Proportioning for Mass Concrete

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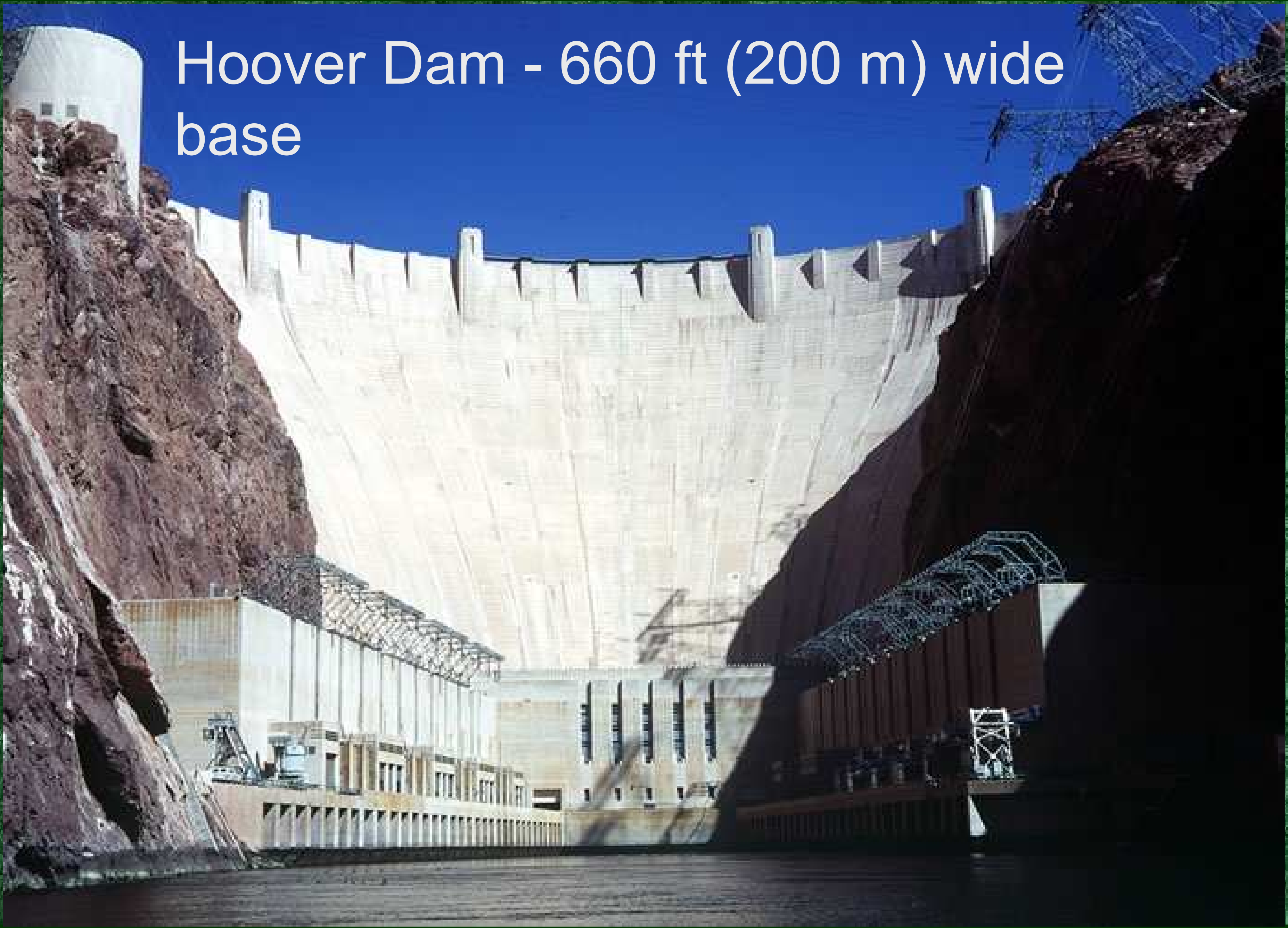
Buzzi Unicem USA

What is Mass Concrete?

ACI defines Mass Concrete as “any volume of concrete with dimensions large enough to require that measures be taken to cope with generation of heat from hydration of the cement and attendant volume change to minimize cracking.”

ACI does not specify an exact minimum thickness, depends on many factors

Hoover Dam - 660 ft (200 m) wide base

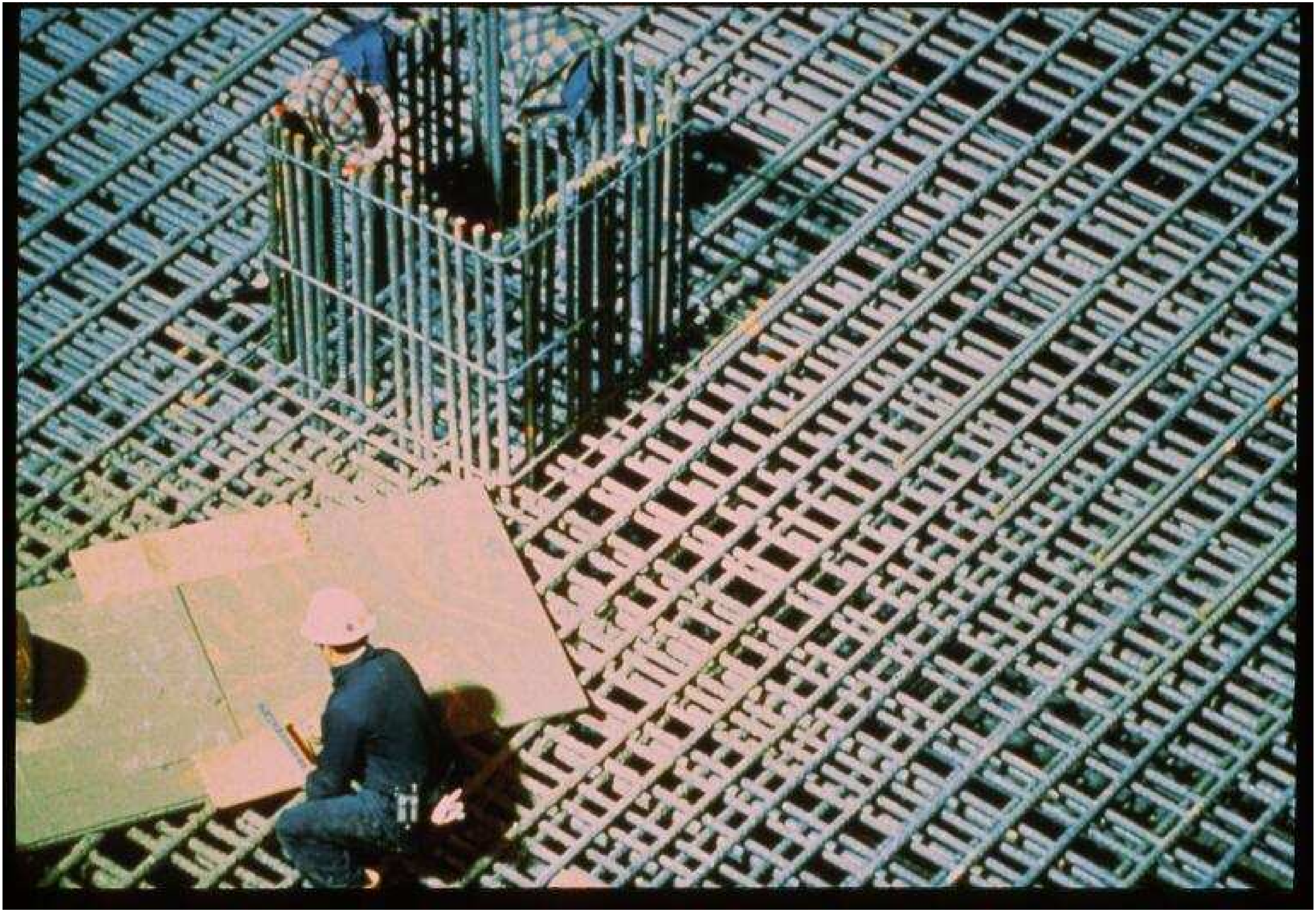


Traditional Mass Concrete Mixes

- Low strength requirements
- 56 or 90 days to achieve strength
- Very large coarse aggregate
- Very low cement contents
- Type IV or Type II(MH)
- High SCM replacements

Mat Foundations, Houston

	Volume	PSI
ENRON Building	11,000	5,000
5 Houston Center	8,500	6,000
1000 Main	12,000	
M D Anderson (2)	12,000	



Mass Concrete

For mass placements, ACI 207 and U. S. Army Corps of Engineers recommend:

Cement or combination of cement with GGBFS and/or fly ash that achieves a maximum Heat of Hydration of 70 cal/gm at 7 days.


77.9F

Critical Temperature Limits

$T_{max} < 165^oF\ (75^oC)$

$\Delta T < 35^oF\ (20^oC)$

Why these Limits?

$T_{max} < 165^oF\ (75^oC)$

Potential to bypass ettringite phase, resulting in DEF

$\Delta T < 35^oF\ (20^oC)$

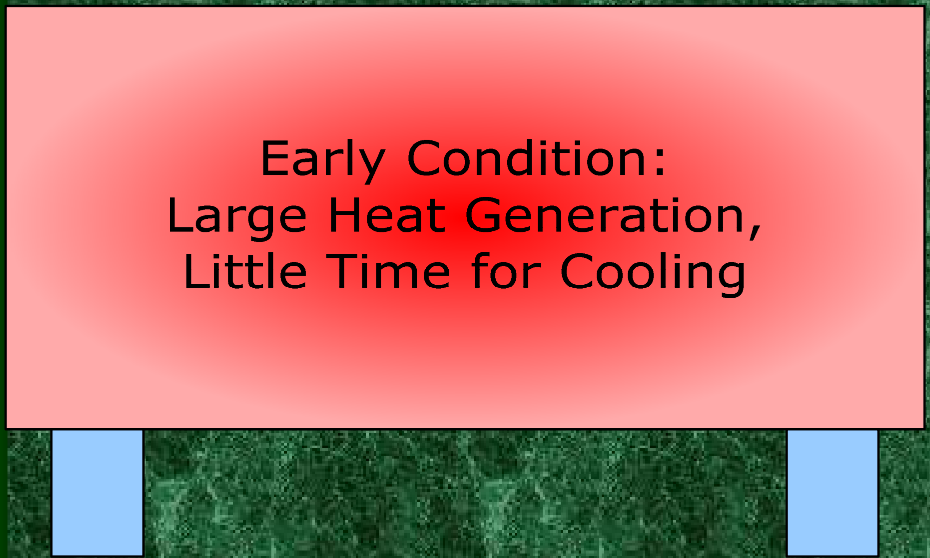
Thermal Stress of different expansion & contraction

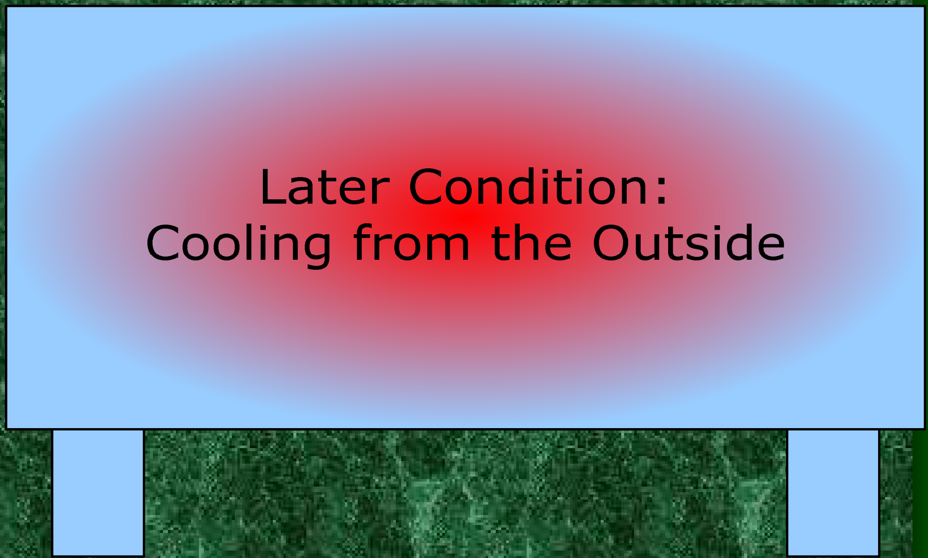
Heating and Cooling

Initial heat generated

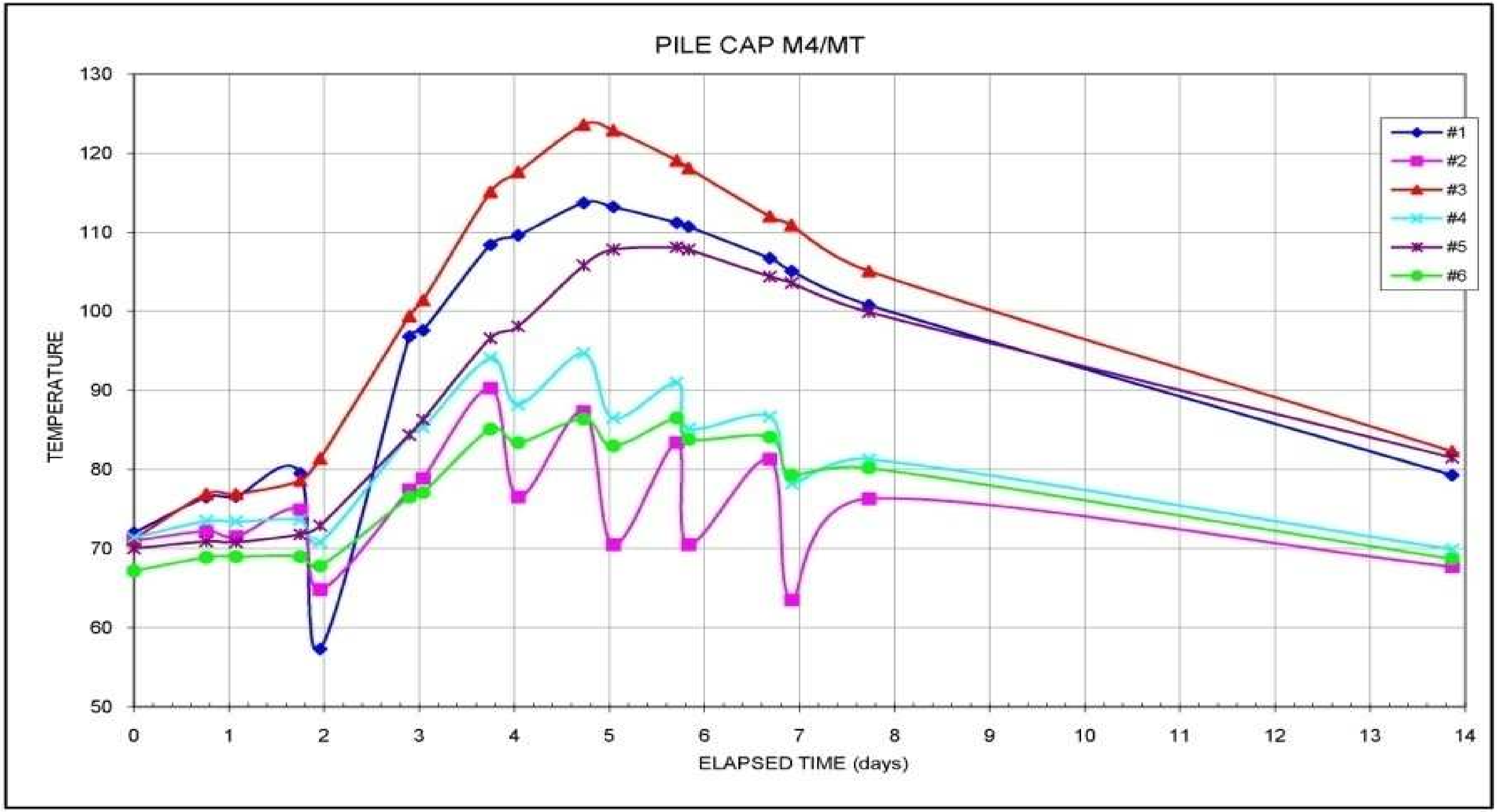
The quicker the peak, the higher the peak (less cooling time)

- As outside cools, inside remains hot.
- As inside cools, it contracts & pulls away from perimeter, cracks

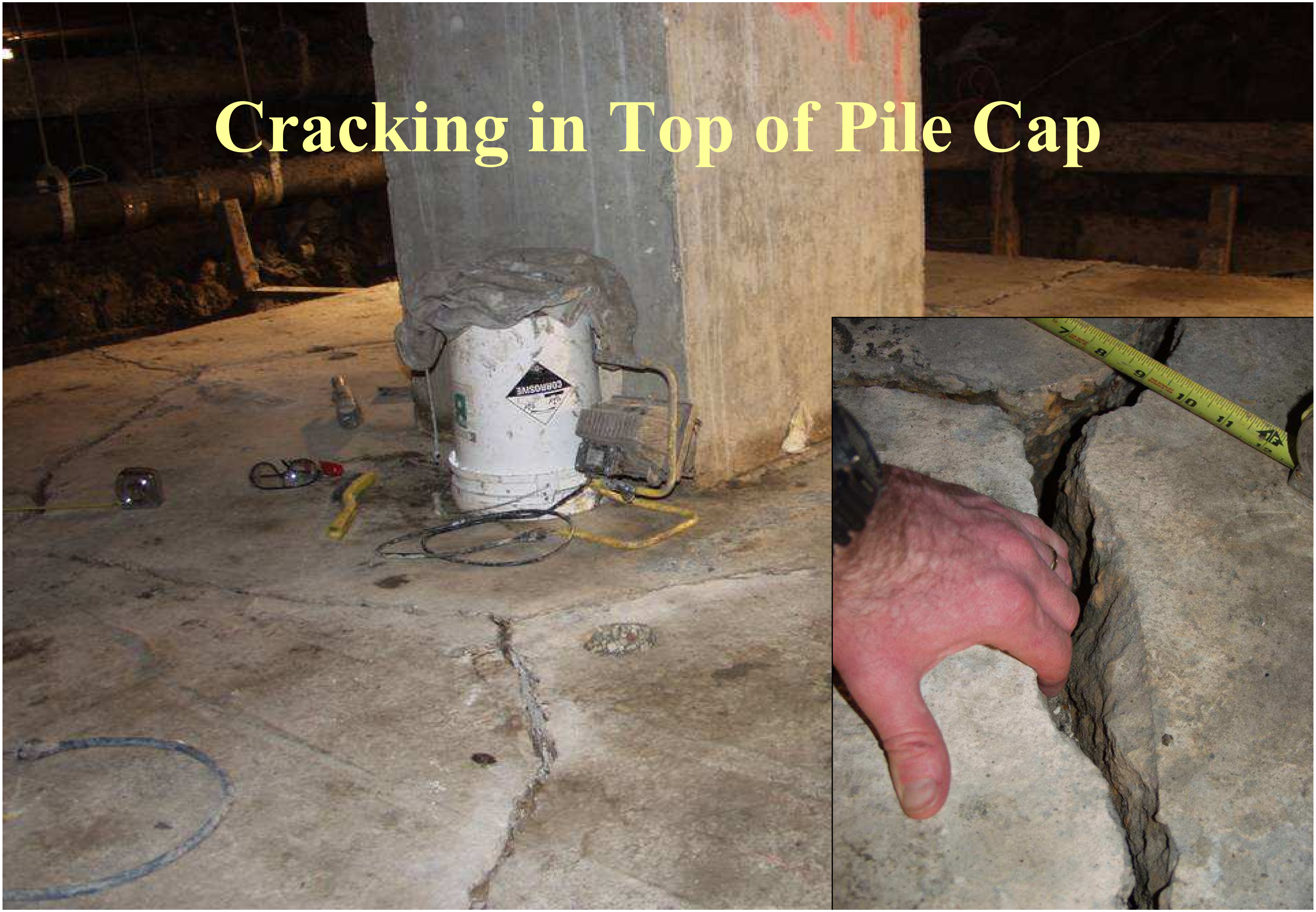




Time-Temperature Plot



Cracking in Top of Pile Cap



Heat Energy

Calculating the change in temperature in a system may be accomplished by using the following formula:

$$\text{Change in Temperature} = \frac{\text{Heat gained or lost}}{\text{Mass x Specific Heat}}$$

Specific heat is defined as the amount of heat energy required to raise 1 g of a substance by 1° Celsius.


GGBF slag
grade 120
Si Silica Fume
(microsilica)
Portland Cement
Type I
Fly Ash
class C

Types Of Portland Cement ASTM C150

I Normal

II Moderate Sulfate Resistance

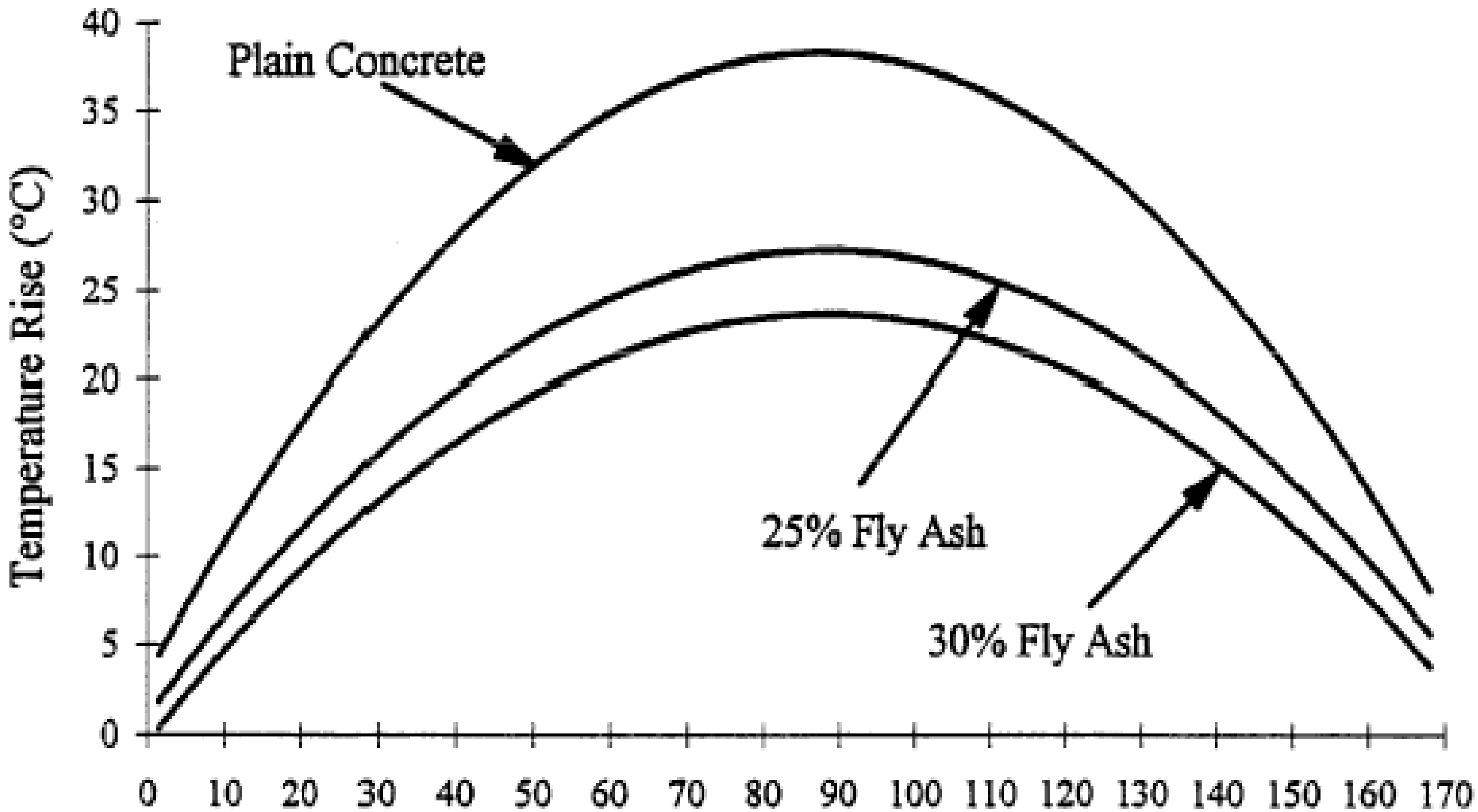
Optional Moderate Heat (MH)

III High Early Strength

IV Low Heat of Hydration

V High Sulfate Resistance

Fly Ash Reduces Heat



Fly Ash Reduces Heat

"The temperature rise can be reduced by using fly ash as a portion of the cementitious material in concrete."

Class F fly ashes almost always reduce heat.

However, be aware that some Class C fly ash may reduce heat, some are heat neutral, and some actually increase heat.

Slag Cement Reduces Heat

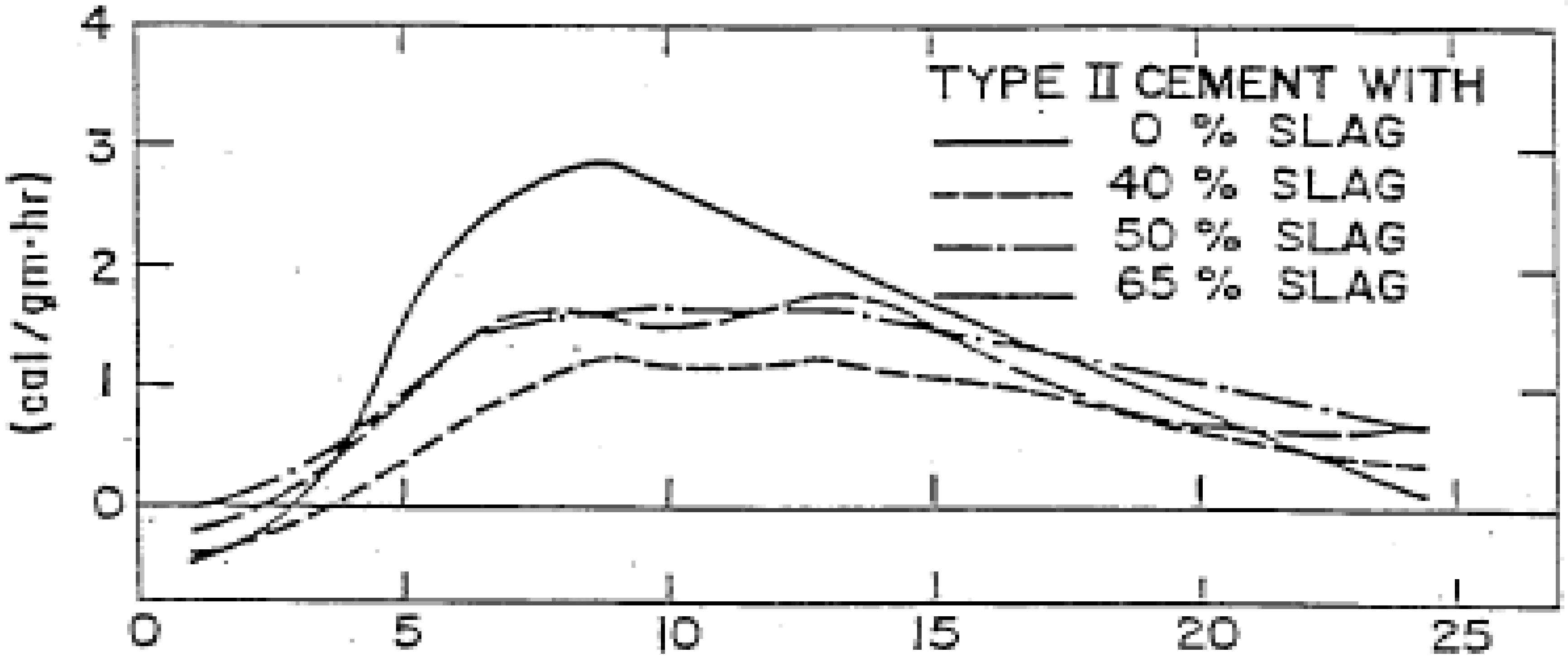


Fig. 1.4—Rate of heat liberation of cements with and without GGBF slag at 27 C (80 F) (Roy and Idorn 1982)

Slag Cement Advantages

Lower Heat of Hydration,
fewer calories/gram of cement

Higher strength performance,
fewer grams of cement,
hence less total heat generated

U S Army Corps of Engineers

Mass Concrete Application

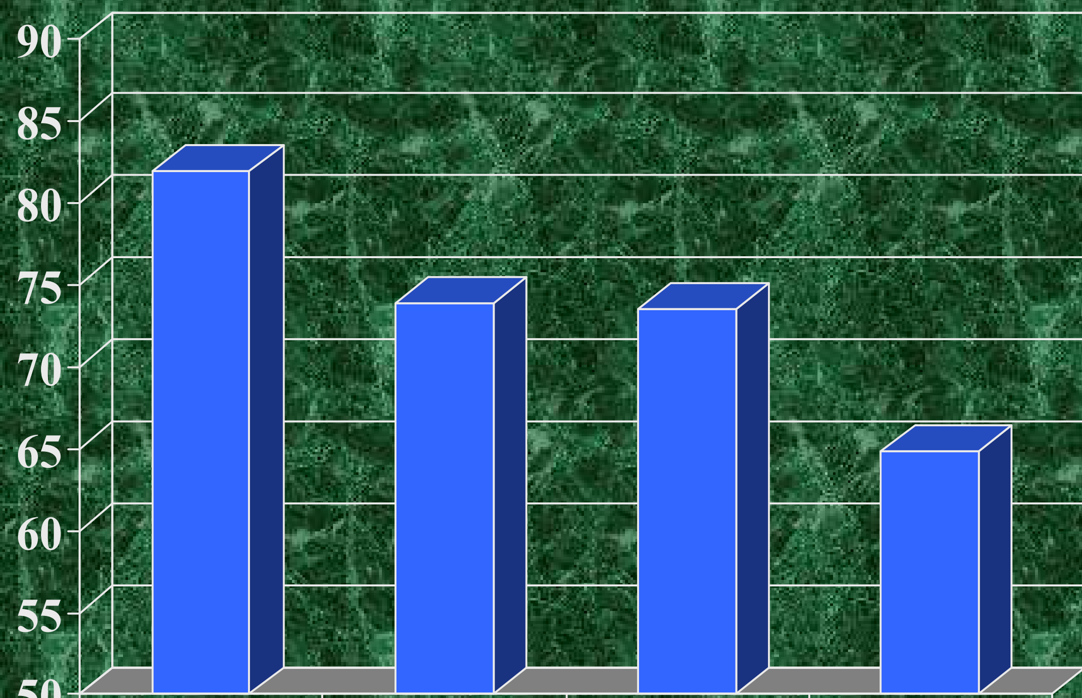
Davis Pond Diversion Project

Luling, LA

1999

Heat of Hydration

with Type II



	100% Portland	65/35 C Ash 1	65/35 C Ash 2	50/50 Slag
■	81.9	73.8	73.5	64.8

ASTM & U S Army Corps of Engineers limit heat to 70 calories/gram at 7 days.


LAMBERT ST. LOUIS
INTERNATIONAL
AIRPORT
ST. LOUIS, MISSOURI
WELCOME
WILLKOMMEN
BIENVENUE
BIENVENIDO
歡迎
ようこそ!
セントルイスへ


3


CON-CURE™


ft
35ft
in
STANLEY
Life Guard
MADE IN U.S.A.

Insulating Values, R

Extruded Polystyrene 5.00/inch

2 inches x 5.00 per inch = 10.00

Normal Weight Concrete 0.11/inch

R-10 / R-0.11 per inch = 91 inches

4” Polystyrene is equivalent to 7’7” of Concrete


MIX 1

Mix Description	Aggregate	1 Day Average	2 Day Average	7 Day Average	14 Day Average	28 Day Average
545 Mass-4	57 Limestone	2359	3657	4983	5314	5454
545 Mass-1A	57 Limestone	1302	2638	3734	3905	4475*
545 Mass-2	57 Limestone	1828	3477	4476	4958	5145
500 Mass-1B	467 Gravel	1143	2665	4104	4643	4824
545 Mass-1B	467 Gravel	1716	3334	4906	5088	5398
590 Mass-1B	467 Gravel	1451	2904	4332	4857	4846
500 Mass-3	57 Gravel	1699	3152	4490	4838	5351
545 Mass-3	57 Gravel	1591	2933	4201	4608	5173
590 Mass-3	57 Gravel	1543	3026	4464	4913	5389

Mix Description	Aggregate	Ambient Temp	Mix Temp	Center Max T	Face Max T
545 Mass-4	57 Limestone	85	76		
545 Mass-1A	57 Limestone	85	76	144	139
545 Mass-2	57 Limestone	95	77		
500 Mass-1B	467 Gravel	85	76	133	132
545 Mass-1B	467 Gravel	90	78	137	135
590 Mass-1B	467 Gravel	90	78	141	133
500 Mass-3	57 Gravel	95	82	140	137
545 Mass-3	57 Gravel	95	79	135	135

Dynergy Power Plant

Cayuga, IN

Maximum In-Place Concrete Temperature Estimator

Portland Type I & Grade 100 Slag

Thickness	10	Feet
Length	295	Feet
Width	133	Feet
Volume	14,531	$Yards^3$

#1	#2	#3	#4	
85	80	75	70	°F
216	216	216	216	Lb/Cu.Yd.
324	324	324	324	Lb/Cu.Yd.
3933	3933	3933	3933	Lb/Cu.Yd.
60	60	60	60	Cal/gm
60	60	60	60	Cal/gm
#1	#2	#3	#4	
61.71	61.71	61.71	61.71	°F
85.0	80.0	[illegible]	70.0	°F
146.7	141.7	136.7	131.7	°F

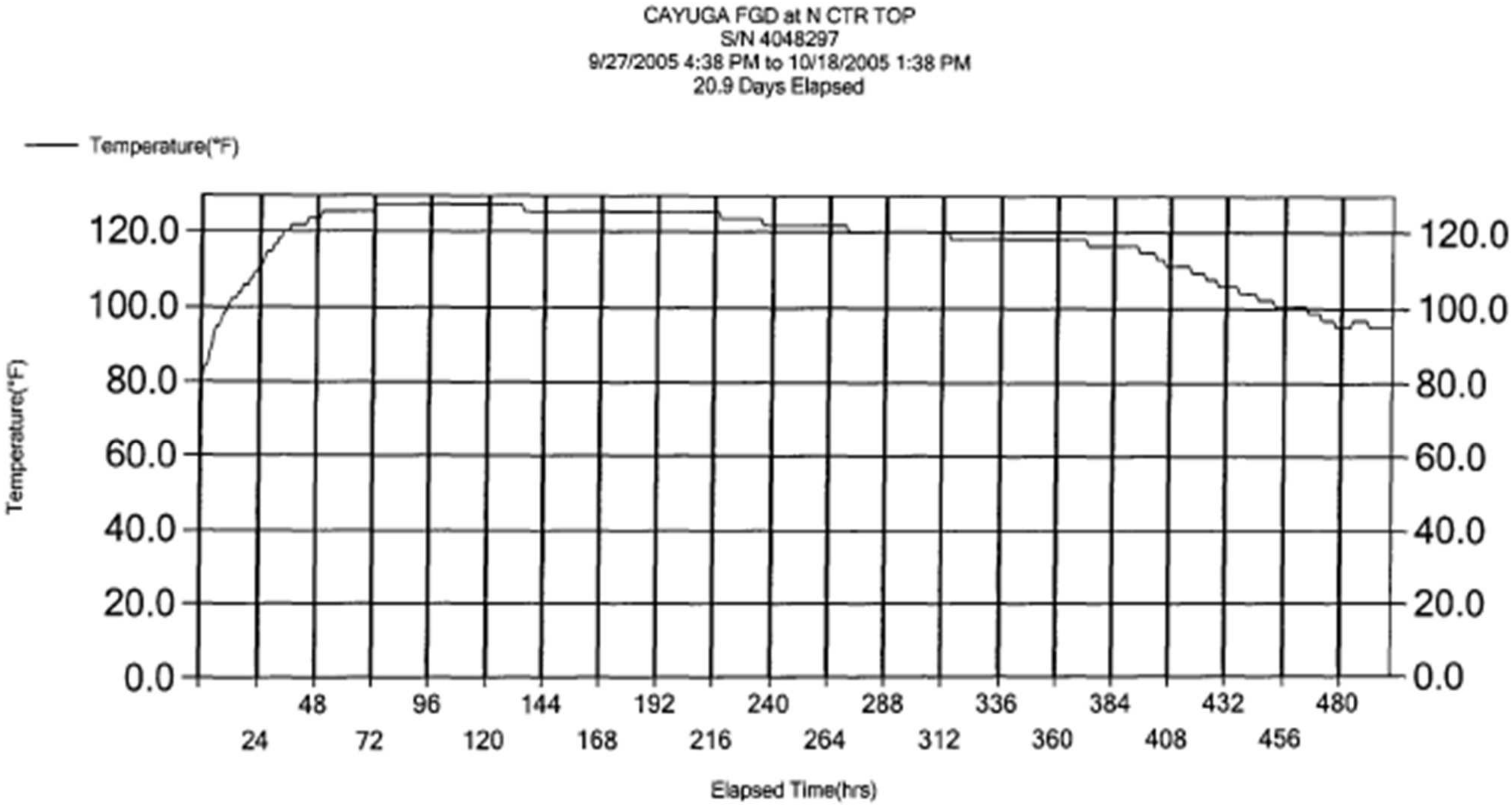
Patriot Engineering
Cayuga FGD Project
Middle Section: Absorber Building

Logger	
S/N:	4048284
Job:	CAYUGA FGD
Location:	NE CORE ABSORBR
Logger ID:	TPL-02-1H28D
Run State:	Locked
Start Date:	9/27/2005 10:30:34 AM
Elapsed Date (Start Date + Elapsed Time):	10/18/2005 1:59:34 PM
Elapsed Time (hrs):	507.48
Data Interval (min):	60
Number of readings:	508

Events

Time (hrs)	Event Description	Temperature (°F)
0.00	MIN TEMPERATURE	[illegible]
49.37	MAX TEMPERATURE	134.6
507.48	LAST READING	[illegible]

Patriot Engineering
Cayuga FGD Project
Middle Section: Absorber Building




7 15 '97

LA Hwy 1 Bridge at Fourchon

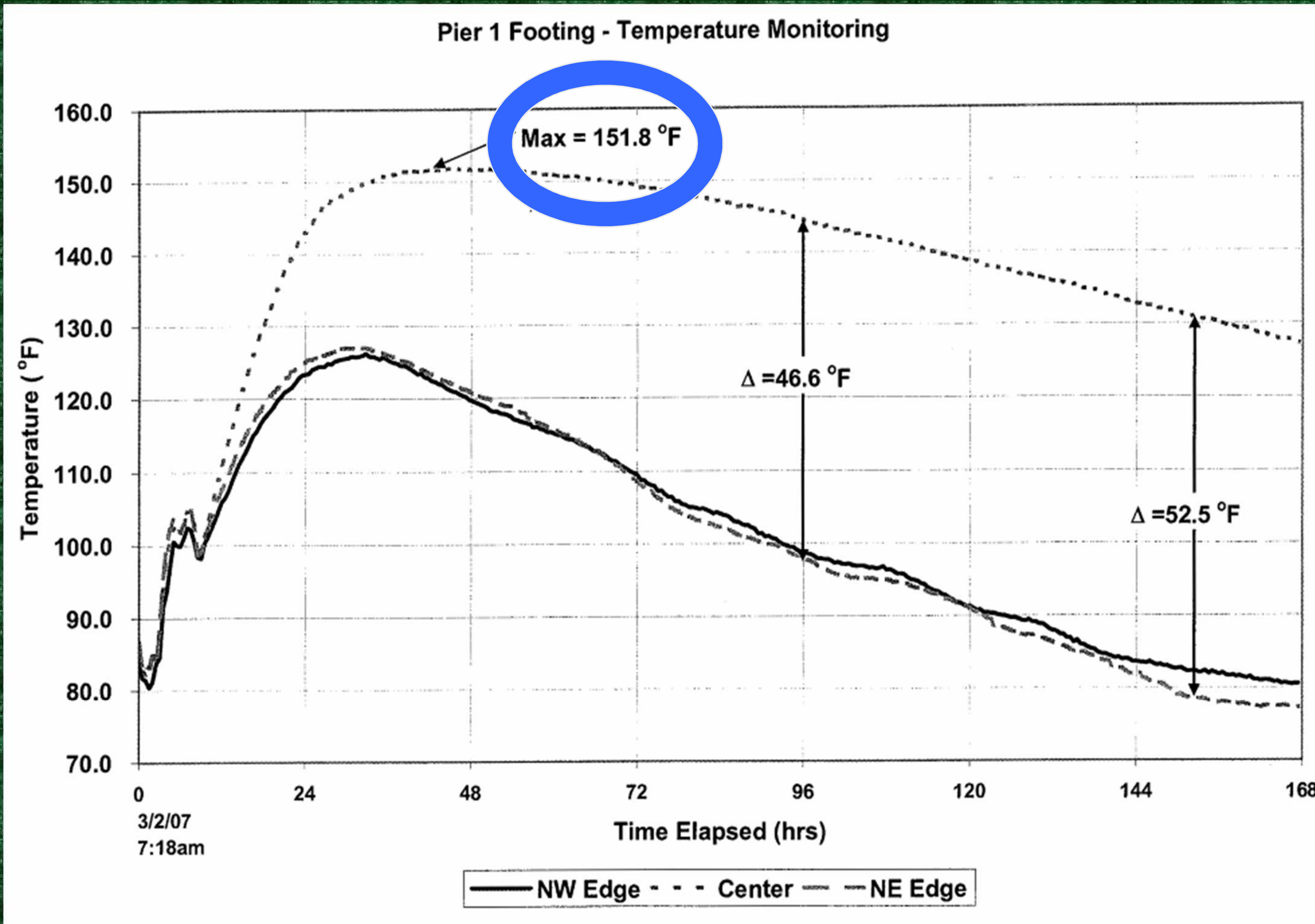
Maximum In-Place Concrete Temperature Estimator

4000 psi

50% Type I/II Portland, 50% G120 Slag + 5% Silica Fume

Thickness	8	Feet
Length	67	Feet
Width	47	Feet
Volume	933	$Yards^3$

		#1	#2	#3	#4	Inch-Pound
T_i	Initial Concrete Temp.	40	60	80	90	°F
P	Mass of Portland Cement	300	300	300	300	Lb/Cu.Yd.
S	Mass of Slag Cement	300	300	300	300	Lb/Cu.Yd.
F	Mass of Silica Fume	30	30	30	30	Lb/Cu.Yd.
W	Unit Weight of Concrete	3907	3907	3907	3907	Lb/Cu.Yd.
H_1	Heat of Hydration - PC	61.5	61.5	61.5	61.5	Cal/G
H_2	Heat of Hydration - SC	61.5	61.5	61.5	61.5	Cal/G
H_3	Heat of Hydration - SF	61.5	61.5	61.5	61.5	Cal/G
T_i	Initial Temperature	40.0	60.0	80.0	90.0	°F
ΔT	Temperature Gain	74.3	74.3	74.3	74.3	°F
T_{max}	Maximum Temperature	114.3	134.3	154.3	164.3	°F



Pier 1 Footing - Temperature Monitoring
Max = 151.8 °F
Δ =46.6 °F
Δ =52.5 °F
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
Temperature (°F)
0
24
48
72
96
120
144
168
3/2/07
7:18am
Time Elapsed (hrs)
NW Edge
Center
NE Edge

Sempra – Cameron LNG

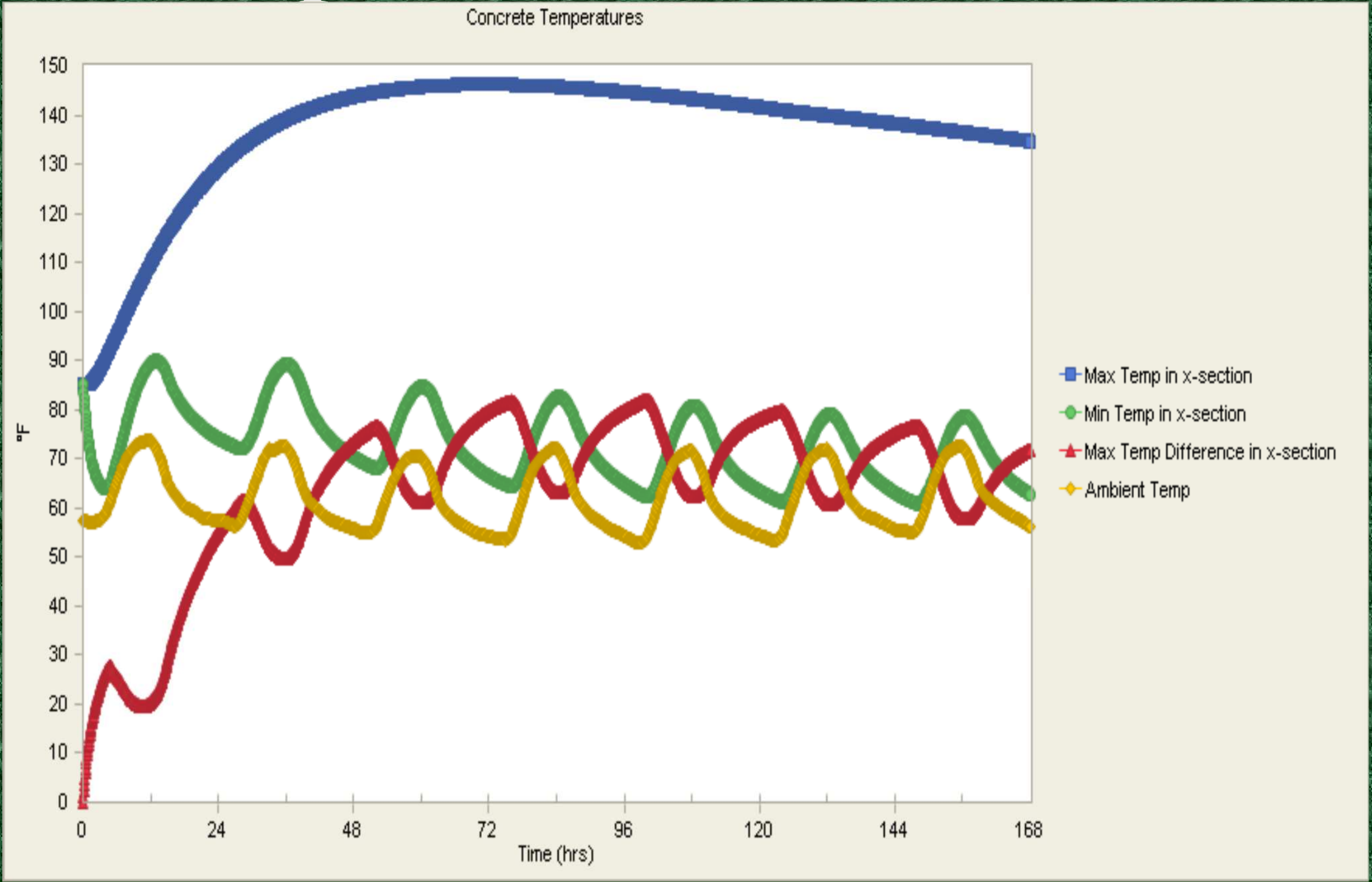
Compressor Foundations

Cement Plant	C	F
Type I/II	80.6	80.7
50% Slag, 25% F Ash	50.8	58.2

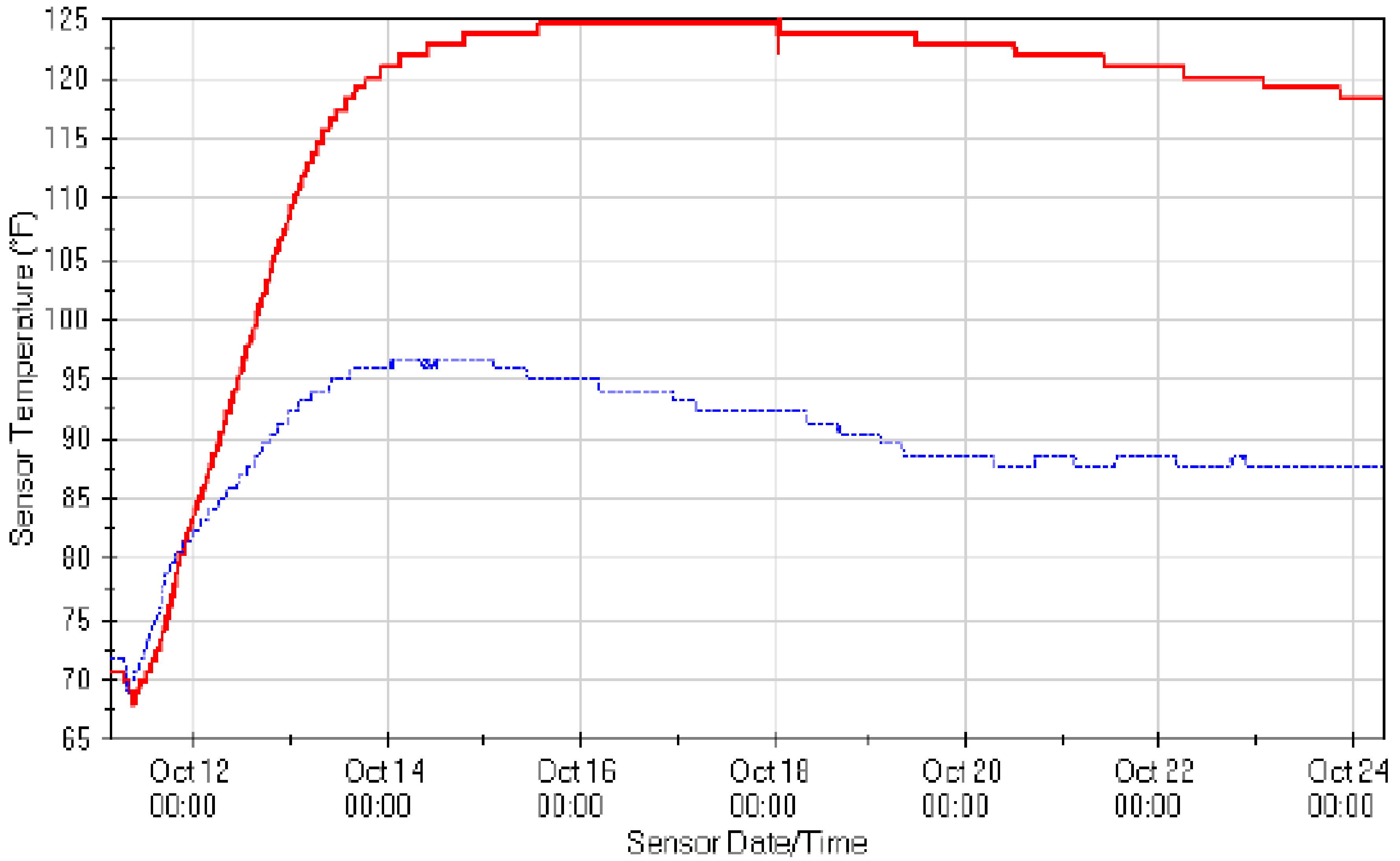
Sempra – Cameron LNG

		Scenario #1	Scenario #2	Scenario #3	Scenario #4	Inch-Pound Units
T_i	Initial Concrete Temp.	70	75	80	85	°F
P	Mass of Portland Cement	132	132	132	132	Lb/Cu.Yd.
S	Mass of Slag Cement	265	265	265	265	Lb/Cu.Yd.
F	Mass of Fly Ash	133	133	133	133	Lb/Cu.Yd.
W	Mass of 1 yd^3 of Concrete	3877	3877	3877	3877	Lb/Cu.Yd.
H_1	Heat of Hydration, Portland	58.2	58.2	58.2	58.2	Cal/G
H_2	Heat of Hydration, Slag	58.2	58.2	58.2	58.2	Cal/G
H_3	Heat of Hydration, Fly Ash	58.2	58.2	58.2	58.2	Cal/G
T_i	Initial Temperature	70.0	75.0	80.0	85.0	°F
ΔT	Temperature Gain	59.60	59.60	59.60	59.60	°F
T_{max}	Maximum Temperature	129.6	134.6	139.6	144.6	°F

Sempra – Cameron LNG



Sempra – Cameron LNG



Sempra – Cameron LNG

The combined chemical composition of the total cementitious system of 25% Type I/II Portland Cement, 50% Grade 120 Slag Cement, and 25% Class F Fly Ash ratio of SO_3 to Al_2O_3 is 0.118. This is far below the threshold of potential for Delayed Ettringite Formation (DEF). DEF typically occurs in mixes that reach temperatures in excess of 165°F and have SO_3 to Al_2O_3 ratios in excess of 0.45 to 0.70. This is the reason for limiting maximum temperatures in place to 165°F.

NCRA Refinery

Cement Plant **C** **P**

Type I/II **77.5**
67.8

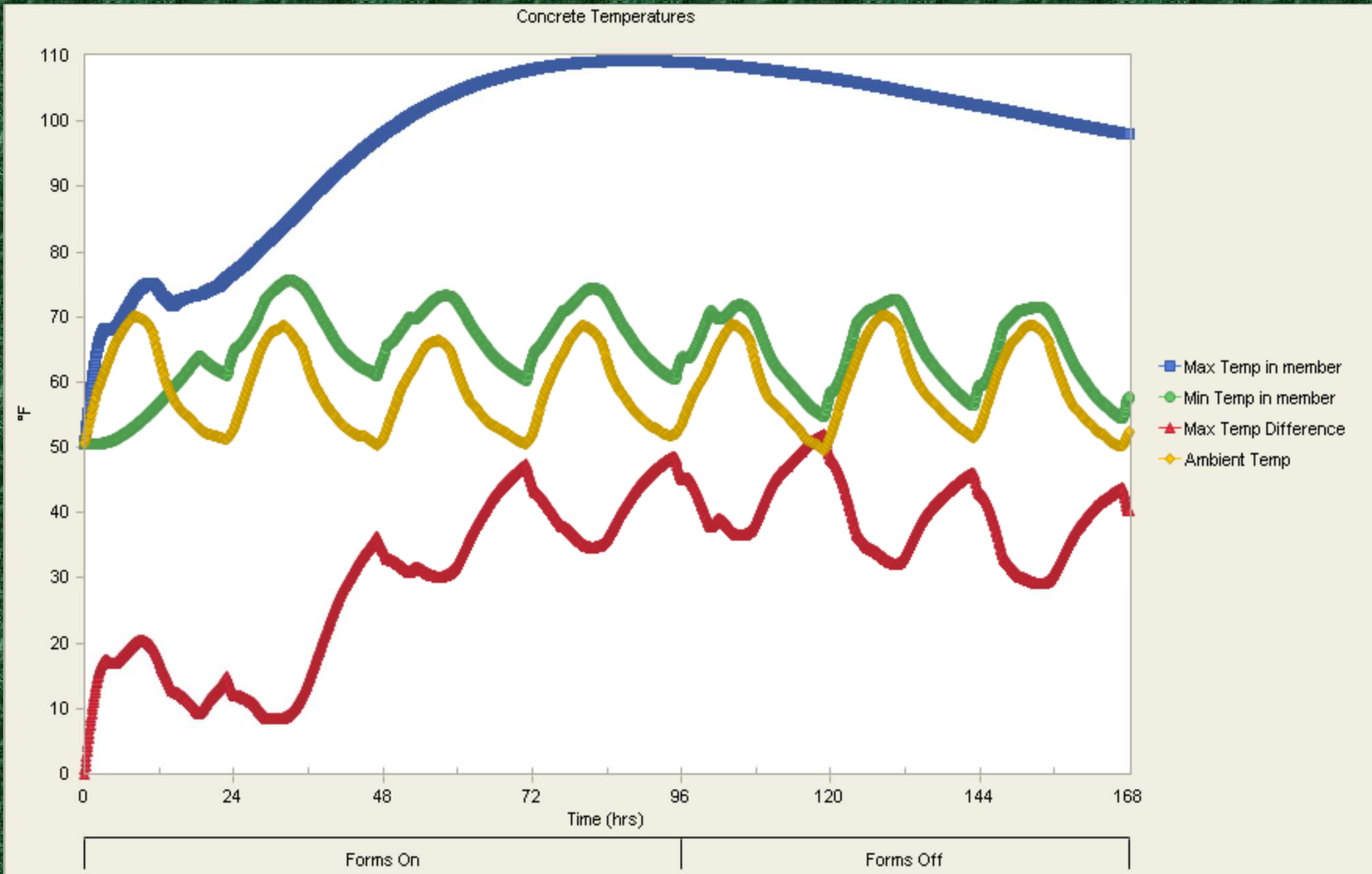
25% C Ash S **79.5**
64.5

25% C Ash A **83.1**

NCRA Refinery

100% Type I/II	82.0
25% Slag	70.0
37.5% Slag	69.4
50% Slag	64.4
30% Slag, 20% C Ash S	67.9

NCRA Refinery



High Strength Concrete

Manhattan / BEERS

Reliant Stadium

Houston NFL Stadium

4 Super Columns

12’6” x 25’-75’ x 150’

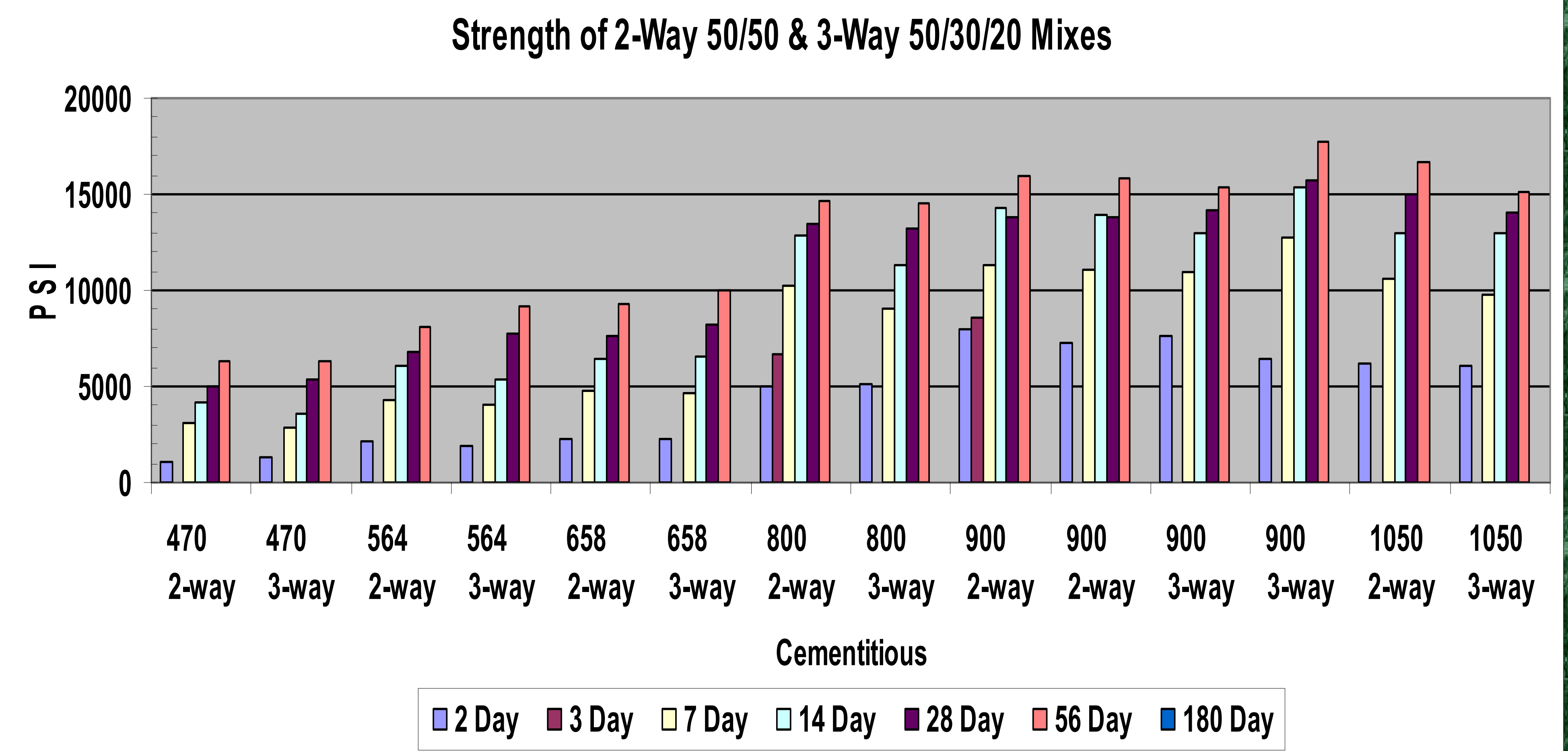
Supporting 7,000,000 pounds

Design Strength: 13,000 psi


382


12. 5. 2000

Houston NFL Stadium



Missouri DOT

Mass Concrete Application

Page Avenue Bridge

Creve Couer Lake

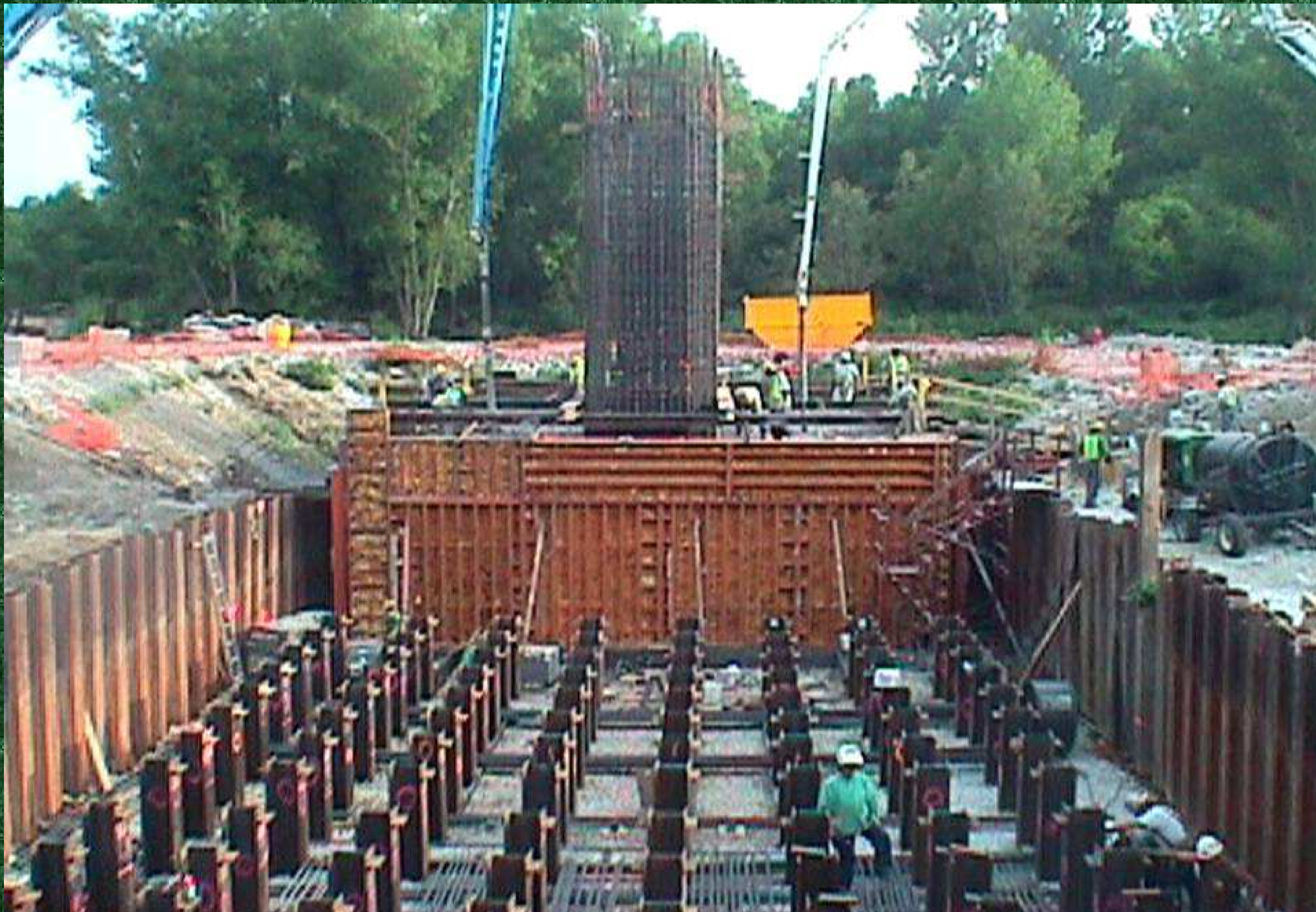
St. Louis, MO

Foundation: 72’ long x 35’ wide x 13’ deep

Reinforced with #14 bars 5” on center

Required low heat of hydration to prevent thermal stress

Limited heat of hydration to 60 cal/gram



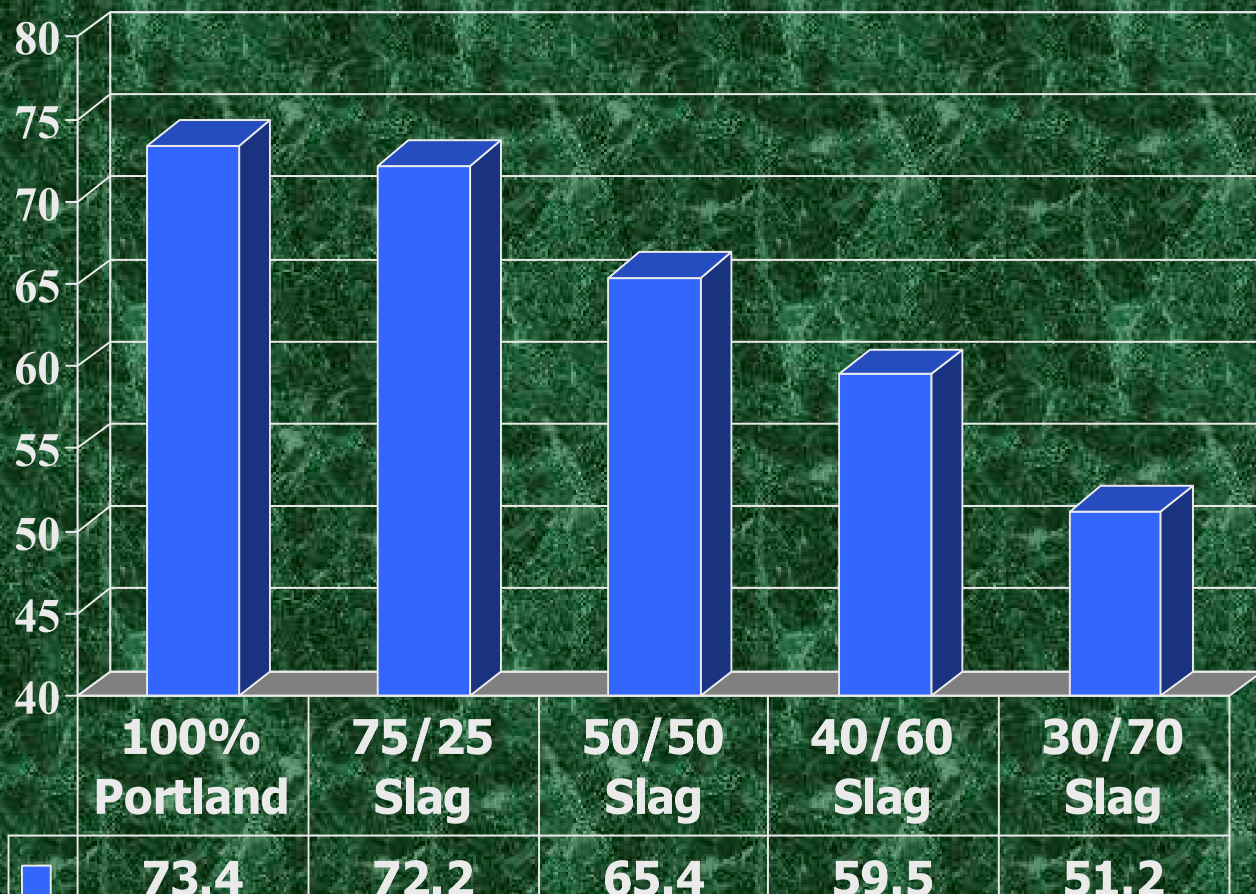
No Type IV low-heat cement was available

Tested Type II and Type II(Moderate-Heat)

With Slag Cement at various %

Heat of Hydration

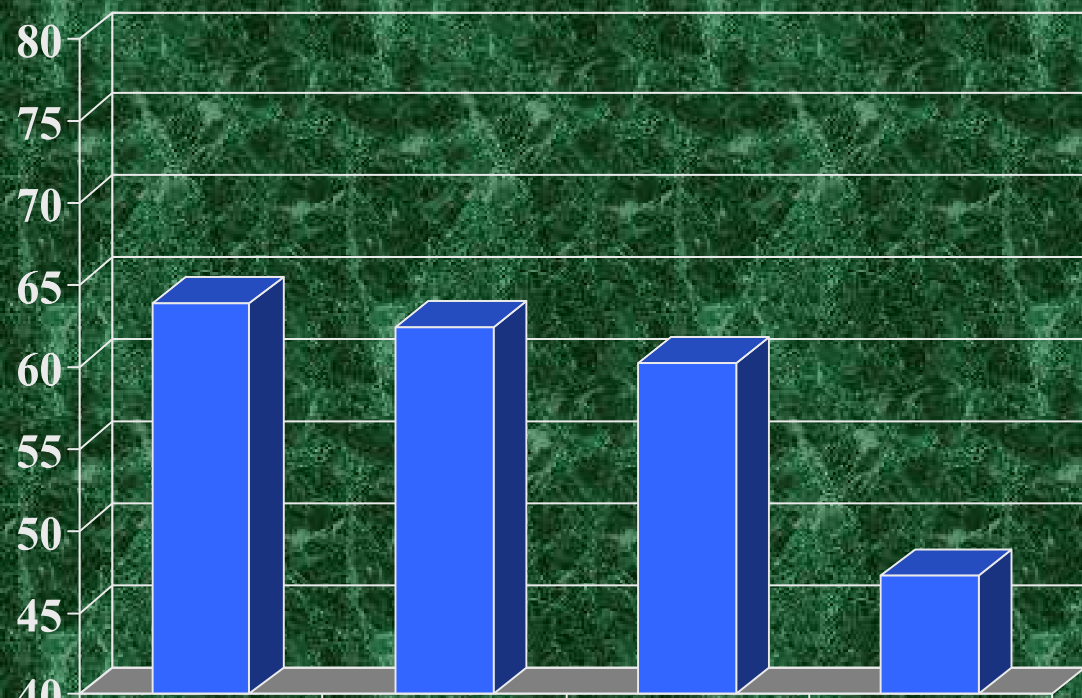
With Cape Type I/II



ASTM & U S Army Corps of Engineers limit heat to 70 calories/gram at 7 days.

Heat of Hydration

with Cape Type II(MH)



	100% Portland	75/25 Slag	50/50 Slag	30/70 Slag
■	63.9	62.4	60.2	47.2

ASTM & U S Army Corps of Engineers limit heat to 70 calories/gram at 7 days.

Maximum Temperature in Place

125^oF

Mat Foundations, Houston

ENRON Building	11,000
5 Houston Center	8,500
1000 Main	12,000
M D Anderson (2)	12,000

Calories/Gram

Mixture	7-Day	28-Day
100% Type I/II	75.70	87.47
70% T I/II + 30% Class C Fly Ash	77.73	89.67
70% T I/II + 30% Class F Fly Ash	75.32	71.38
50% Type I/II + 30% Slag	70.17	[illegible]

ENRON Building

Houston, TX

11,000 Cubic Yard

Mat Foundation

5,000 psi with Low Heat

550 # Total Cementitious

50% Portland

30% Slag

20% Fly Ash

MR W/R

5 Houston Center

Houston, TX

8,500 cubic yard

Mat Foundation

6,000 psi with Low Heat

517 # Total Cementitious

50% Portland

30% Slag

20% Fly Ash

MR W/R

Specification:

6,000 psi @ 56 Days

Performance:

6,000 + psi @ 14 Days

Max Temp - 130^{o}F

City of Austin

Austin, TX

45’ tall x 50’ wide x 3’ thick

Chilling Towers

4,000 psi with Low Heat

517 # Total Cementitious

30% Portland

35% Slag

35% Fly Ash

MR W/R

Specification:

4,000 psi @ 28 Days

Performance:

5,500 + psi @ 28 Days

Specification:

$T < 165^{o}F$, $\Delta T < 35^{o}F$

Performance:

$T < 139^{o}F$, $\Delta T < 25^{o}F$

with Ambient = $112^{o}F$