Lessons Learned From Using Type 1L Cement in Mass Concrete Placements

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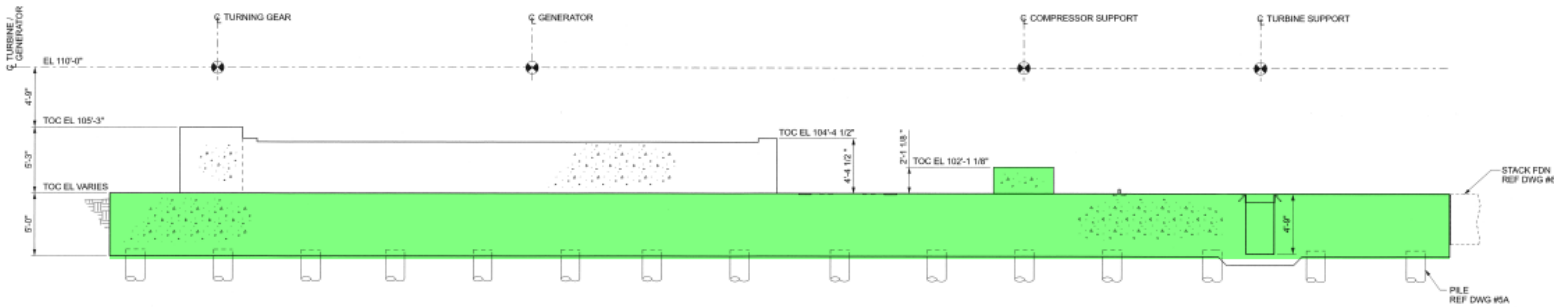
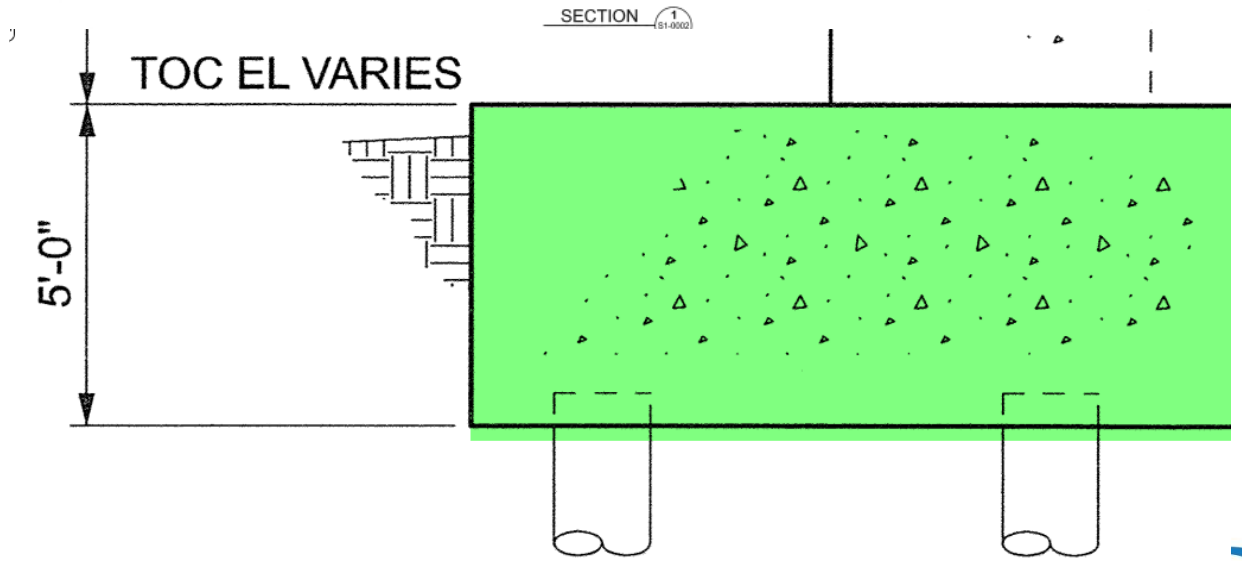
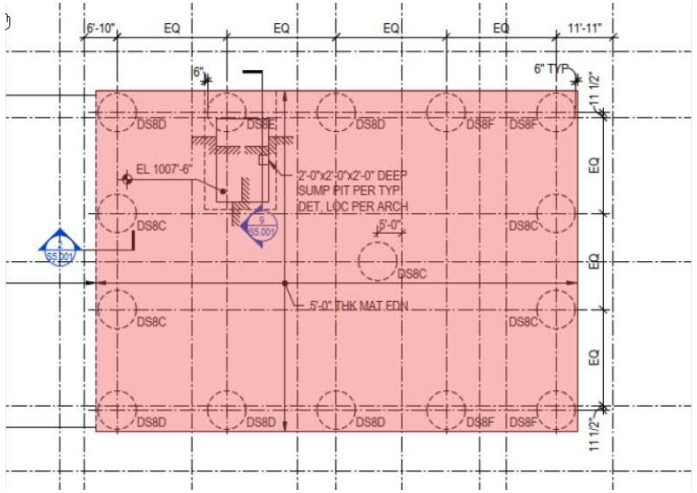
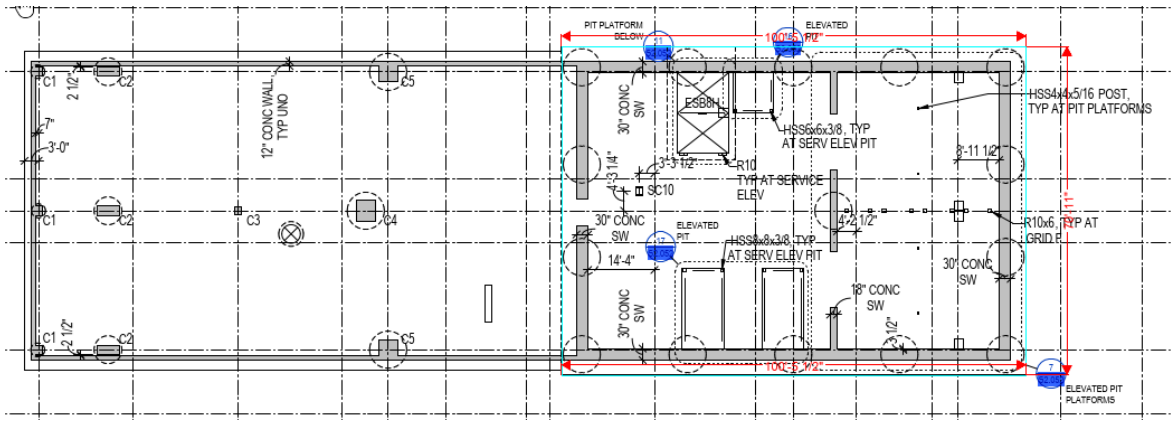
Terracon

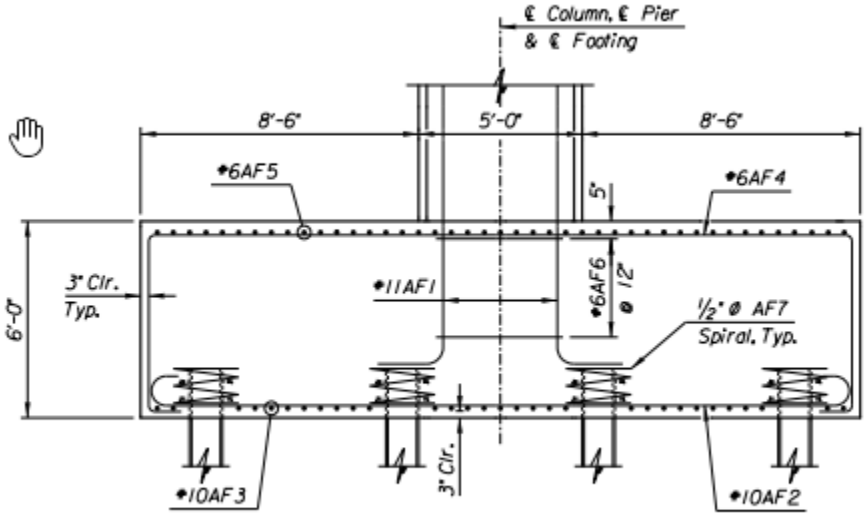
It starts simply enough











SECTION C-C

ASTM C150

- ASTM C150 (22) – Standard Specification for Portland Cement
  - Covers 10 types of Portland Cement
  - Includes limestone up to 5% by mass
    - Contents of C_3S, C_2S, C_3A, and C_4AF are adjusted in phase composition
    - Limestone content of Portland cement is derived from CO_2 in finished cement.
  - Mill Certificate Chemical contains:
    - % Al_2O_3
    - % Fe_2O_3
    - % MgO
    - % SO_3
    - % $CaCO_3$ in Limestone
    - equivalent alkalis
    - Loss on ignition
  - Blaine Fineness 260 - 430

ASTM C595

- ASTM C595 (21) – Standard Specification for Blended Hydraulic Cements
  - Adds suffixes for S, P, and L for **S**lag, **P**ozzolan, and **L**imestone
  - Limestone content is greater than 5% but ≤ 15% by mass
  - Adds percentages to descriptors for blended mass (binary and ternary)
    - Type IL(10) = 90% Type 1 Portland Cement and 10% Limestone, etc.
  - Mill certificate Chemical Analysis contains
    - % Sulfate,
    - Loss on Ignition,
    - Equivalent alkali content
  - Blaine fineness has no specification

Cement Mill Test Report

CHEMICAL ANALYSIS

Item	Spec limit	Test Result
Rapid Method, X-Ray *(C 114)*		
SiO2 (%)	---	27.6
Al2O3 (%)	---	6.3
Fe2O3 (%)	---	2.1
CaO (%)	---	53.5
MgO (%)	---	5.2
Sulfur as SO3 (%)	3.0 max*	2.9
Sulfur as Sulfide (%)	2.0 max	0.30
Loss on ignition (%)**	3.0 max	2.3
Insoluble residue (%)	1.0 max	0.45
Total Alkalis	---	0.50

PHYSICAL ANALYSIS

Item	Spec limit	Test Result
Air content of mortar (%) *(C 185)*	12 max	9
Blaine Fineness (m2/kg) *(C 204)*	---	482
Fineness, Residue retained on a 45 um sieve (%)	---	2.2
Autoclave expansion (%) *(C 151)*	0.80 max -0.20 min	0.03
Compressive strength (PSI) *(C 109)*		
3 days	1890 min	2780
7 days	2900 min	4140
28 days	3620 min	6730
Time of setting (minutes) Vicat Initial (C191)	45 - 420	139
Mortar Bar Expansion (%) *(C 1038)**	.02 max	0.008
Specific Gravity (C188)	---	3.04

* May exceed 3.0% SO3 maximum based on our C 1038 results of <0.02% expansion at 14 days.

Cement Mill Test Report

ASTM C 595 and AASHTO M 240 Standard Requirements

CHEMICAL ANALYSIS

Item	Spec limit	Test Result
Rapid Method, X-Ray *(C 114)*		
SO3 (%)*	3.0 max	3.5
Loss on ignition (%)	10 max	4.1
Equivalent Alkalies (%)	---	0.48
CaCO3 in Limestone (%)	70 min	76
Inorganic Processing Addition	3.8 max	0.9

PHYSICAL ANALYSIS

Item	Spec limit	Test Result
Blaine Fineness (m2/kg) *(C 204)*	---	404
Fineness, Residue passing on a 45 um sieve (%)	---	98.9
Density *(C604)***	---	3.11
Air content of mortar (%) *(C 185)*	12 max	7
Autoclave expansion (%) *(C 151)*	-0.20 to +0.80	0.07
Time of setting (minutes)		
Vicat Initial *(C 191)*	45 - 420	104
Compressive strength (MPa, [PSI]) *(C 109)*		
1 day	---	14.7 [2127]
3 days	13.0 [1890] min	27.3 [3959]
7 days	20.0 [2900] min	34.1 [4951]
28 days**	25.0 [3620] min	44.3 [6425]
Mortar Bar Expansion (%) *(C 1038)*	0.020 max	0.010
Heat of Hydration - 3 day (kJ/kg) (C 1702)**	335 max	316
Sulfate Resistance - 180 days (%) (C 1012)**	0.10 max	0.040

Project 1 Experience

State Bridge Construction - Central US

MASS CONCRETE:

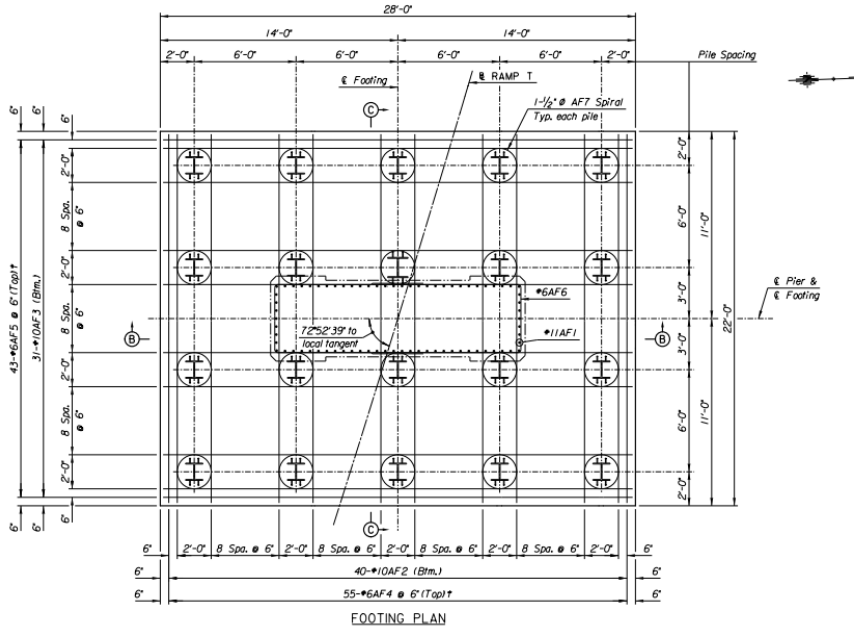
Mass concrete provisions apply to the pier footings, columns, and capbeams. Prior to mass concrete construction, the Contractor shall submit to the Engineer for approval a Thermal Control Plan, including design calculations. The Thermal Control Plan shall show complete details and determine the maximum allowable temperature differentials between the hottest point of the concrete and the exterior faces in order to minimize potential of cracking that could result from excessive heat of hydration. As a minimum, the Thermal Control Plan shall include the mix design, duration and method of curing, procedures to control concrete temperature at time of placement, methods of controlling temperature differentials, temperature sensor types and locations, temperature monitoring and recording system, and field measures to ensure conformance with the required maximum concrete temperatures and temperature differentials.

The temperature at the central core of the footing, column, or capbeam shall not exceed 160° F during placement and curing. The footing shall be placed in one continuous operation without additional construction joints not shown in the plans.

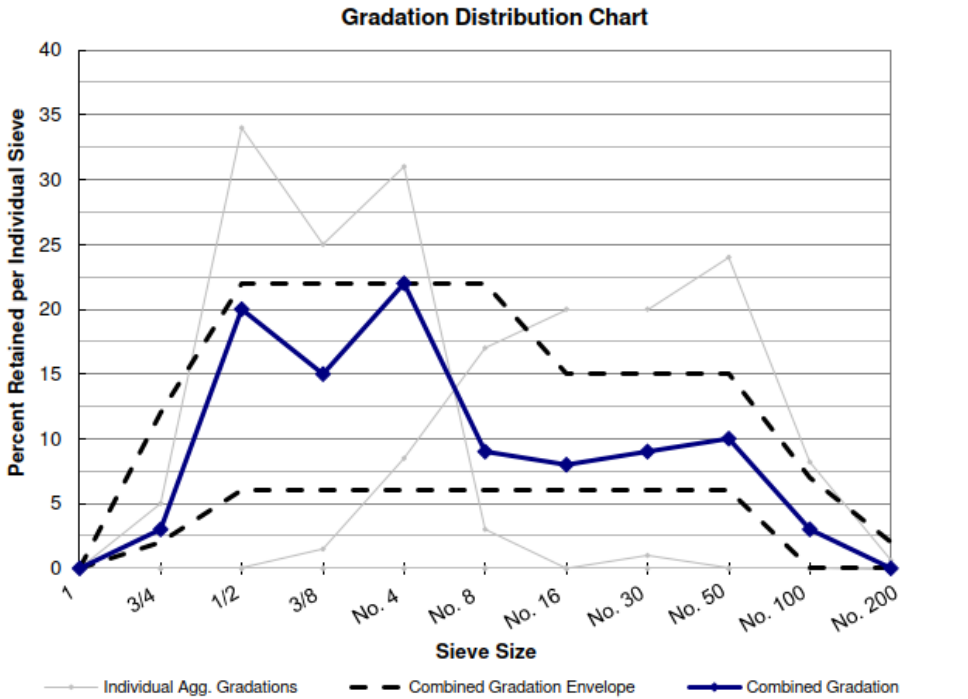
The maximum temperature difference shall be held to 35°F between any two points within the footing, column, or capbeam in any one pour, during placing and until three consecutive days have been recorded where the difference between where the difference between the interior concrete temperature and the average daily air temperature is less than 35°F. The Contractor shall propose, for approval, construction methods that will achieve the uniformity of temperature and if any methods prove inadequate, shall adopt different and/or additional measures as necessary to achieve the uniformity. Methods may include insulated forms or mechanical cooling systems. Temperatures must be observed at not less than four locations within the pour.

State Bridge Construction - Central US

- 4,000-psi at 28 days (0.39 w/c)
- 19mm Nominal Aggregate (Limestone)
- 60% Type 1L Cement
- 40% Class F Fly Ash
- Air Entrainment
- Type F - High Range Water Reducer
- Type F – Mid Range Water Reducer
- 4.75” slump, 6% air
- Max Temp 160 ºF, Max Differential 35 ºF
- Footing Dimensions 22’ x 28’ x 6’



State Bridge Construction - Central US



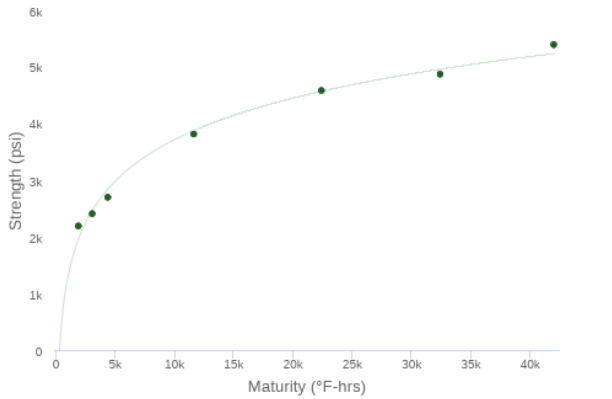
Mix Info.

Mix ID:	
Plant Name:	
Calibration Method:	Temperature-time factor (TTF)
Datum Temperature:	14.0 °F
Calibration Equation:	f_c = -6025.41 + 2440.57.log(M)
Calibration Date:	2023-06-22 09:28:33

Calibration Data

	Maturity Index (°F-hrs)	Strength (psi)
1-day	1934.0	2203.0
2-day	3111.7	2429.0
3-day	4430.0	2710.0
7-day	11632.0	3840.0
14-day	22422.0	4610.0
21-day	32442.0	4890.0
28-day	42049.0	5420.0

Calibration Curve

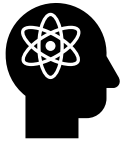


Predicted vs. Actual Results

Mix ID	Date of Placement	Time of Placement	Concrete Temp	Ambient Temp	Slump	Air Content	Max Temp Predicted	Differential Predicted
AE	10/12/23	8:00 AM	82	61	5.5	5.2	142	33
AE	10/24/23	8:45 AM	76	56	5.0	4.9	140	31
AE	12/12/23	10:15 AM	61	36	5.0	7.0	130	21
AE	2/8/24	11:30 AM	73	54	4.0	6.5	138	32

7-day Avg.	28-day Avg.	Max. Temp	Differential Temp	Curing Method
5,260	7,490	136	30	Burlap and Plastic Sheet
4,850	6,460	124	28	Curing Blankets
4,970	6,850	114	22	Double Curing Blankets
3,750	5,890	140	34	Curing Blankets

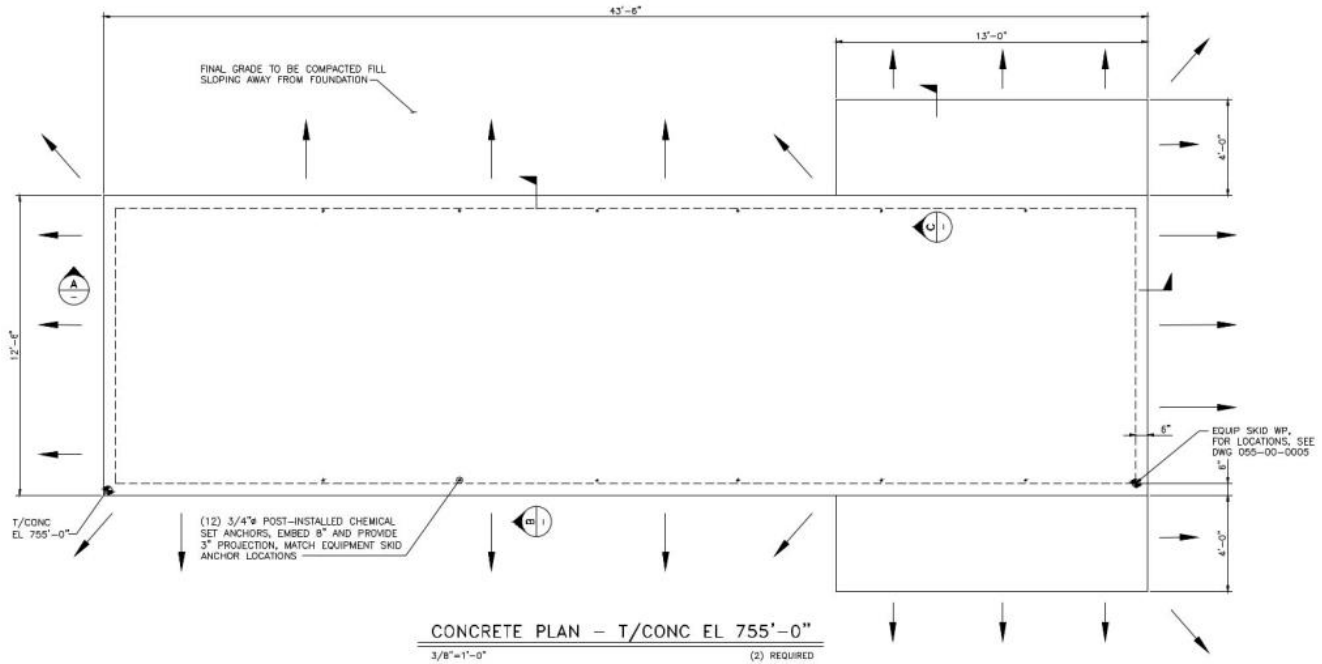
The Lessons Learned



- **Communicate early and often throughout the process**
- **Facts over Gossip**
- **Data Driven Decisions**
- **EDUCATE YOUR CLIENT**
- **Best Practices are Best Practices**
- **Learn from the Data**

Project 2 Experience

Nitrogen Plant – North Central US



Nitrogen Plant – North Central US

DIVISION 03 – CONCRETE

A. FORMWORK

1. REFERENCES
   A. ACI 301 "SPECIFICATIONS FOR STRUCTURAL CONCRETE"
   B. ACI 347 "GUIDE TO FORMWORK FOR CONCRETE"
2. THE CONTRACTOR SHALL BE RESPONSIBLE FOR DESIGN, CONSTRUCTION AND BRACING OF ALL FORMWORK AND SHORING.
3. PROVIDE 3/4" X 3/4" CHAMFER ON ALL EXPOSED EXTERIOR CORNERS, UNLESS OTHERWISE SPECIFIED.

STRUCTURAL CONCRETE MIXES

CLASS/USE	f'c 28 DAY COMPRESSIVE STRENGTH	MAXIMUM W/ (C+P) RATIO	MAXIMUM AGGREGATE SIZE	TOTAL AIR CONTENT	SLUMP RANGE
FOOTINGS, MATS CAPS	4,000 PSI	0.45	1 1/2"	4.0–7.0%	3"–5"

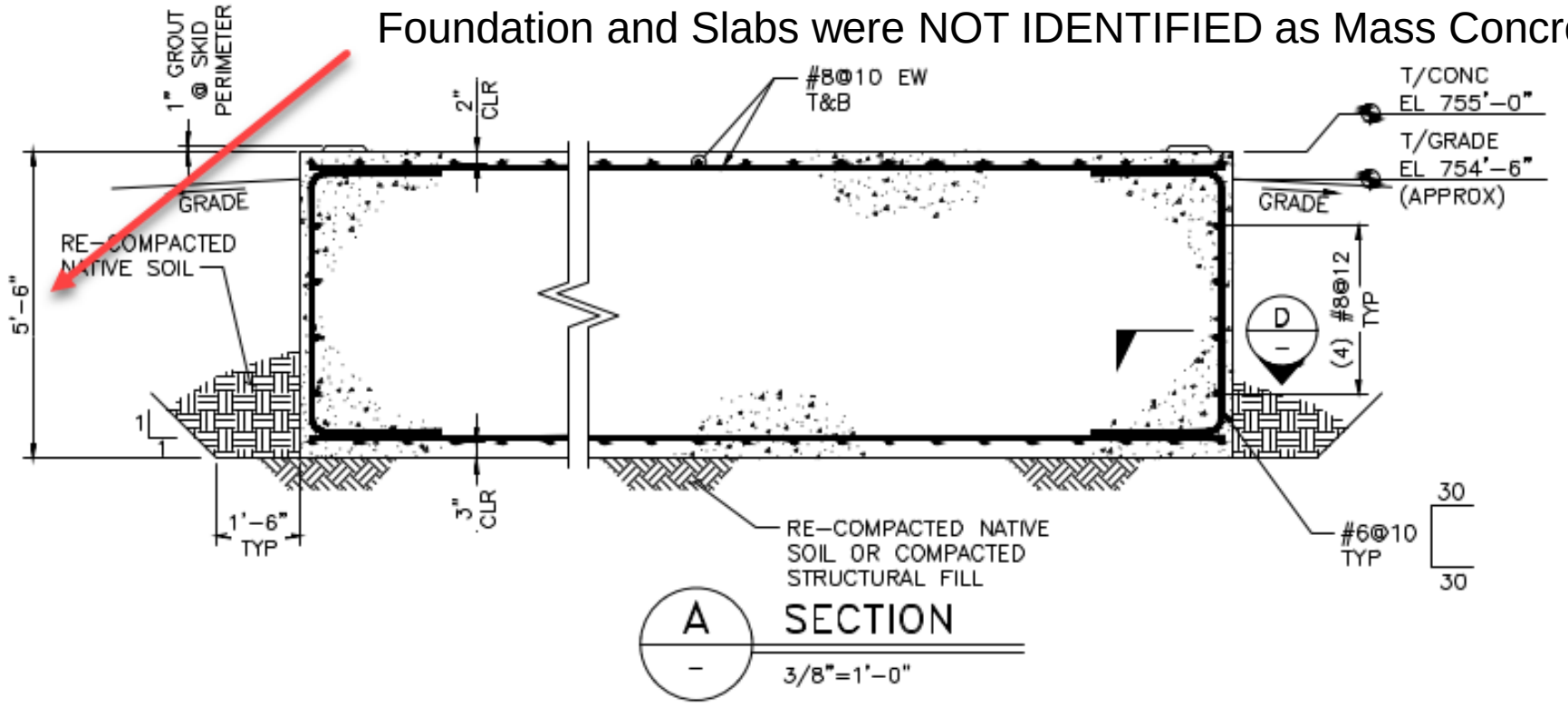
CONCRETE CLASS/USE NOTES:
A. FOR EXTERIOR SLABS, SLUMP RANGE 4"–6"

G. CAST–IN–PLACE CONCRETE

1. REFERENCES
   A. ACI 301 "SPECIFICATIONS FOR STRUCTURAL CONCRETE"
   B. ACI 318 "BUILDING CODE REQUIREMENTS FOR STRUCTURAL CONCRETE"
   C. ACI 306.1 "STANDARD SPECIFICATION FOR COLD WEATHER CONCRETING"
   D. ACI 350 "ENVIRONMENTAL ENGINEERING CONCRETE STRUCTURES"
   E. ACI MNL–15 "FIELD REFERENCE MANUAL"
2. COORDINATE WITH OTHER TRADES TO ENSURE ALL GROUNDING, SLEEVES, EMBEDMENTS AND OTHER ITEMS ARE INSTALLED BEFORE CONCRETE PLACEMENT. IF CUTTING REINFORCEMENT APPEARS NECESSARY TO INSTALL SUCH ITEMS, CONTACT THE ENGINEER.
3. PLACE CONCRETE AT A UNIFORM RATE AS CLOSE AS POSSIBLE TO FINAL POSITION TO PREVENT MIX SEGREGATION.
4. CONSIDER CONCRETE SHRINKAGE IN PLACEMENT SEQUENCE. IF NOT SPECIFICALLY DETAILED, CONSTRUCTION JOINTS MUST BE APPROVED BY THE ENGINEER – BOTH TYPE AND LOCATION.
5. CONSOLIDATE ALL CONCRETE PLACEMENTS WITH THE AID OF MECHANICAL VIBRATION.
6. PLACE FOOTINGS, PILE CAPS AND MATS IN A CONTINUOUS OPERATION WITHOUT INTERRUPTIONS. THE LAYER METHOD MAY BE USED PROVIDED LAYER/LIFT THICKNESS RANGE IS 12 TO 30 INCHES WITH NO MORE THAN 30 MINUTES ELAPSING BETWEEN PLACING OF ADJACENT LAYERS – VIBRATE TO MELD LAYERS TOGETHER TO AVOID A HORIZONTAL PLANE OF WEAKNESS.
7. LAYER/LIFT THICKNESS IN WALLS SHOULD NOT BE GREATER THAN 36 INCHES.
8. FLOAT AND BROOM FINISH EXTERIOR CONCRETE SURFACES. THE ADDITION OF FREE WATER AS A FINISHING AID IS PROHIBITED.
9. WHEN SLAB CONTRACTION JOINTS ARE ACCOMPLISHED BY SAW CUTTING, 'SOFT–CUT' JOINT[illegible] AS SOON AS PRACTICAL – USUALLY W[illegible]

Nitrogen Plant – North Central US

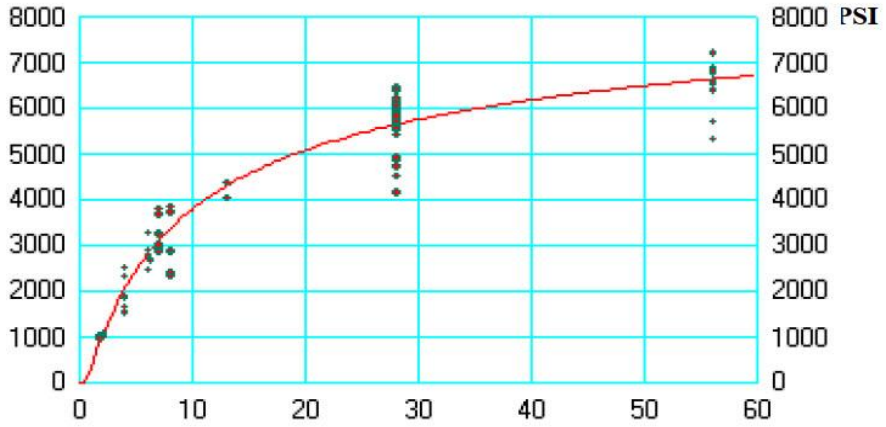
Foundation and Slabs were NOT IDENTIFIED as Mass Concrete in specifications

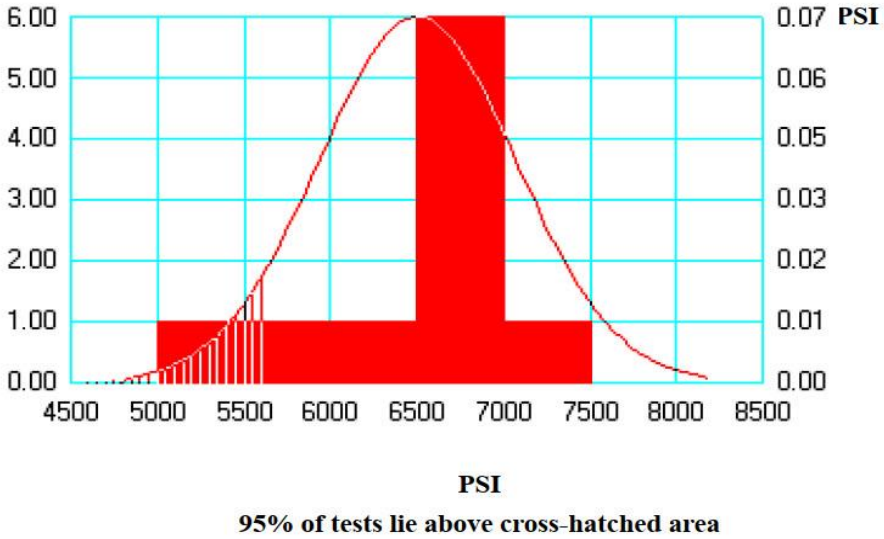


Nitrogen Plant – North Central US

- 4,500-psi at 56 days (0.45 w/c)
- #57 Stone
- 50% Type 1L Cement
- 50% Slag Grade 100
- Type F - High Range Water Reducer
- Type B&D - Stabilizer
- 3” to 5” Slump
- 4% to 7% Air (Foundation) and 0% to 3% Air (Slabs)

Contractor Supplied Data





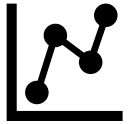
STRENGTH SUMMARY, Compression Strengths Either 4" x 8" Or 6" x 12"

No. Of Tests	Avg Slump	Avg Air	Avg 1 Day	Avg 3 Day	Avg 7 Day	Avg 28 Day	Avg Acc Age
10	5.60	6.75			3230	5690	6510

Max Temp 160 ºF, Max Differential 50 ºF

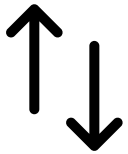
The Lessons Learned

- **Review the plans and specifications thoroughly**



- **Producer experience with 1L cement is helpful**
  - **Test performance history saved time**

- **Communicate with the engineer on any questions**



- **Compliance = performance**

- **Follow ACI guidance from specifications**

Project 3 Experience

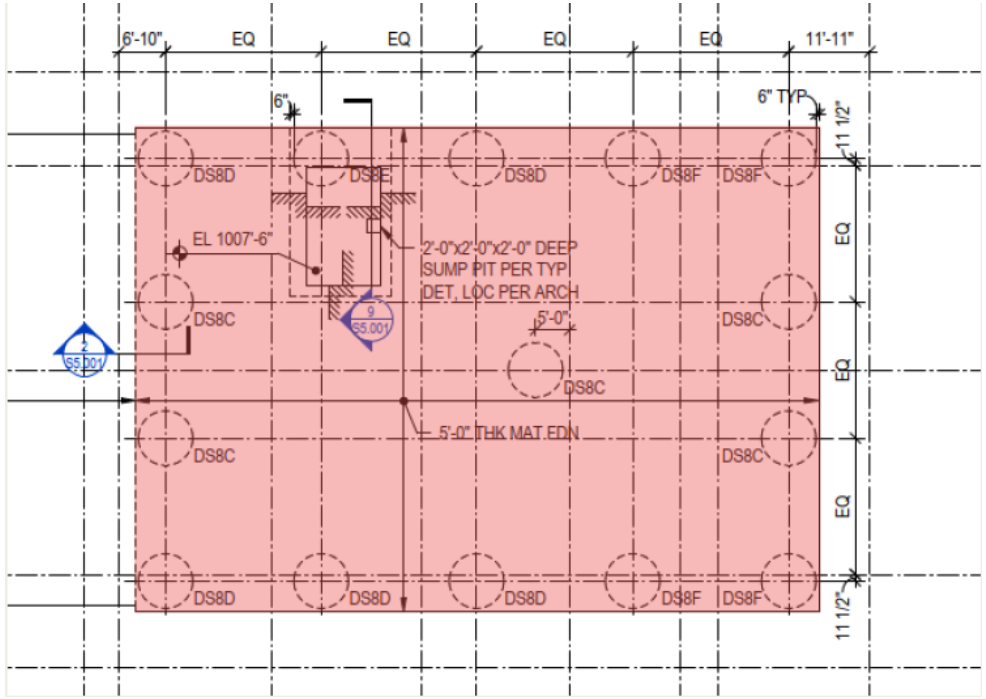
High Rise Office Building - Central US

The General Notes for "**Massive Concrete**":

*"The temperature of concrete at time of placement shall not exceed **95** degrees F. The maximum internal temperature during curing shall not exceed **160** degrees F. The maximum temperature difference between center and surface of placement shall not exceed **50** degrees F. Conform to the requirements of ACI 305.1 and ACI 306.1 for hot-weather and cold-weather concreting, respectively. If cooling methods are employed, they shall not increase the water-cement ratio or slump beyond allowable limits. The concrete shall be cooled gradually so that the surface temperature drop does not exceed **20** degrees Fahrenheit in any 24-hour period after placement."*

High Rise Office Building - Central US

- 6,000-psi at 56 days (0.44 w/c)
- #67 Limestone Aggregate
- 50% Type 1L Cement
- 30% Slag
- 20% Class C Fly Ash
- Type F - High Range Water Reducer
- 8” slump, 0-3% Air (No AE)
- Max Temp 160 ^{o}F, Max Differential 50 ^{o}F
- Thickened Slab – 100.5’ x 71’ x 5’ deep



Sensor Installation in 2 Test Cubes

(P1) Center A and B, middle outside face

(P2) Top outside face

(P3) Inside configuration

Maturity Calibration Results

Company Information

Company Name:	
Producer Name:	
Contact Name:	-

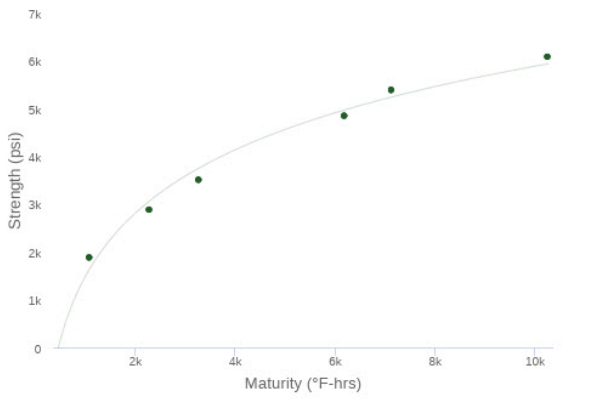
Mix Info.

Mix ID:	6000 AE HRWR Chilled
Plant Name:	01
Calibration Method:	Temperature-time factor (TTF)
Datum Temperature:	32.0 °F
Calibration Equation:	f_c = -11691.41 + 4398.56.log(M)
Calibration Date:	2023-08-22 12:14:31

Calibration Data

Maturity Index (°F-hrs)	Strength (psi)
1077.7	1890.0
2278.4	2900.0
3269.0	3530.0
6178.9	4860.0
7119.3	5400.0
10257.6	6100.0

Calibration Curve



Air Entrained Mix

Company Information

Company Name:	
Producer Name:	
Contact Name:	-

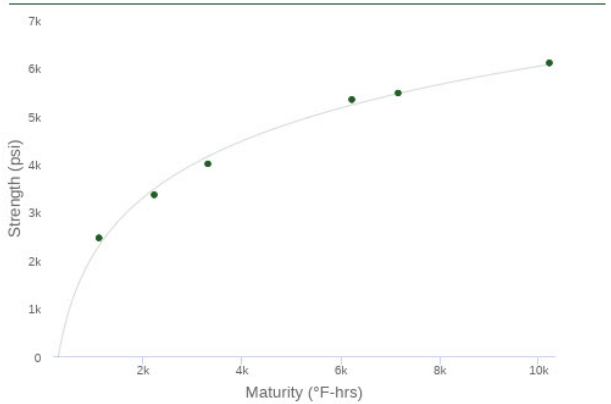
Mix Info.

Mix ID:	6000 NA HRWR Chilled
Plant Name:	01
Calibration Method:	Temperature-time factor (TTF)
Datum Temperature:	32.0 °F
Calibration Equation:	f_c = -9602.06 + 3912.63.log(M)
Calibration Date:	2023-08-22 12:29:27

Calibration Data

Maturity Index (°F-hrs)	Strength (psi)
1115.2	2470.0
2232.8	3370.0
3321.8	4010.0
6227.0	5350.0
7166.5	5490.0
10226.0	6120.0

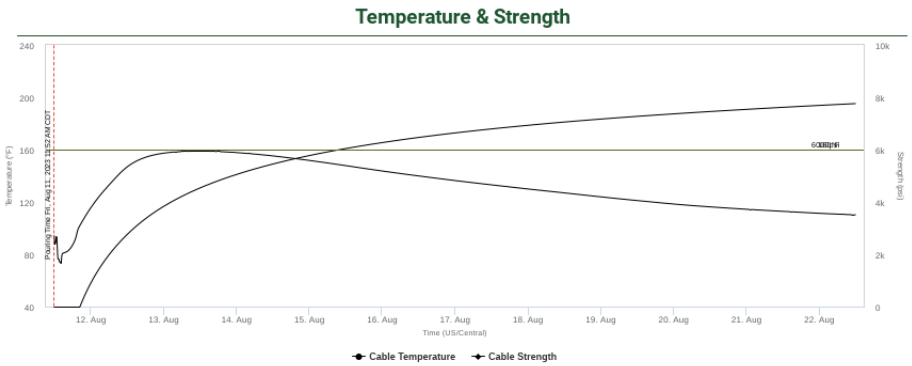
Calibration Curve

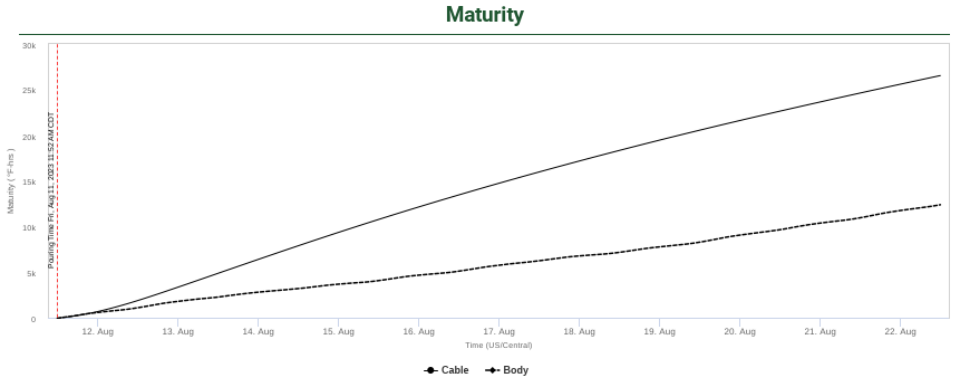


No Air Mix

Air Entrained Cube (East Cube Body)

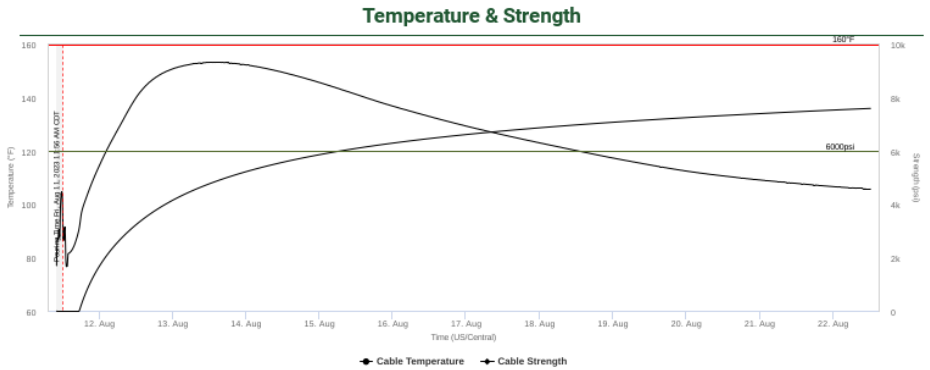
Probe Location	Minimum Temp	Maximum Temp	Maturity Index	14-day Average Strength
Center	56.0 ºF	106.7 ºF	12448.9 ºF hrs.	6,320 psi
Mid-Height Exterior	59.0 ºF	112.1 ºF	12576.7 ºF hrs.	6.340 psi
Top Side Exterior	68.3 ºF	119.0 ºF	13887.9 ºF hrs.	6,530 psi
Summary	**61.1 ºF**	**112.6 ºF**	**---**	**6,400 psi**

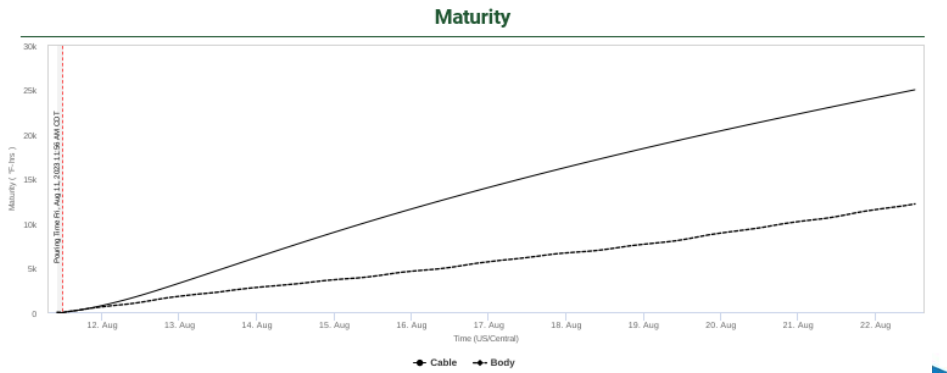




Non-Air Entrained Cube (West Cube Body)

Probe Location	Minimum Temp	Maximum Temp	Maturity Index	14-day Average Strength
Center	54.3 ºF	104.7 ºF	12115.4 ºF hrs.	6.370 psi
Mid-Height Exterior	56.9 ºF	103.7 ºF	12280.5 ºF hrs.	6,400 psi
Top Side Exterior	64.8 ºF	104.6 ºF	13695.5 ºF hrs.	6,580 psi
Summary	**58.7 ºF**	**104.3 ºF**	**---**	**6,450 psi**





Laboratory Test Results for Cubes

Mix ID	Date of Placement	Time of Placement	Concrete Temp	Ambient Temp	Slump	Air Content	Unit Weight
Air Ent.	8/11/23	2:15 PM	82	79	8	4.3	141.0
No Air	8/11/23	1:25 PM	81	79	7.5	2.3	148.3

Mix ID	1-day Avg.	3-day Avg.	7-day Avg.	10-day Avg.	14-day Avg.	Max. Temp	Differential Temp
Air Ent.	1,890	3,530	5,400	6,100	6,400	153.8	43.0
No Air	2,470	5,350	5,490	6,120	6,450	159.1	46.0

High Rise Office Building - Central US

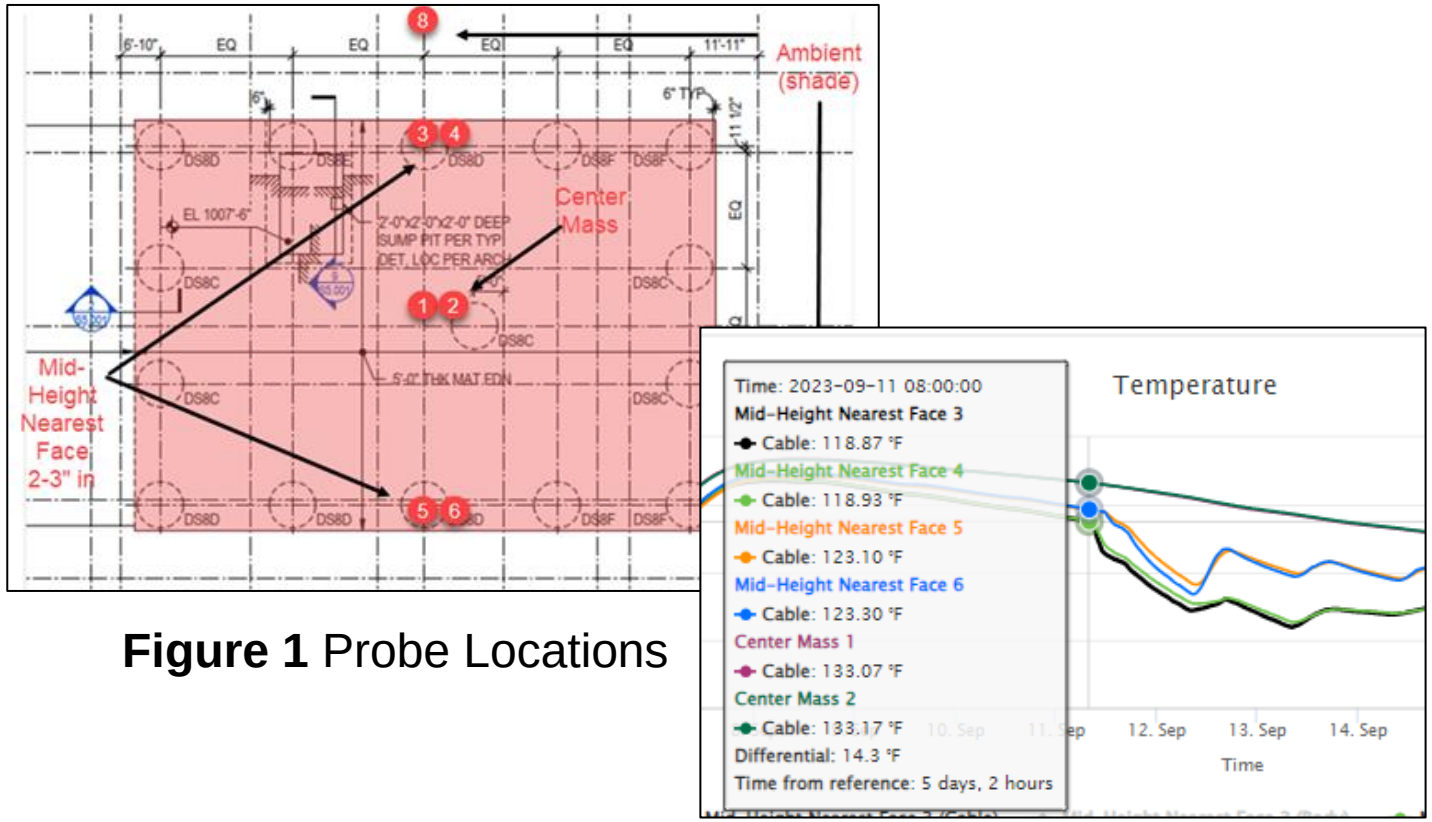


Figure 1 Probe Locations

Figure 2 Temp data at 8am on 9/11/23

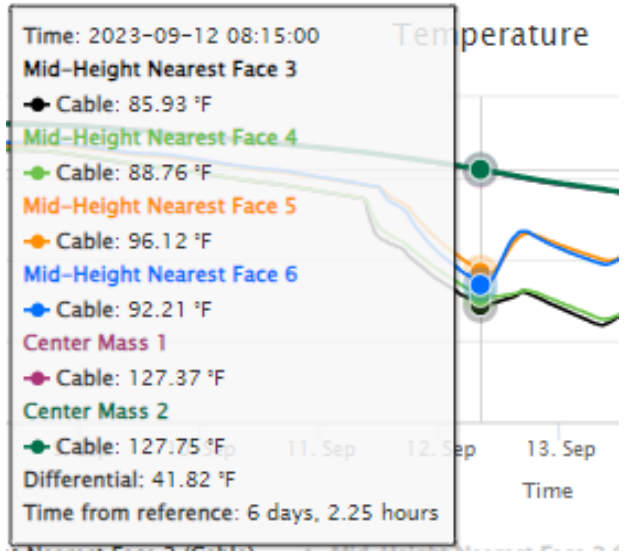


Figure 3 Temp data at 8:15am on 9/12/23

High Rise Office Building - Central US

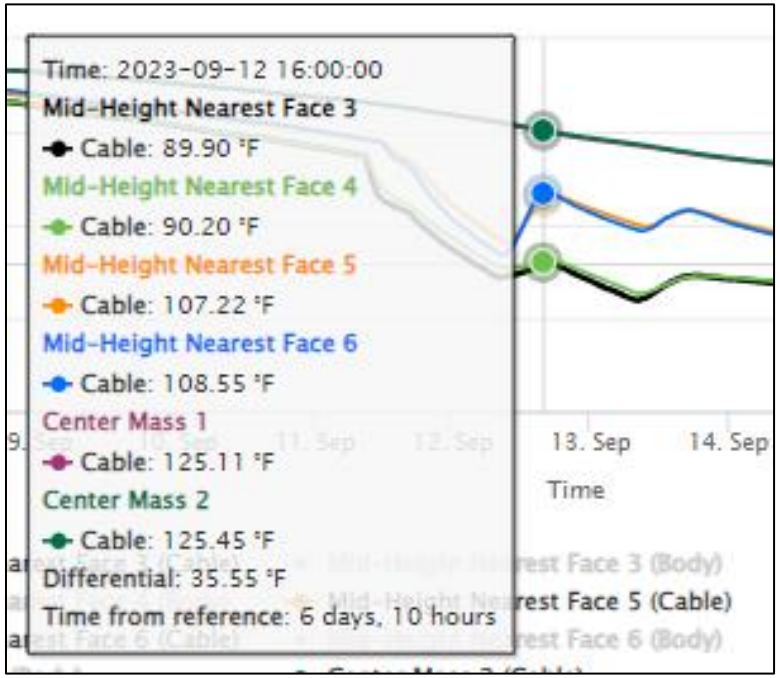


Figure 4 Temp data at 4pm 9/12/23

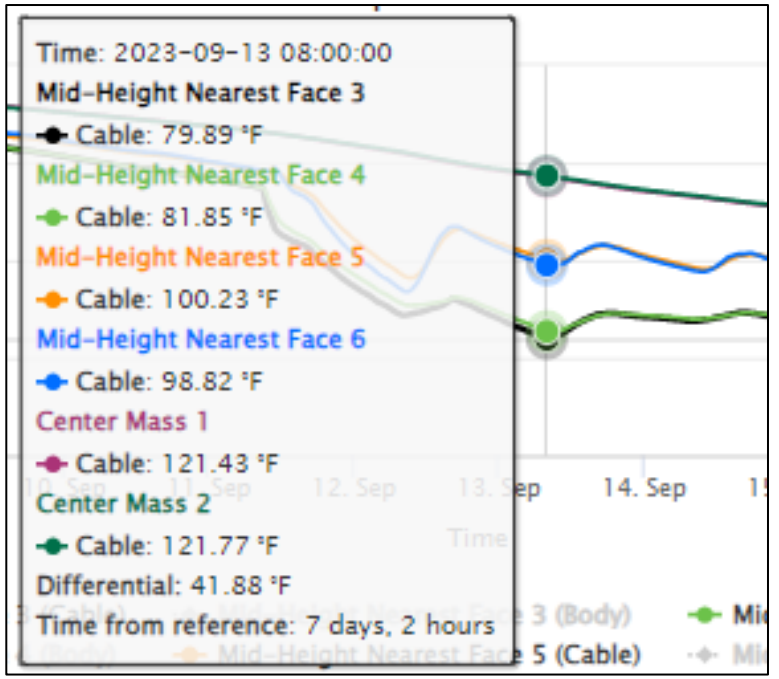


Figure 5 Temp data at 8am 9/13/23

Laboratory Test Results for Actual Placement

Mix ID	Date of Placement	Time of Placement	Concrete Temp	Ambient Temp	Slump	Air Content
No Air 6,000 psi @ 56	9/11/23	8:00 AM	82	60[1]	7.5	2.3
Air Ent. 5,000 psi @ 28	10/25/23	9:15 AM	80	54[2]	5	5

[1] Temperature high was 76 °F,
[2] Temperature high was 64 °F

Mix ID	7-day Avg.	28-day Avg.	56-day Avg.	Max. Temp	Differential Temp
No Air	5,450	7,860	9.020	143	42
Air Ent.	5,830	6,850	7,630	141	35

The Lessons Learned

- **Relationships equal success**
- **Honest communication equals integrity**
- **Quality and Safety over Schedule**
- **Compliance = performance**
- **Follow ACI guidance from specifications**

The Final Lessons Learned

- **Did the use of 1L impact the project success?**
- **Follow ACI guidance and specifications**
- **Pre-Task Plan and Set Realistic Expectations**
- **Don’t assume – Verify**
- **Communicate Early and Often**

Thank you for your time!

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