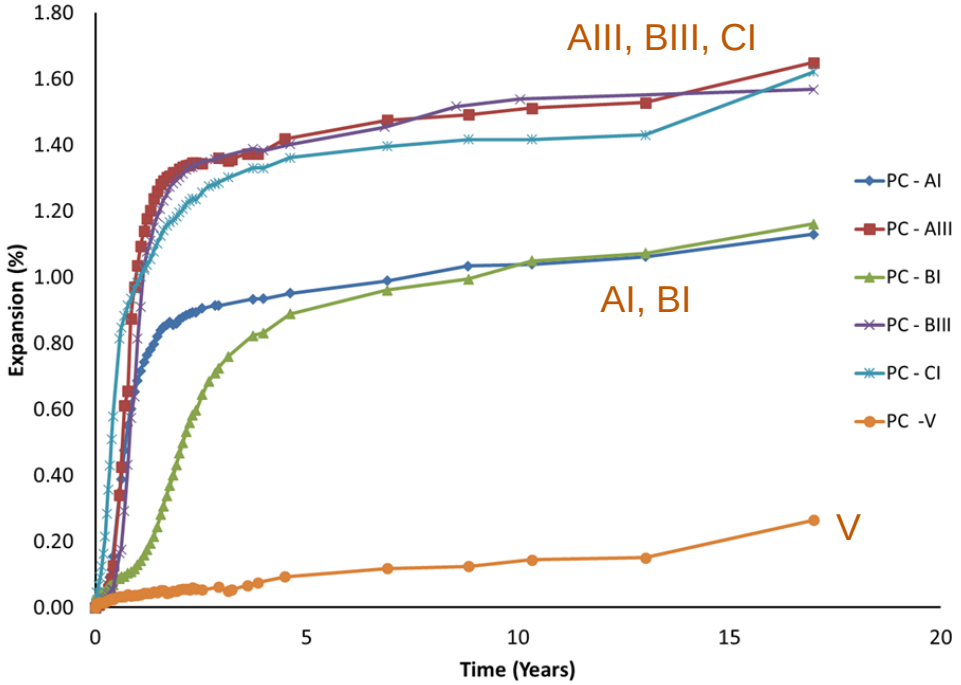
What is the critical temperature for DEF to occur?

- Kelham
- A-III Cement

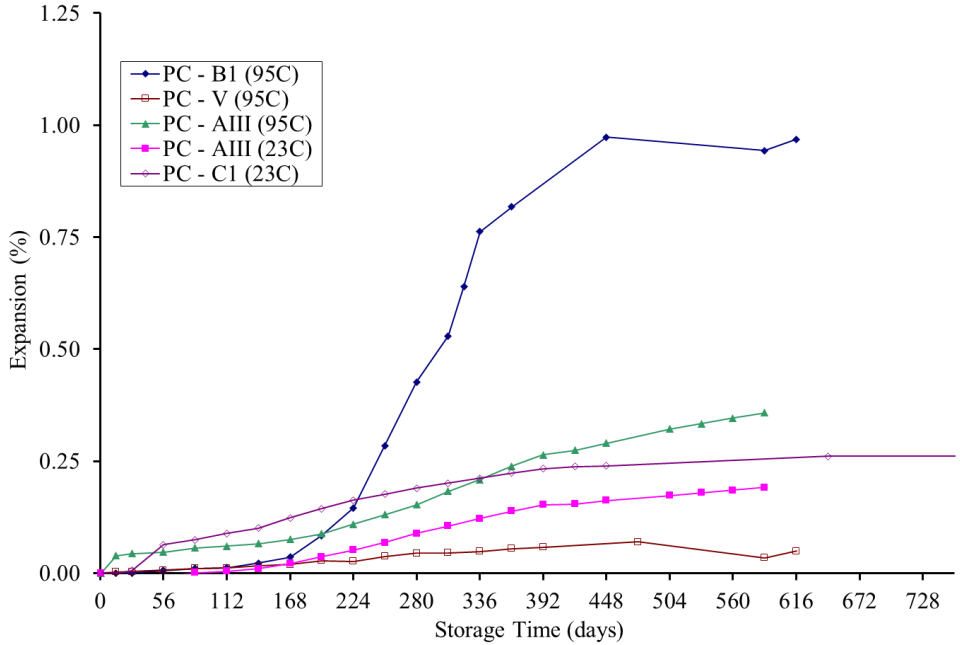


Cement Prevention?

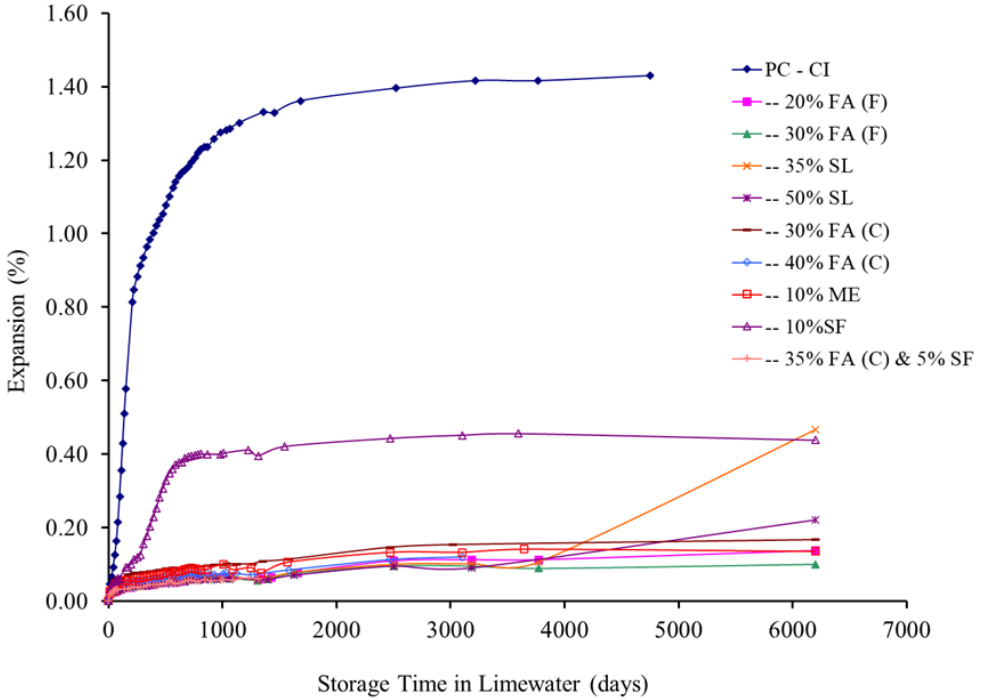
- Kelham
- 95 ° C



Storage Type

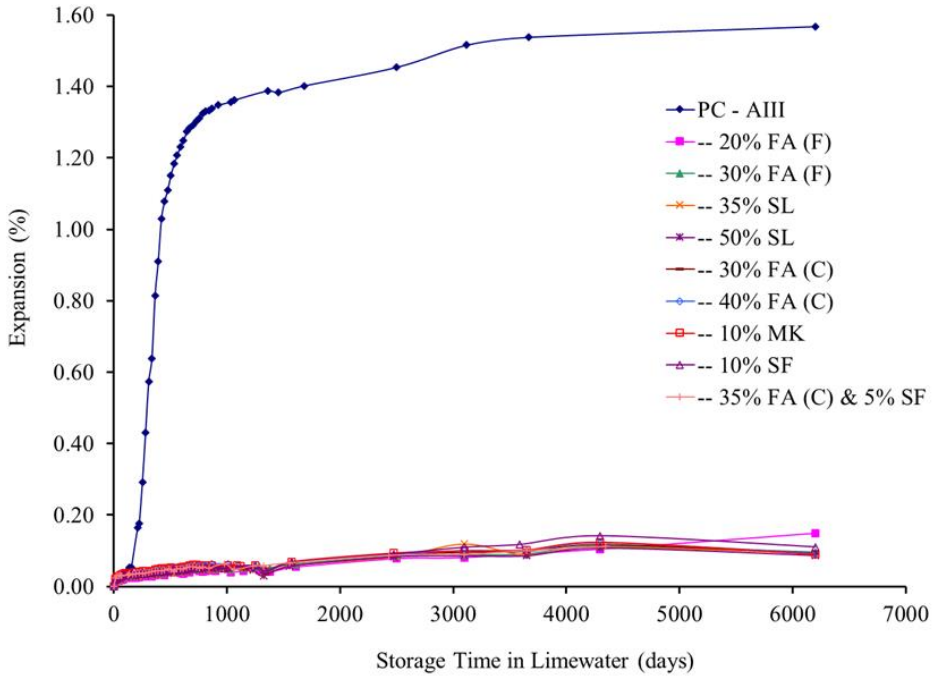


Kelham
95 ° C
CI – High
Alkali Cement

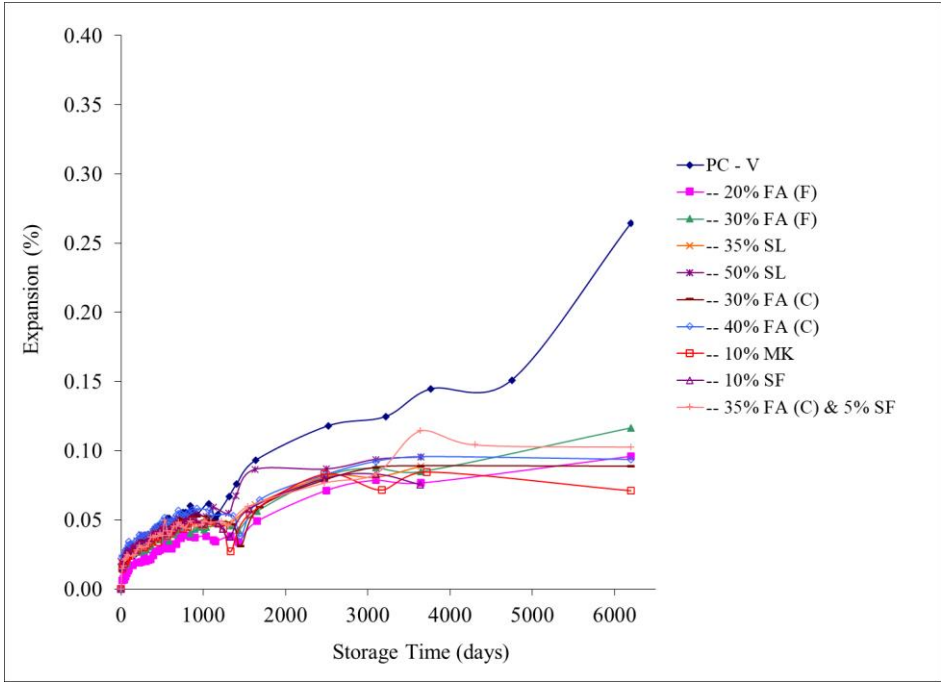


Laboratory Testing
Materials
Test Methods
Temperature
Cements
Prevention
Aggregates
Exposure Blocks
History

Kelham
95 ° C
Type III Cement

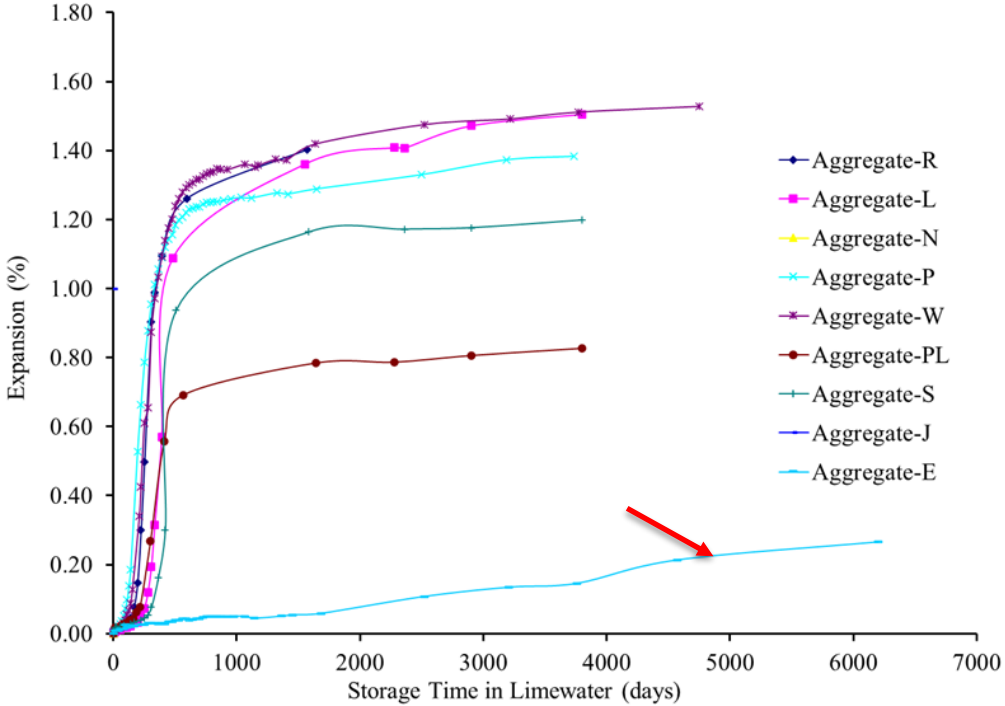


Kelham
95 ° C
Type V Cement



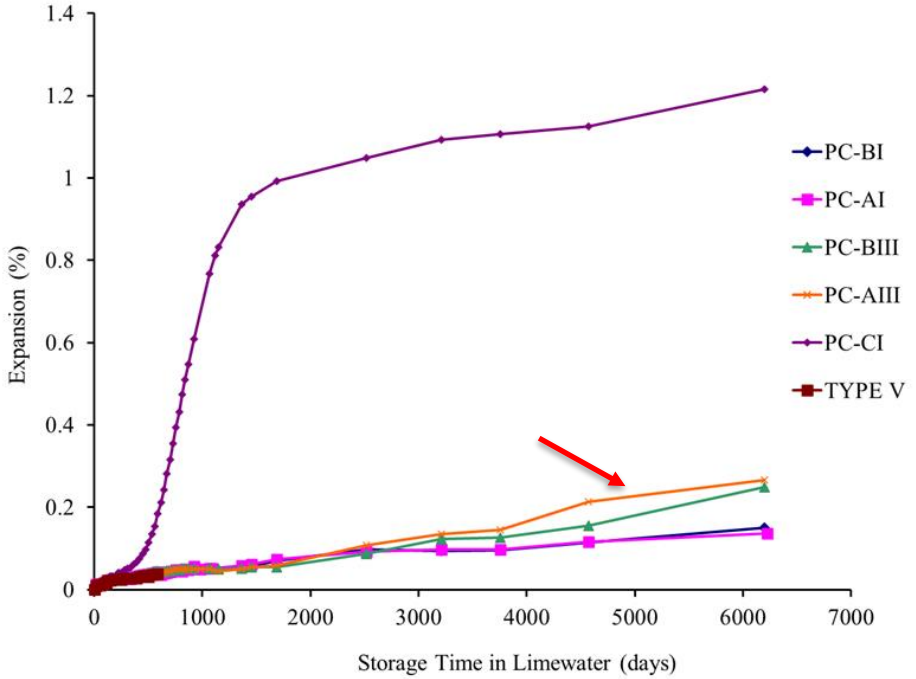
Why Aggregates?

- Kelham
- 95 ° C
- A-III Cement



Why Aggregates?

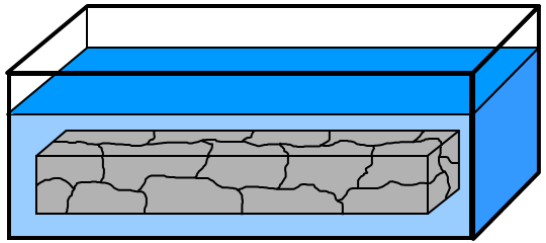
- Manufactured Sand
- Kelham
- 95 ° C



Laboratory Test Method Summary

- Specifications for 70 ° C max temperature are in line. All cements do show expansion
- ASTM C150 Type V cement show slight expansion in long-term expansion
- Specifications for Prevention are in line with ACI documents. Slag possible expansion after 15 years.

Benchmarking Laboratory Tests to Field Exposure Blocks



Laboratory Testing

TxDOT Exposure Site

Materials

Cement Type | Admixture | Prevention | DEF in Structures | Laboratory Evaluation | Case Study

TxDOT Exposure Site

- Over 1200 blocks
  - 2022 – Site demolished
- 125 DEF Blocks
  - Over 20 types of cements
  - Several types of SCMs
  - Lithium Admixture

Research underway to understand cement constituents

Type: Cement D Typle III (700 lb)
Max Temp: 178

Type: Cement E Type I/II (700 lb)
Max Temp: 194

Type: Cement F I/II (700 lb)
Max Temp: 184

Research underway to determine if SCMs are able to Prevent DEF

Type: Cement M – Type White (700)
25% Class F Fly Ash
Max Temp: 194

Cement D – Type III (525)
25% Class F Fly Ash

Type: Cement C – Type III (525lb)
25% Class F Fly Ash
Max Temp: 185

Research underway to determine if Lithium Nitrate can Prevent DEF

Cement D – Type III
700 lbs cement
200% Lithium
Max Temp 198F

TxDOT Exposure Site Summary

- Evaluate cements and how they performed
- Evaluate SCMs and how they have performed
- Continue monitoring

Laboratory Testing

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Test Methods

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Prevention

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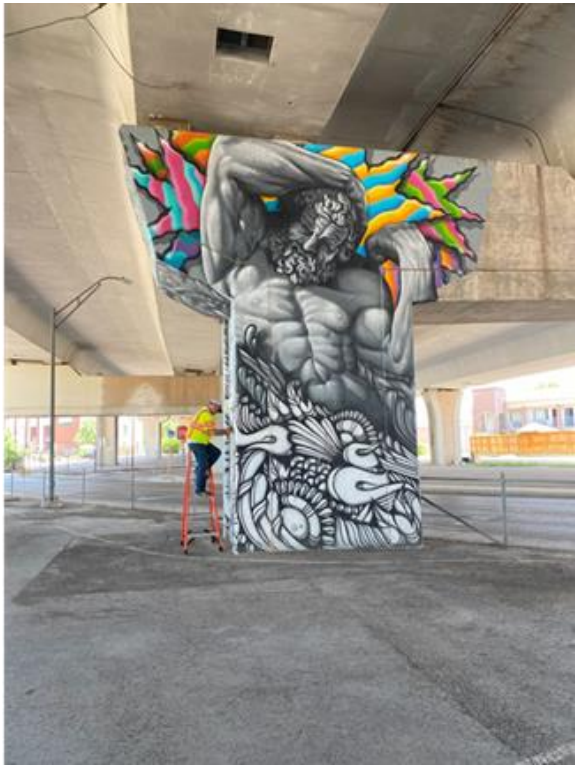


Cement Type | Admixture | Prevention | DEF in Structures | Laboratory Evaluation | Case Study

Very Common Question

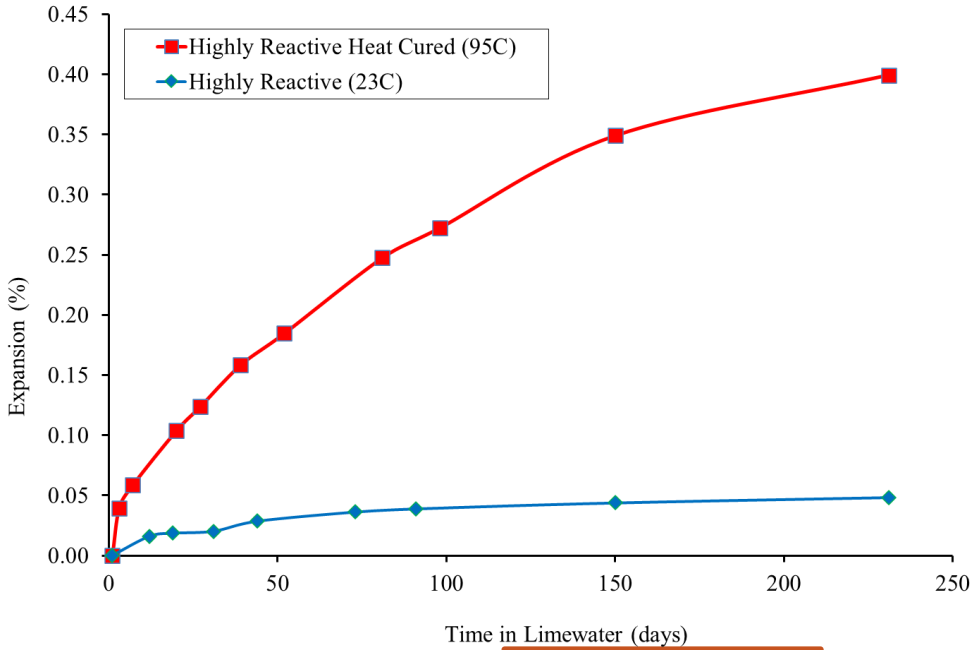
- My internal concrete temperature was above 70 ° C will the structure have DEF?

Validating Residual Expansion from Concrete Cores

- Initial testing on 6 X 12” cylinders
- Two Mixtures
  - Non-reactive aggregates
  - Highly reactive aggregate
- Two curing temperatures
  - Room Temperature 23 ° C
  - Heat Cured to 95 ° C following Kelham Regime
- 2 inch cores from each cylinder
  - Pinned and placed in limewater for residual expansion

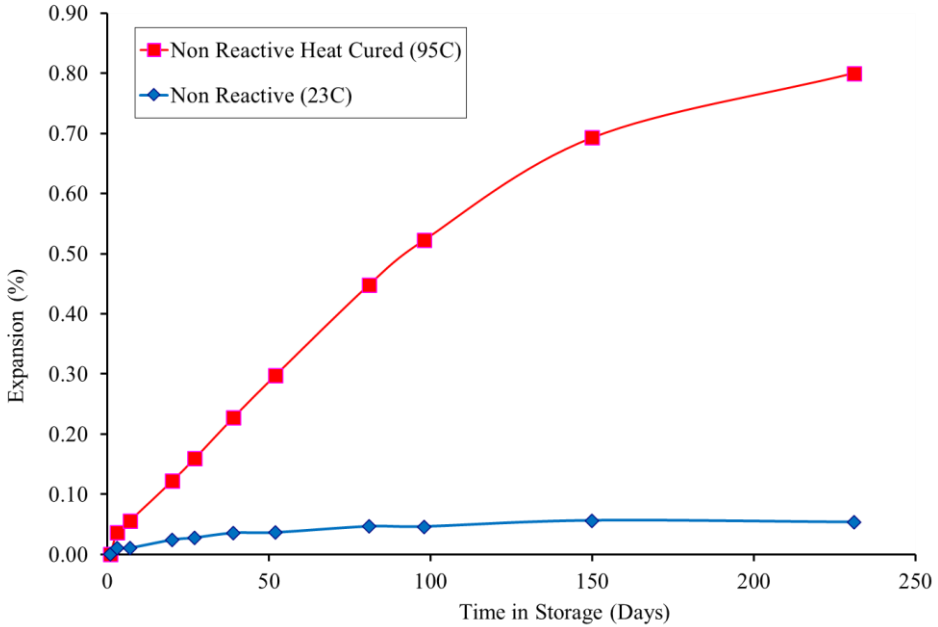
Validating Residual Expansion from Concrete Cores

- Residual Expansion of Highly Reactive Aggregate



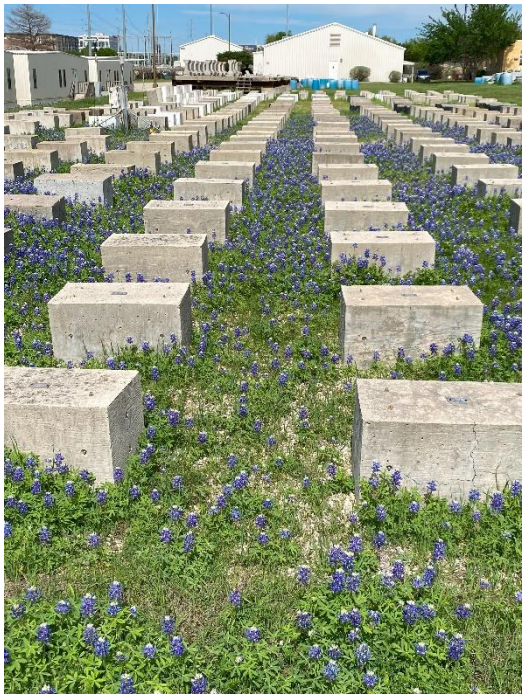
Validating Residual Expansion from Concrete Cores

- Residual Expansion of Non-Reactive Aggregate

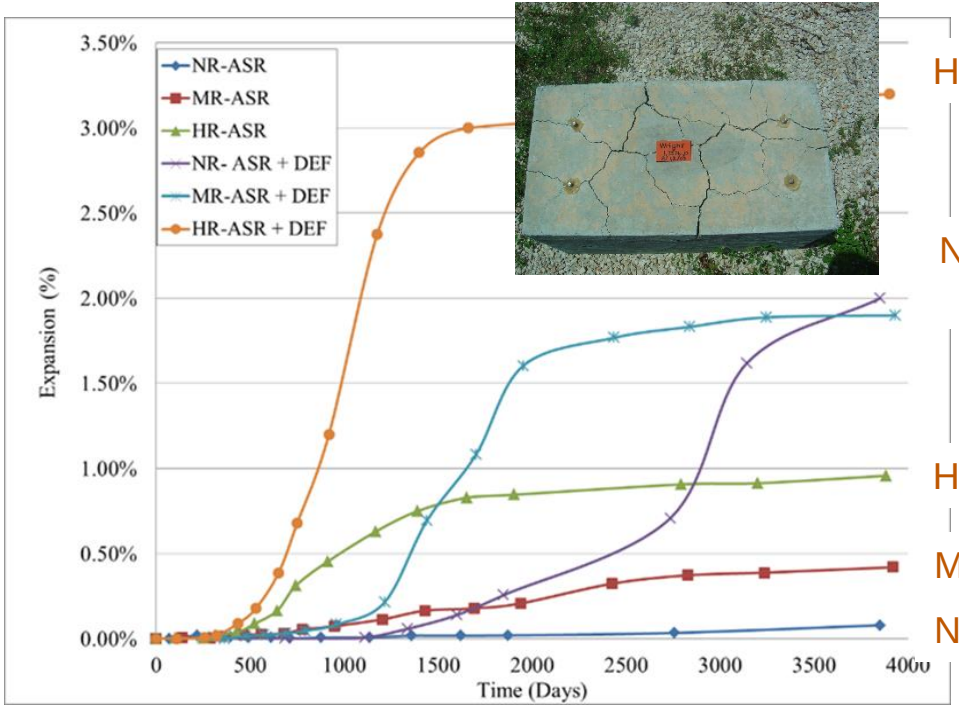


Validating Residual Expansion from Concrete Cores

- Outdoor Exposure Blocks
- Heat Treated vs. Non-Heat Treated
- Influence of ASR on DEF
- Six Mixtures
  - Non-Reactive (NR)
  - Non-Reactive + Heat-Treatment (NR+DEF)
  - Moderate-Reactive (MR)
  - Moderate-Reactive + Heat-Treatment (MR+DEF)
  - Highly Reactive (HR)
  - Highly Reactive (HR+DEF)



Validating Residual Expansion from Concrete Cores



Highly Reactive Aggregate - DEF

Non-Reactive Aggregate - DEF

Mod Reactive Aggregate - DEF

Highly Reactive Aggregate - ASR

Mod Reactive Aggregate - ASR

Non-Reactive Aggregate - ASR

Validating Residual Expansion from Concrete Cores

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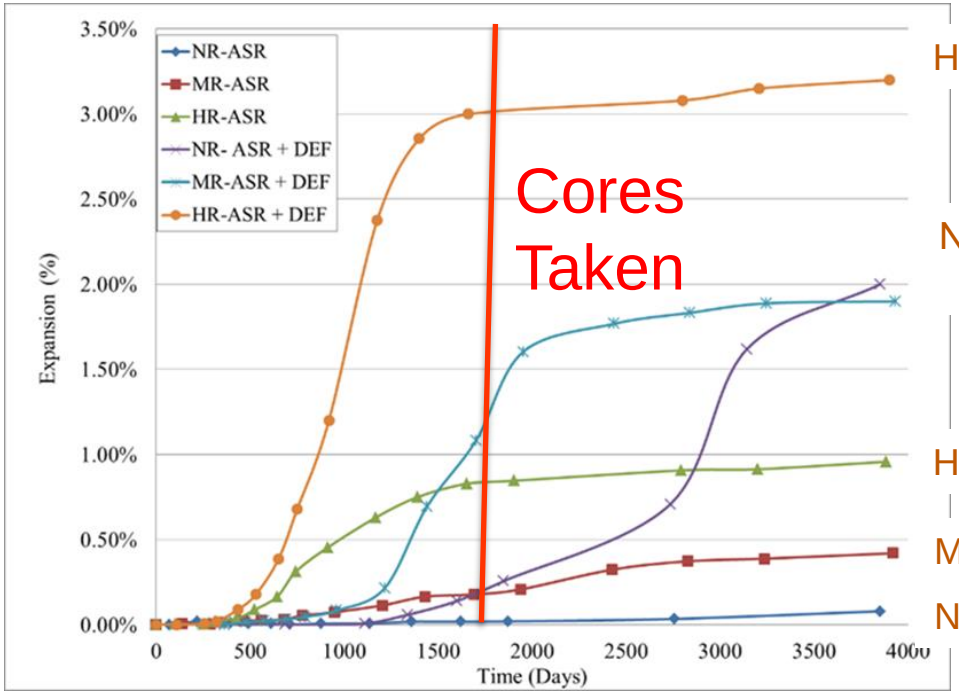


Highly Reactive Aggregate - DEF

Non-Reactive Aggregate - DEF

Mod Reactive Aggregate - DEF

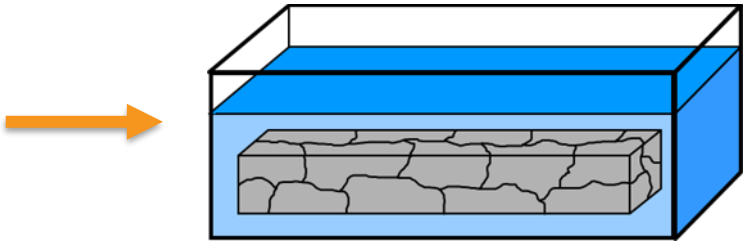
Highly Reactive Aggregate - ASR

Mod Reactive Aggregate - ASR

Non-Reactive Aggregate - ASR

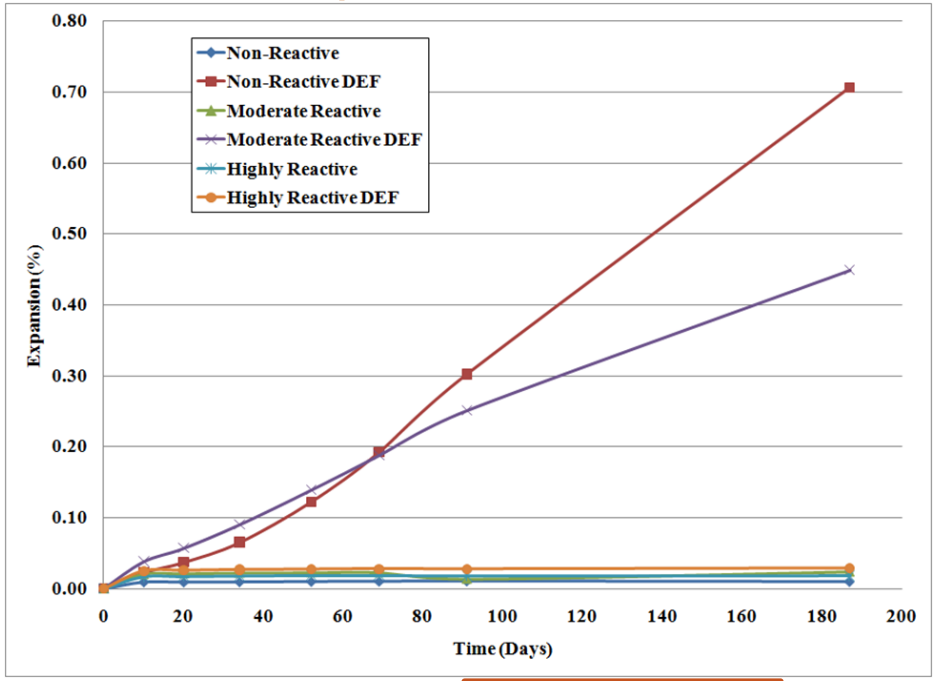
Validating Residual Expansion from Concrete Cores

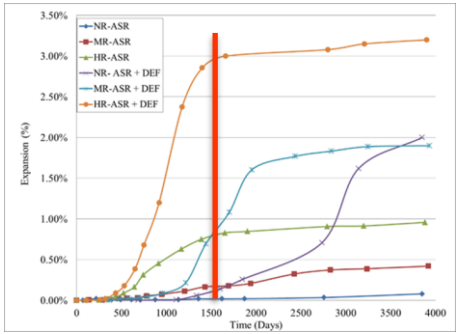
- Residual Expansion
- Microscopy



Validating Residual Expansion from Concrete Cores

- Residual Expansion





Laboratory Testing

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Cement Type

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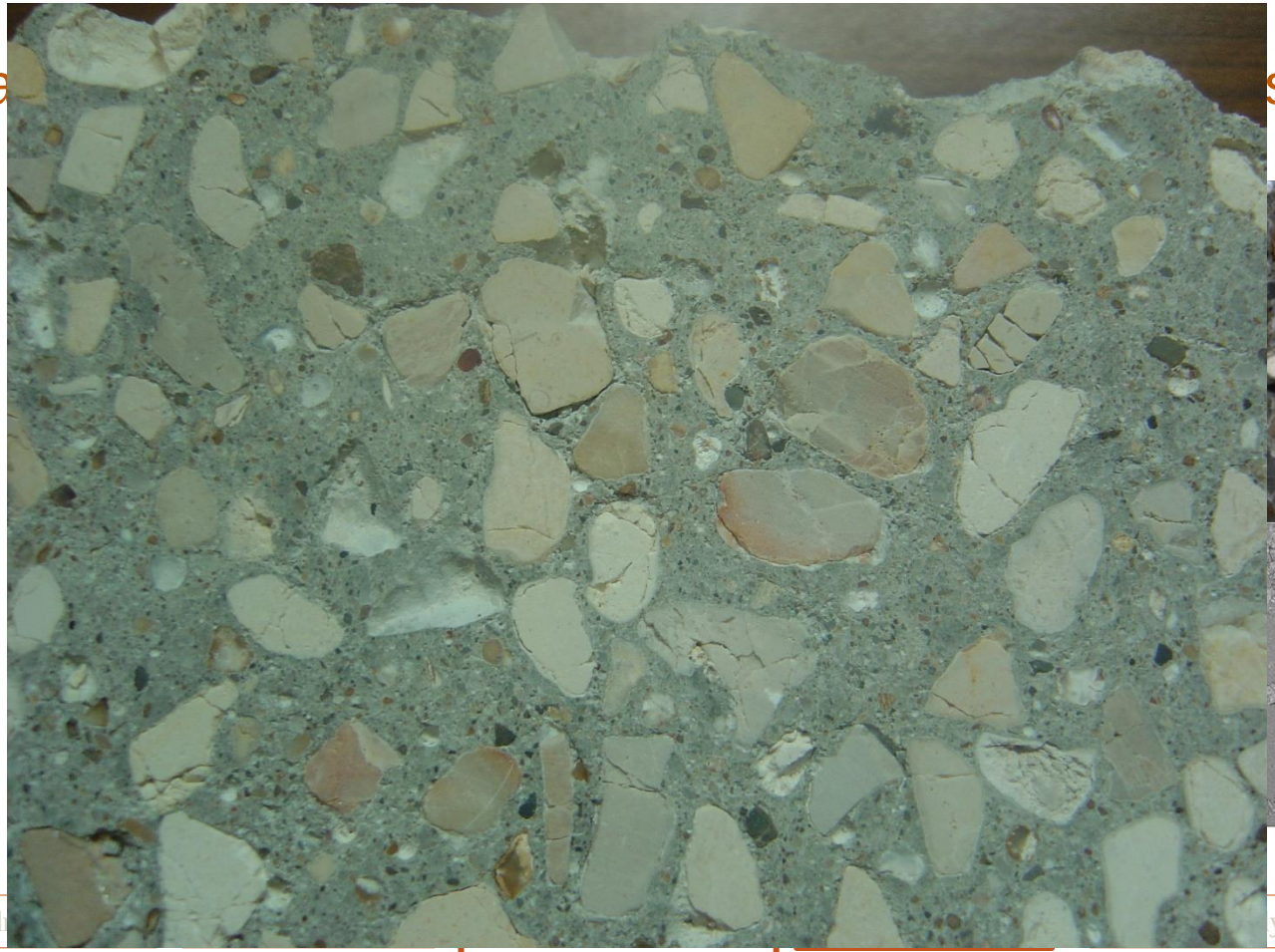
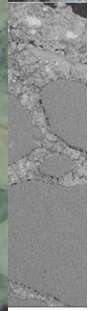


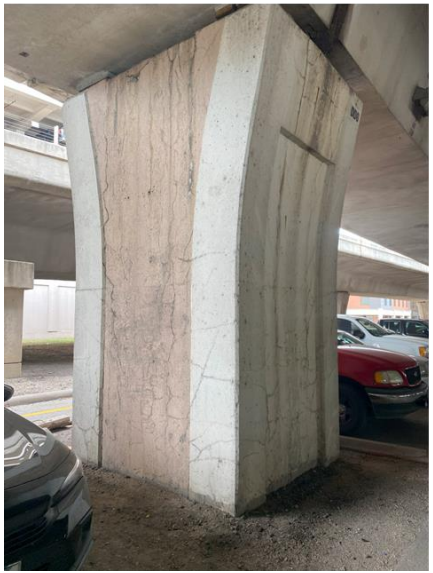


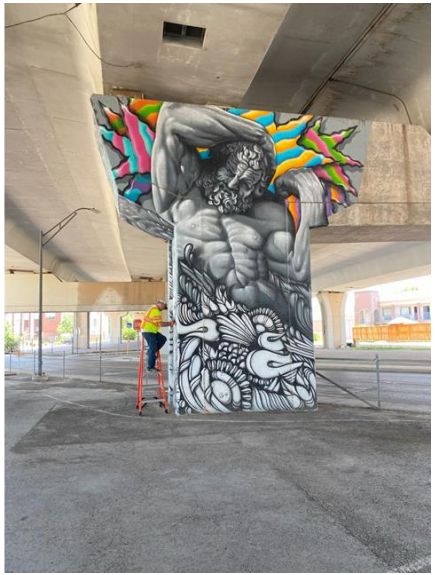
Mixture A Mixture D

MR-ASR MR-ASR+DEF

Case Study

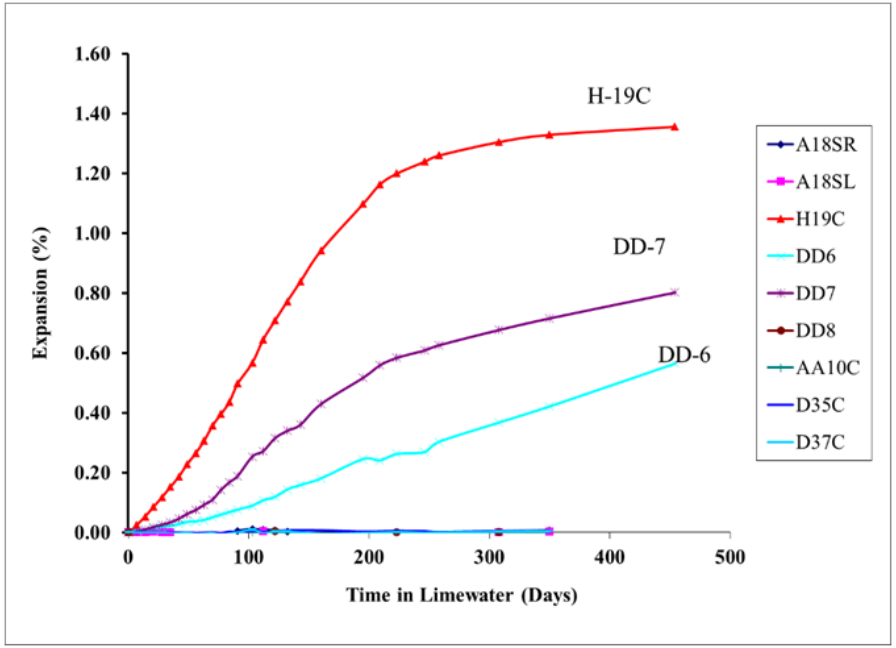
- Structures with severe cracking
- Cores taken in 2006





Case Study

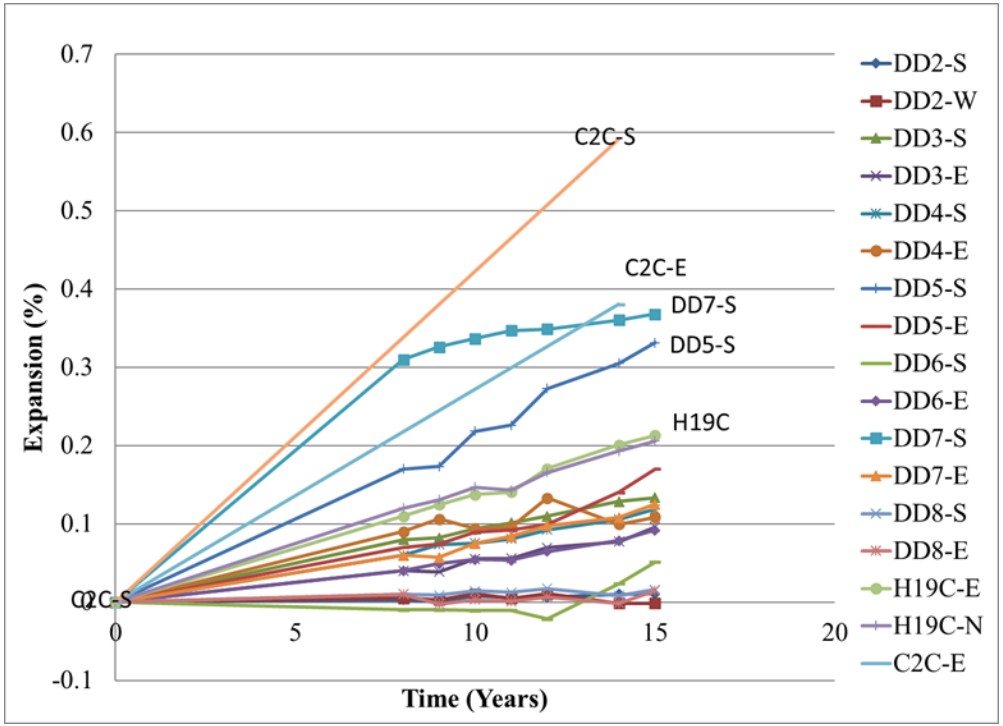
- Residual Expansion



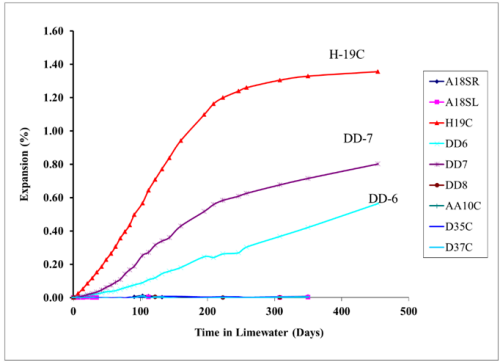
Case Study

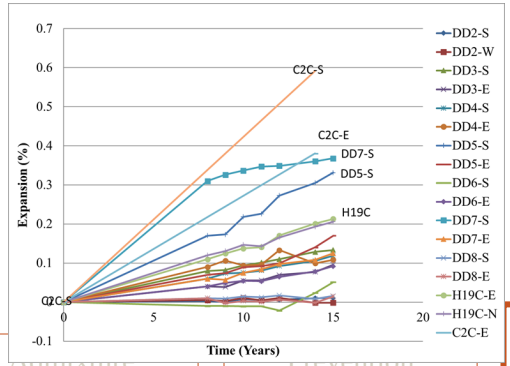
- Instrument Columns with demec points for expansion

Case Study – Column Expansions after 15 years



Case Study – Determining the potential expansion remaining in a structure





- For DD7 column, Cores in 2006 showed a potential of 0.80% expansion
- 15 years of monitoring has shown DD7 expanding 0.35%
- 0.45% potential expansion
- New cores in 2024

Any Questions?