OCTOBER 29, 2023



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

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Presentation Outline



Cement Type

Admixture

Prevention

DEF in Structures

Laboratory Evaluation



ASTM C150 Cements

Laboratory Testing
Materials
Temperature
Test Methods
Cements
Prevention
Aggregates
Exposure Blocks

(%)	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 ₂ O ₃	4.10	4.89	5.30	5.10	5.50	4.10
Fe ₂ O 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 ₃ A	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

History

Cement Type

Prevention

DEF in Structures

aboratory Evaluation

UFFA

50.65

26.64

4.66

10.85

2.23

.41



Laboratory Testing	Suppleme	entary	Cemen	titious	Materia	als
Materials	(%)	FA (F)	FA(C)	SL	SF	MK
Temperature	SiO ₂	50.79	35.80	35.91	93.17	51.00
Test Methods	Al ₂ O ₃	24.25	21.40	11.98		40.00
Cements	Fe ₂ O ₃	4.18	5.60	0.94	2.10	1.00
Prevention	CaO	14.76	24.30	44.10	0.80	2.00
	MgO	2.31	4.80	8.90	0.30	0.20
Aggregates	SO ₃	0.57	1.20	1.63	0.20	
Exposure Blocks	Alkali	0.20	1.40	0.58	0.48	0.50
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Cement Type

Prevention

DEF in Structures



Laboratory Testing	•	F
Materials		•
Test Methods		
Temperature		
Cements		
Prevention		
Aggregates		operature (°C)
Exposure Blocks		Ter
History		
Cement Type	Admi	xture

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

DEF in Structures







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Laboratory Testing	WI
Materials	OC
Test Methods	•
Temperature	•
Cements	•
Prevention	
Aggregates	
Exposure Blocks	
History	
Cement Type	Admixt

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

DEF in Structures

Laboratory Evaluati







Laboratory Testing	Cemen	t Preventi	ion?			
Materials	• Kelha	am _{1.80}		AIII, BII	I, CI	
Test Methods	• 30 (1.60				
Temperature		1.40	Comments of the second se			PC - AI
Cements		(%) 1.00				PC - AIII PC - BI
Prevention		Expansic 08.0		AI, DI		→←PC - BIII
Aggregates		0.60				PC -V
Exposure Blocks		0.20				-• V
History		0.00	0 5	10 Time (Years)	15	20
Cement Type	Admixture	Prevention	DEF in Structures	Laboratory Evaluation	(Case Study























Laboratory Testing Materials Test Methods Temperature Cements Prevention Aggregates Exposure Blocks	Why A • Manu Sanc • Kelha • 95 ° (ggregates ufactured am C	Expansion (%)) 1 1 1 0 0 0
History Cement Type	Admixture	Prevention]





Laboratory Testing	
Materials	-
Test Methods	
Temperature	
Cements	
Prevention	
Aggregates	
Exposure Blocks	
History	
Cement Type	l

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.

ixture

Prevention

DEF in Structures







TxDOT Exposure Site

Materials





Laboratory Testing	
Materials	
Test Methods	
Temperature	
Cements	
Prevention	
Aggregates	
Exposure Blocks	

TxDOT Exposure Site

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





DEF in Structures



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







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



Laboratory Testing	Т
Materials	•
Test Methods	•
Temperature	
Cements	
Prevention	
Aggregates	
Exposure Blocks	
History	
Comont Type	Adm

FxDOT Exposure Site Summary

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

DEF in Structures

Continue monitoring





Laboratory Testing	
Materials	
Test Methods	and the second se
Temperature	TOIL
Cements	
Prevention	
Aggregates	
Exposure Blocks	







Cement Type

Prevention

DEF in Structures

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Laboratory Testing
Materials
Test Methods
Temperature
Cements
Prevention
Aggregates
Exposure Blocks







Prevention

DEF in Structures

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Materials	Very
Test Methods	• IVIy
Temperature	ter
Cements	wi
Prevention	
Aggregates	
Exposure Blocks	
History	
Comont Turno	Admixtura

/ery Common Question My internal concrete temperature was above 70 ° C will the structure have DEF?

DEF in Structures

Case



Laboratory Testing	V
Materials	•
Test Methods	•
Temperature	
Cements	•
Prevention	
Aggregates	•
Exposure Blocks	
History	
Cement Type	А

Alidating 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

e

Prevention











Laboratory Testing Materials Test Methods Temperature Cements Prevention Aggregates	 Validatin Outdoor E Heat Treat Influence o Six Mixture Non-Rea Non-Rea Moderate Highly Rea
Exposure Blocks	
History	

alidating 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)



DEF in Structures

Laboratory Evaluation





Materials

Validating Residual Expansion from Concrete Cores

Test Methods
Temperature
Cements
Prevention
Aggregates

Exposure Blocks

Admixture

Prevention

DEF in Structures

Laboratory Evaluation

Laboratory Testing	Validati
Materials	Kesi Micro
Test Methods	
Temperature	
Cements	
Prevention	
Aggregates	. • 🙂
Exposure Blocks	
History	
Coment Type	Admixture

ng Residual Expansion from Concrete Cores

- dual Expansion
- oscopy

Case Study

- Structures with severe cracking
- Cores taken in 2006

Coment Type

Exposure Blocks

Admixtur

Prevention

DEF in Structures

Laboratory Evaluatio

Case Study

Residual Expansion

Case StudyInstrument Columns with demec points for expansion

Exposure Blocks

Admixture

Prevention

DEF in Structures

Laboratory Evaluatio

Case Study – Column Expansions after 15 years Laboratory Testing 0.7 -DD2-S -DD2-W 0.6 C2C-S -DD3-S → DD3-E 0.5 ----DD4-S -DD4-E C2C-E 0.4 -DD5-S Expansion (%) DD7-S -DD5-E DD5-S -DD6-S 0.3 -DD6-E H19C 0.2 ----DD7-E ---DD8-S 0.1 -H19C-E **Exposure Blocks** 020-5 20 ----H19C-N 10 5 15 —С2С-Е -0.1 Time (Years) **DEF** in Structures Case Study

Case Study – Determining the potential expansion remaining in a structure

- H-19C -A18SR -A18SL -H19C DD-7 DD6 -DD7 -DD8 DD-6 ___D35C -D37C 100 200 300 400 500 Time in Limewater (Days) -DD2-S -DD2-W c2c-s -DD3-S --DD3-E --DD4-S --DD4-E C2C-E -DD5-S DD7-S -DD5-E DD5-S -DD6-S -DD6-E H19C -DD7-E ----DD8-S -H19C-E 5 10 15 -C2C-E DEF in Structures Time (Years)
 - 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?

