I-86/1-15 System IC

Drilled Shaft Construction Lessons Learned

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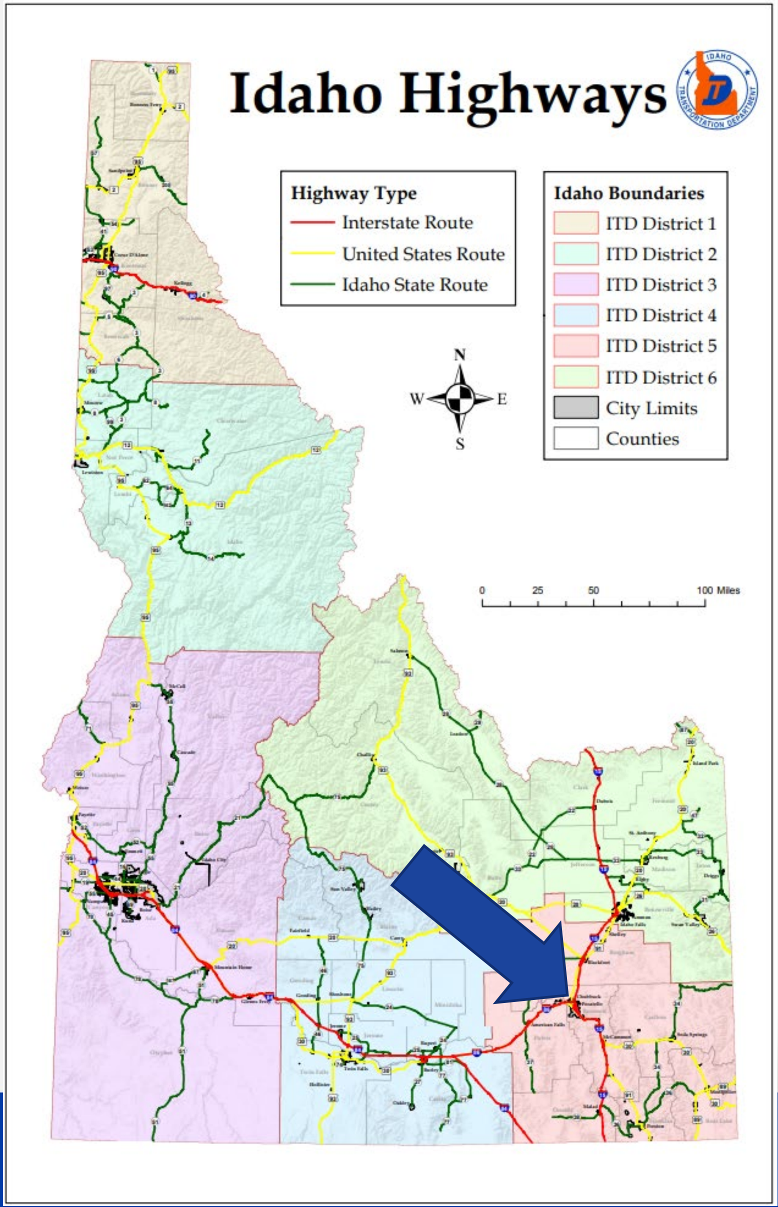
In Memory of Braydan DuRee

Project Overview – I-86/I-15 System IC

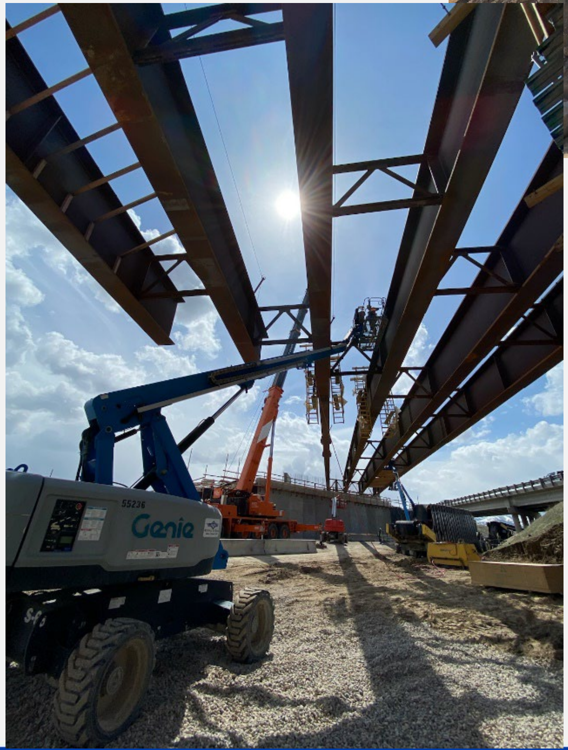
- One of Idaho's largest and most expensive construction projects ($111.9M)
- Replaces the entire three leg interchange in the heart of Pocatello, Idaho
- Eight New Bridges and Ten MSE retaining walls
  - Existing bridges built in 1960s
- Construction Started in Summer of 2022
- Anticipated completion in Fall 2024



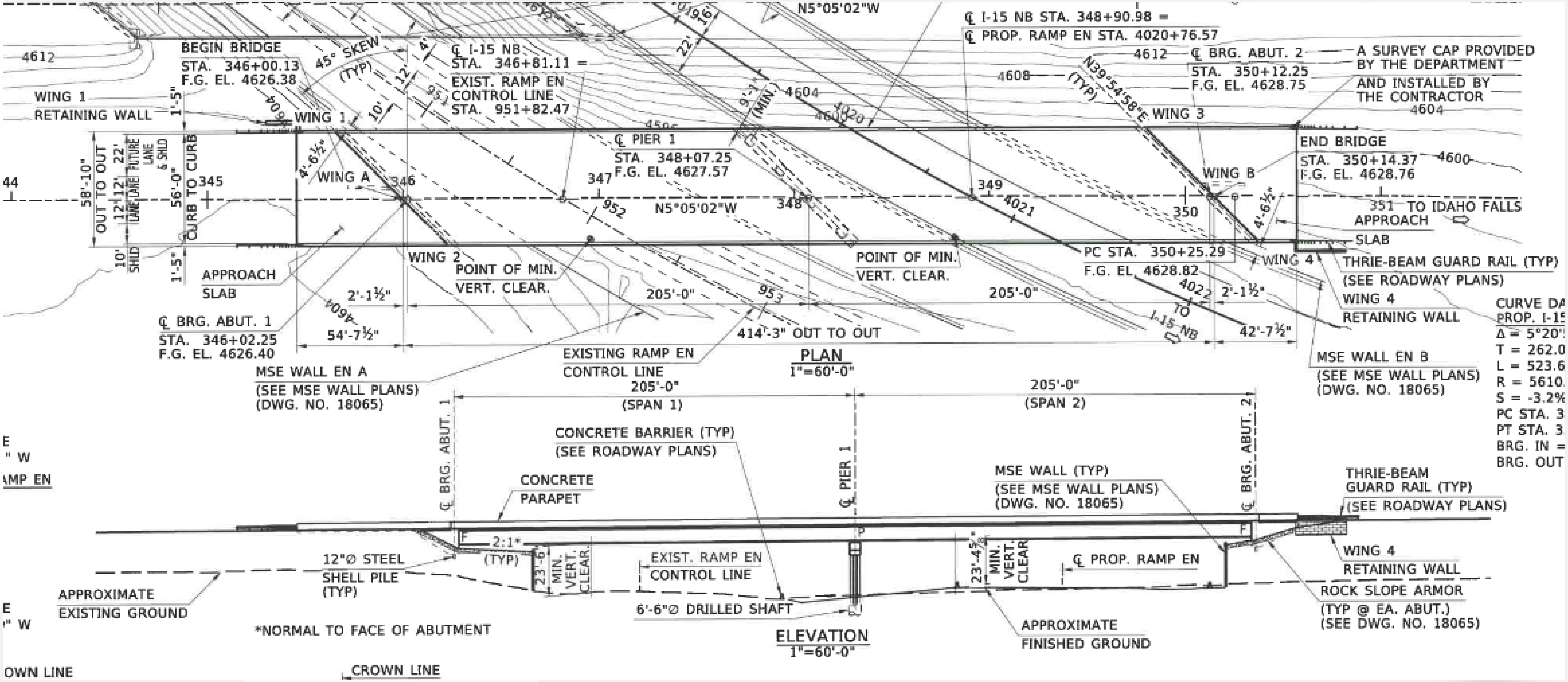
Proposed Reconstruction

Bridge & Drilled Shaft Details

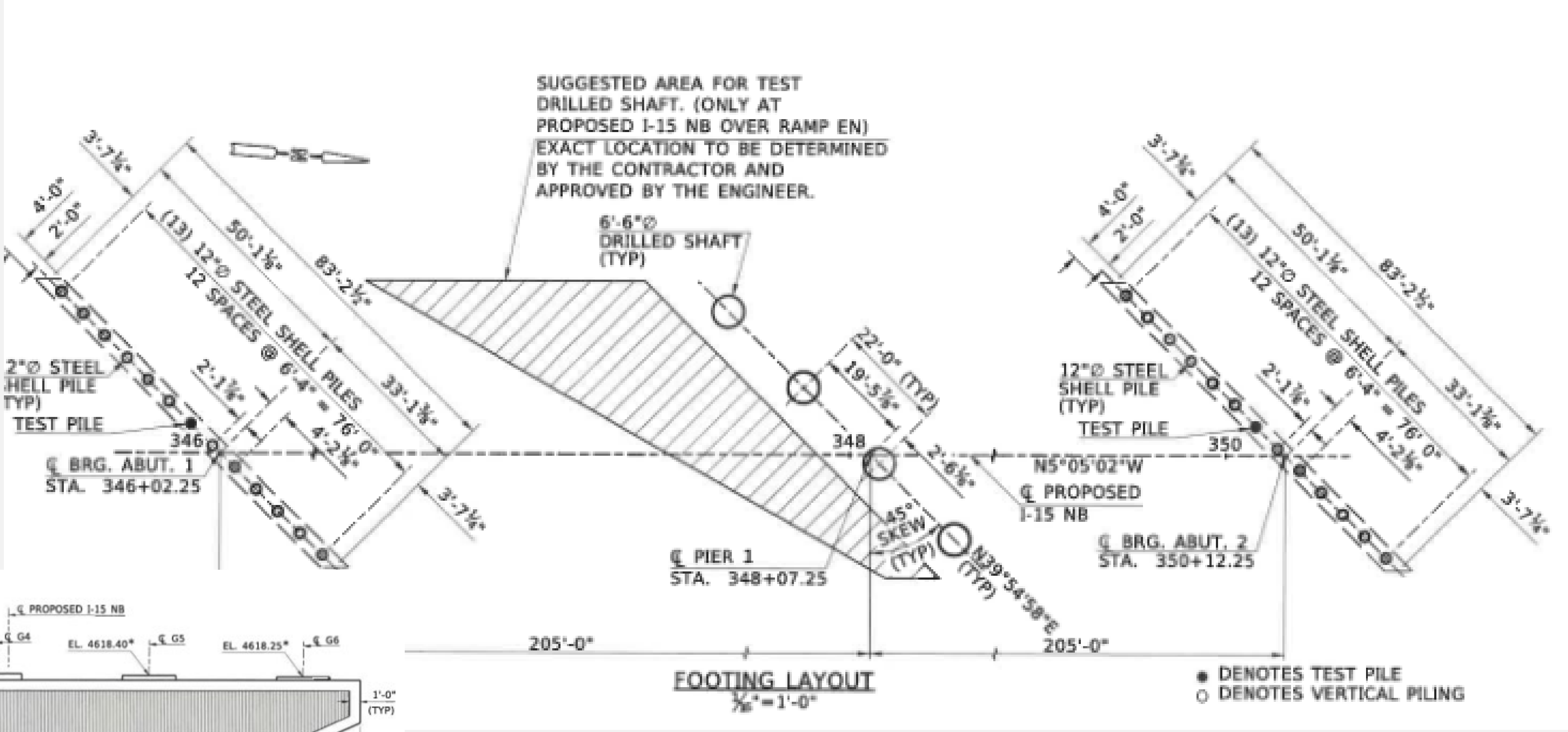
- Two Span Steel Girder Bridges – 45 Degree Skew
- 6’-6” (2.0m) Diameter Drilled Shafts (as designed)
  - 50’ Long Shafts during Design
- 5’-0” “Diameter” Column
- Constructed using Oscillating Method
  - Large boulders anticipated at project site
- 42 - #10 in Drilled Shaft (1.1% Steel)
- 10’ Permanent Casing at Top
- 16 Drilled Shafts – 800 feet total

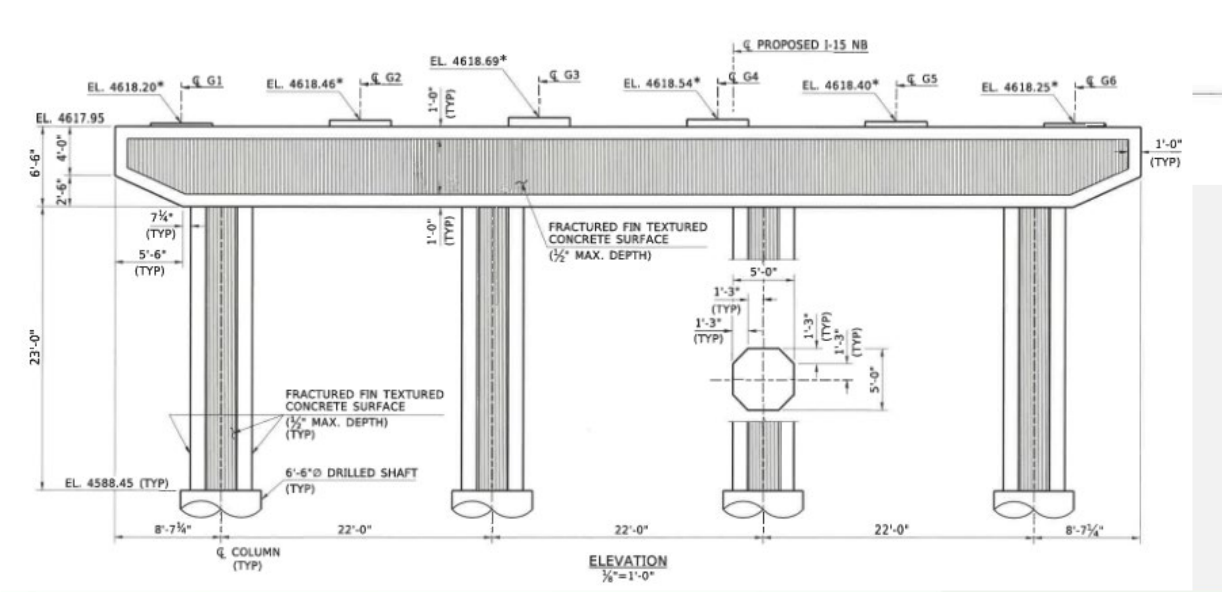


Bridge Layout

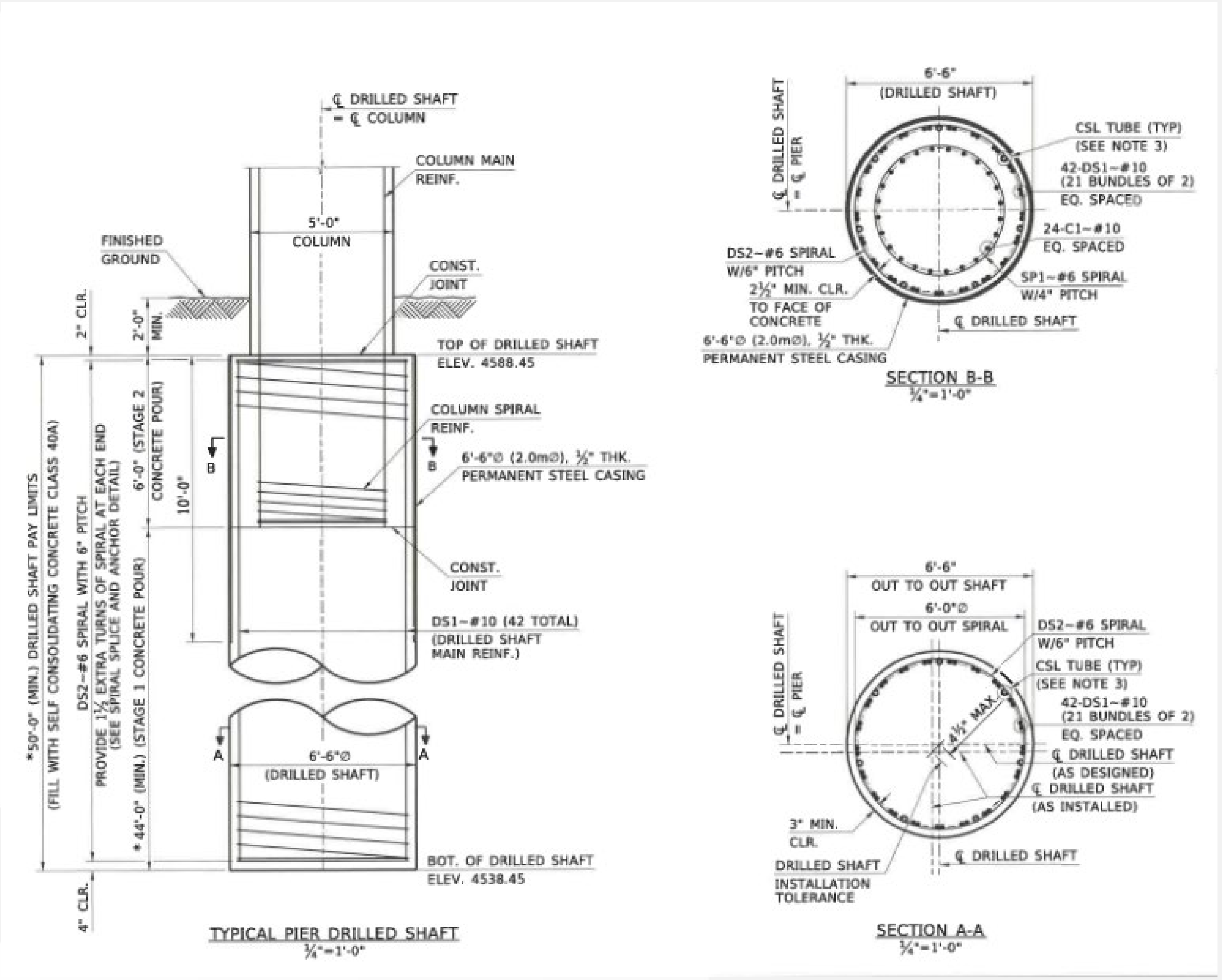


Drilled Shafts



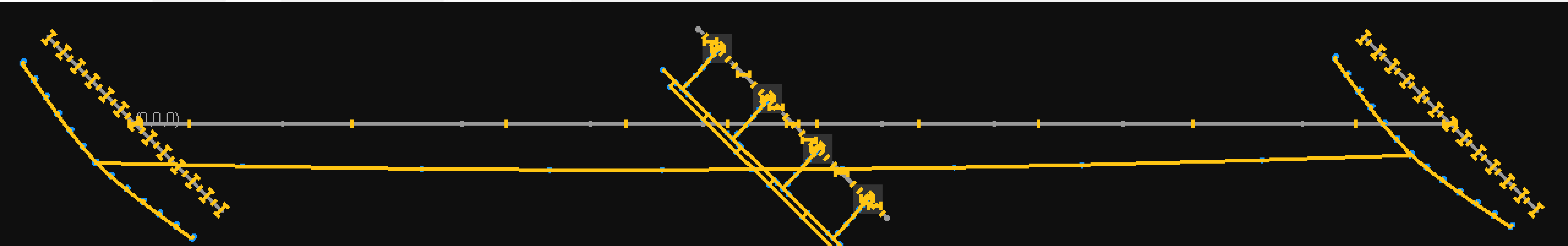


Drilled Shafts



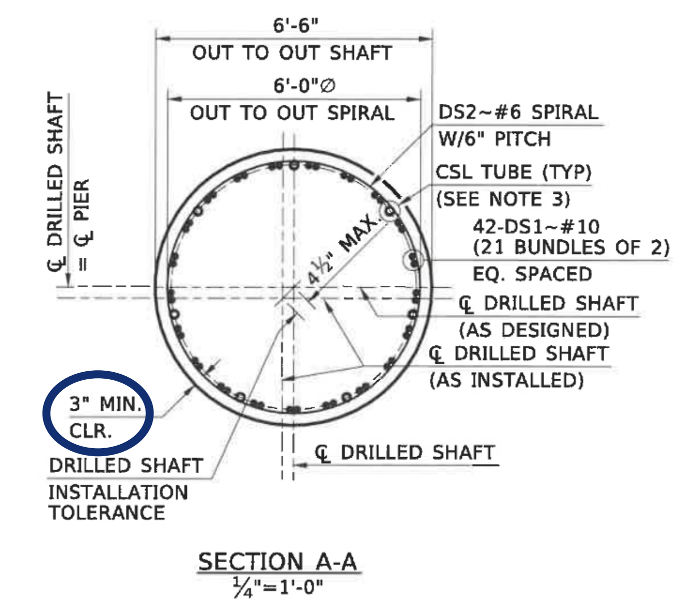
Drilled Shaft Design

- Designed using AASHTO LRFD Bridge Design Specifications
- Seismic Zone 2 – Force Based Design (S_{D1} = 0.26)
- RSA analysis in Larsa4D with Lpile
- Drilled Shaft Diameter effects included in Lpile and RSA
- Critical Bridge in accordance with ITD Policy
  - R Factor of 3.5 applied to column demands
  - R Factor of 1.0 applied to shaft demands
- Extreme Event II – CT controlled column design
- Extreme Event I – Seismic controlled shaft design



Drilled Shaft Size Change

- After Advertisement - driller concerned with concrete cover on shaft
- Oscillating casings are ~2” thick
- Recommended 2.2m shaft diameter



Drilled Shaft Size Change - Considerations

- What sizes are available?
  - Braydan reached out to numerous drillers to determine if the 2.2m size was common
- Does the design still work?
  - Bigger is not always better
- How much time do we have?
  - Wanted to release addendum in time to prevent pushing bid opening
- How do the quantities/pay items change?
  - Paid for the drilled shafts by the foot
- How involved are the changes on the plans?
  - Able to cloud/redline changes in Bluebeam, plan changes took a few hours at most.

Drilled Shaft Size Change - Lessons Learned

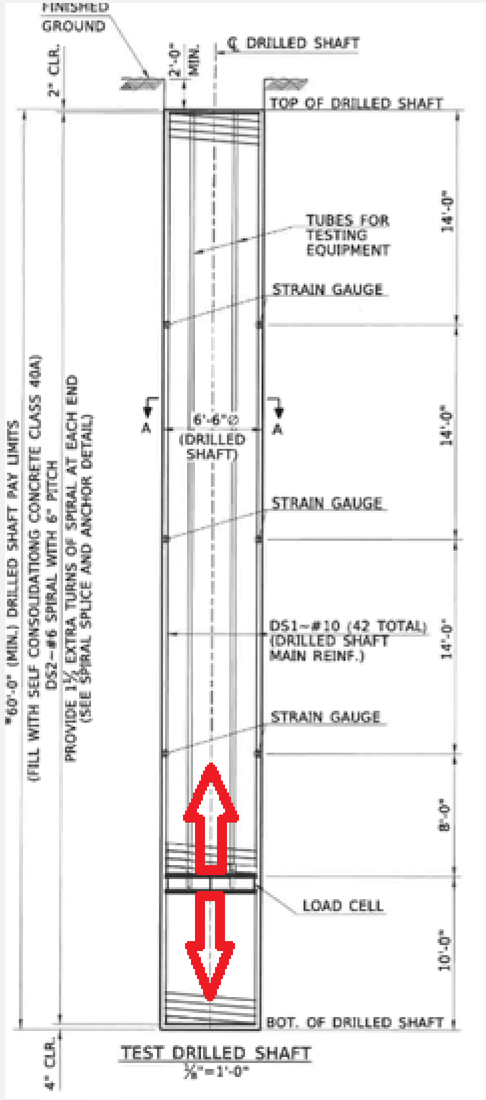
- Use more cover on drilled shafts (6” preferable)
  - Reducing cage diameter results in a smaller column
  - Cover requirements added to ITD Bridge Design Manual
- Column controlled this design, reducing column size may have been feasible
  - Did not have enough time during bid advertisement to investigate column change
- Change during bid advertisement was embarrassing
  - Better to be embarrassed than deal with a major change order or construction issue
- WSDOT has excellent guidance for drilled shaft cage diameters and cover for oscillating casing
  - Table 7.8.2-2 in the WSDOT Bridge Design Manual

Table 7.8.2-2 Expected Reinforcing Cage Diameters and Clear Cover

Nominal (Outside) Metric Casing Diameter		Maximum (Outside) Reinf. Cage Diameter to Accommodate Metric Casing[1]		Inside Diameter of Metric Casing[2]	Nominal (Outside) Metric Slip Casing Diameter[3]			Cage Clearance Below Slip Casing	Cage Clearance at Slip Casing[4]
Meters	Feet	Inches	Feet	Inches	Inches	Feet	Meters	Inches	Inches
3.73	12.24	130.52	10.88	140.52	137.52	11.46	3.49	8.16	3.0
3.43	11.25	118.71	9.89	128.71	125.71	10.48	3.19	8.16	3.0
3.00	9.84	101.81	8.48	111.84	108.81	9.07	2.76	8.15	3.0
2.80	9.19	95.51	7.96	105.51	102.51	8.54	2.60	7.36	3.0
2.50	8.20	83.70	6.98	93.70	90.70	7.56	2.30	7.36	3.0
2.20	7.22	71.89	5.99	81.89	78.89	6.57	2.00	7.36	3.0
2.00	6.56	64.02	5.34	74.02	71.02	5.92	1.80	7.36	3.0

Test Drilled Shaft

- One Sacrificial Test Shaft – 60 ft. long
  - Bi-Directional Load Cell Test (Osterberg Cell)
- Gave ITD a high level of confidence
- Increased geotechnical axial resistance factor to 0.7
  - Table 10.5.5.2.4-1 in AASHTO BDS
- Reduced length of production shafts *both* during design and construction



Test Drilled Shaft - Results

- Bi-directional load test resulted in a maximum axial equivalent top load of 5903 kips
  - Strength Limit state axial demand = 2560 kips
- Test Shaft cost ~$200,000
- Reduced all production shafts by 5’
  - Controlled by lateral stability
  - Saved ~$170,000 in production shaft costs

TABLE 3. RECOMMENDED MINIMUM SHAFT LENGTH

Bridge	Min. Length for Lateral Stability (feet)	Min. Length for Axial Capacity (feet)	Recommended Minimum Shaft Length [1] (feet)	Top of Shaft Elevation (feet)	Highest Bottom of Shaft Elevation (feet)
I-15 NB Over Ramp EN	45	23	45	4588.45	4543.45
I-15 SB Over Ramp EN	45	25	45	4586.44	4541.44
I-15 SB over Ramp NW	45	20	45	4571.51	4526.51
I-15 NB over Ramp NW	45	20	45	4578.88	4533.88

GeoEngineers

Test Drilled Shaft - Results

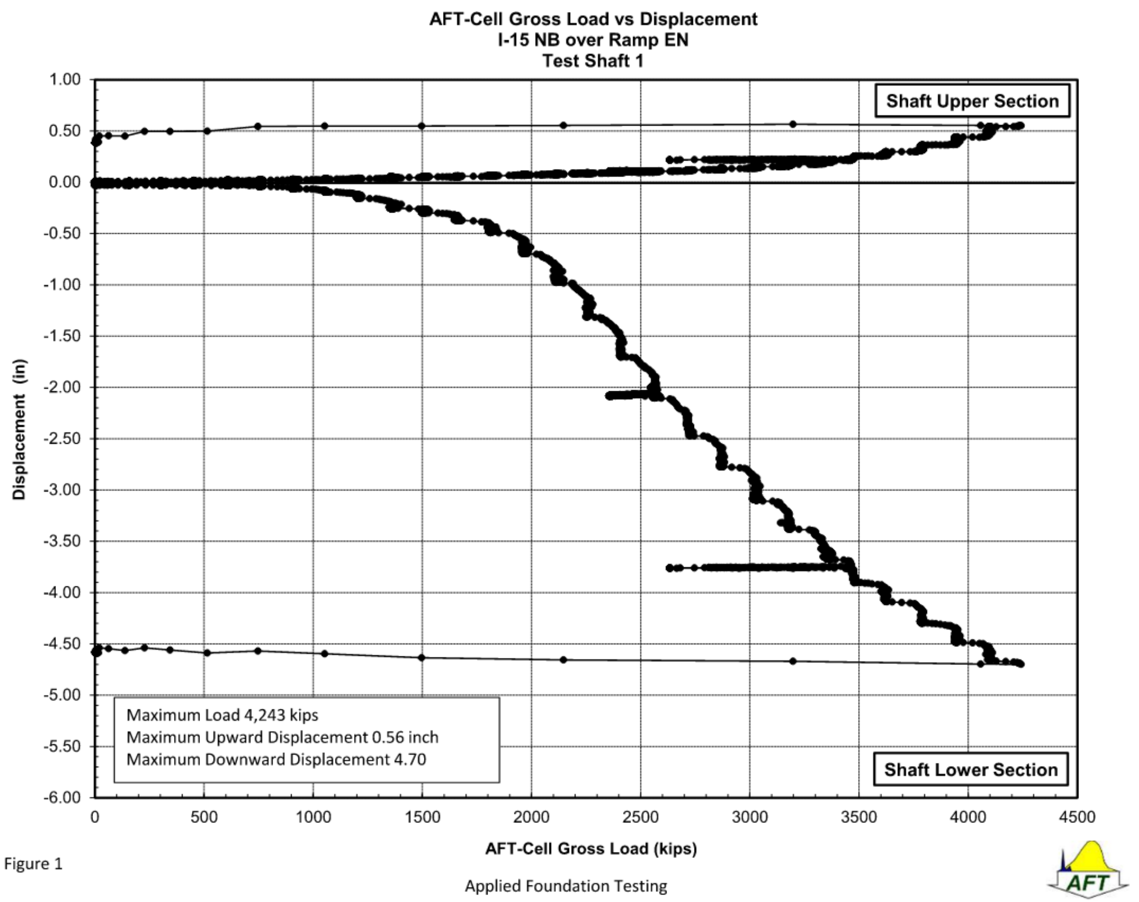


Figure 1

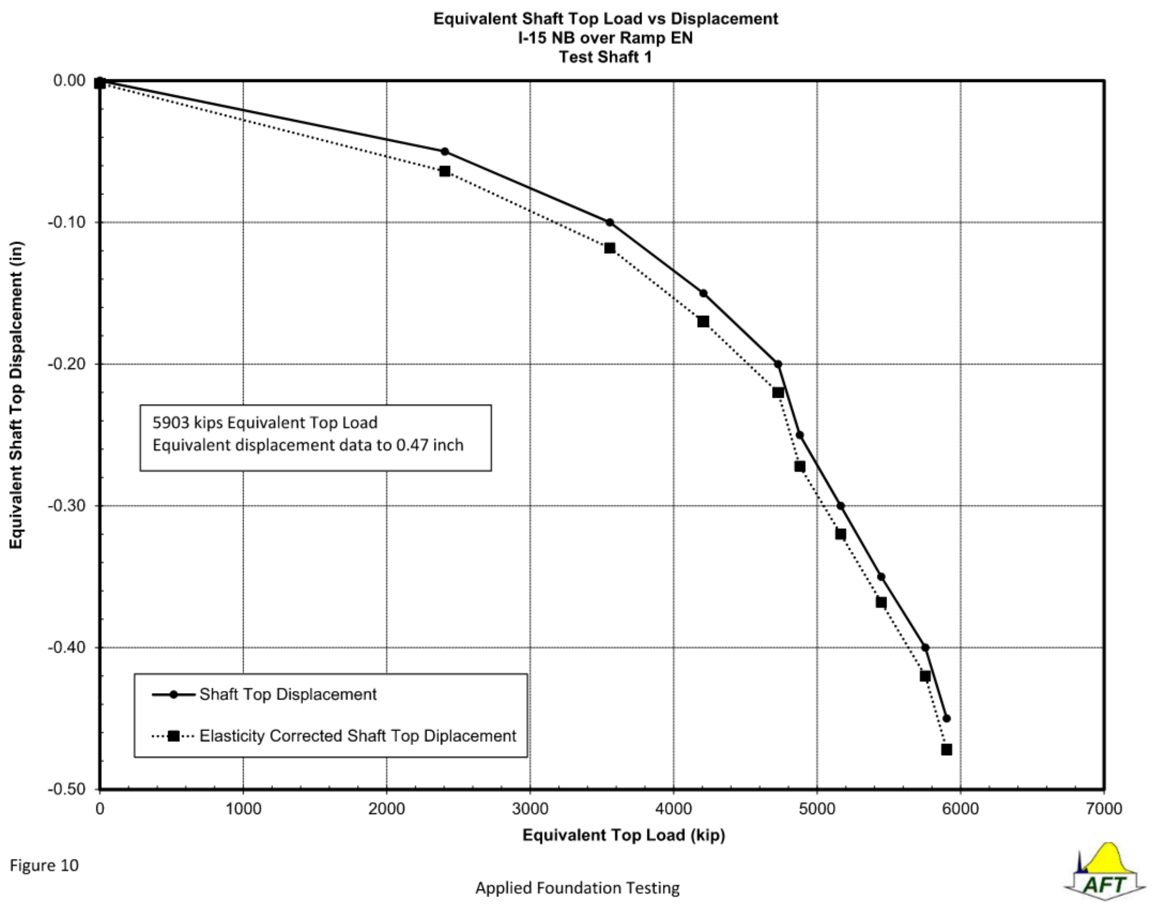


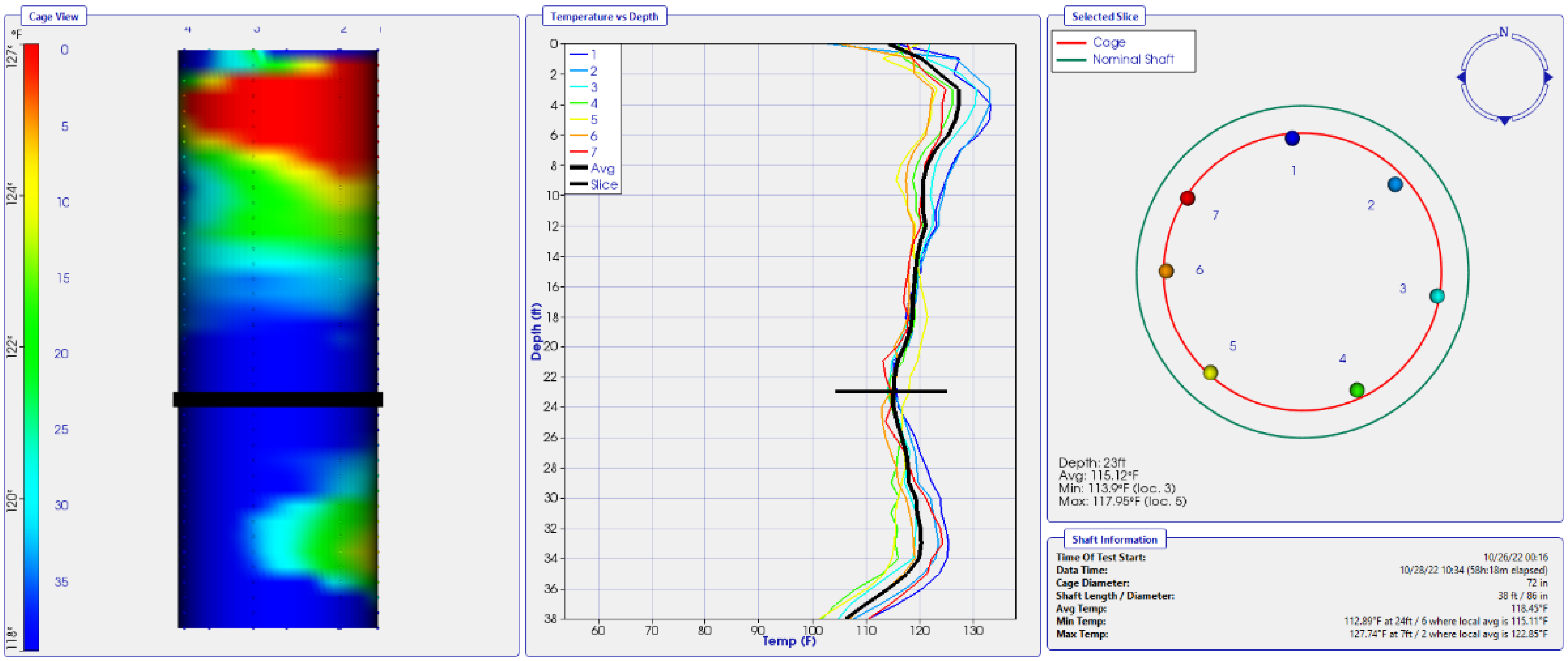
Figure 10

TIP & CSL Test Results

- TIP = Thermal Integrity Profiling
- CSL = Cross-Hole Sonic Logging
- Contract required both TIP and CSL testing
- Overall results were very good from both TIP and CSL testing
- Two shafts had questionable results – having both the TIP and CSL was beneficial to vetting issues

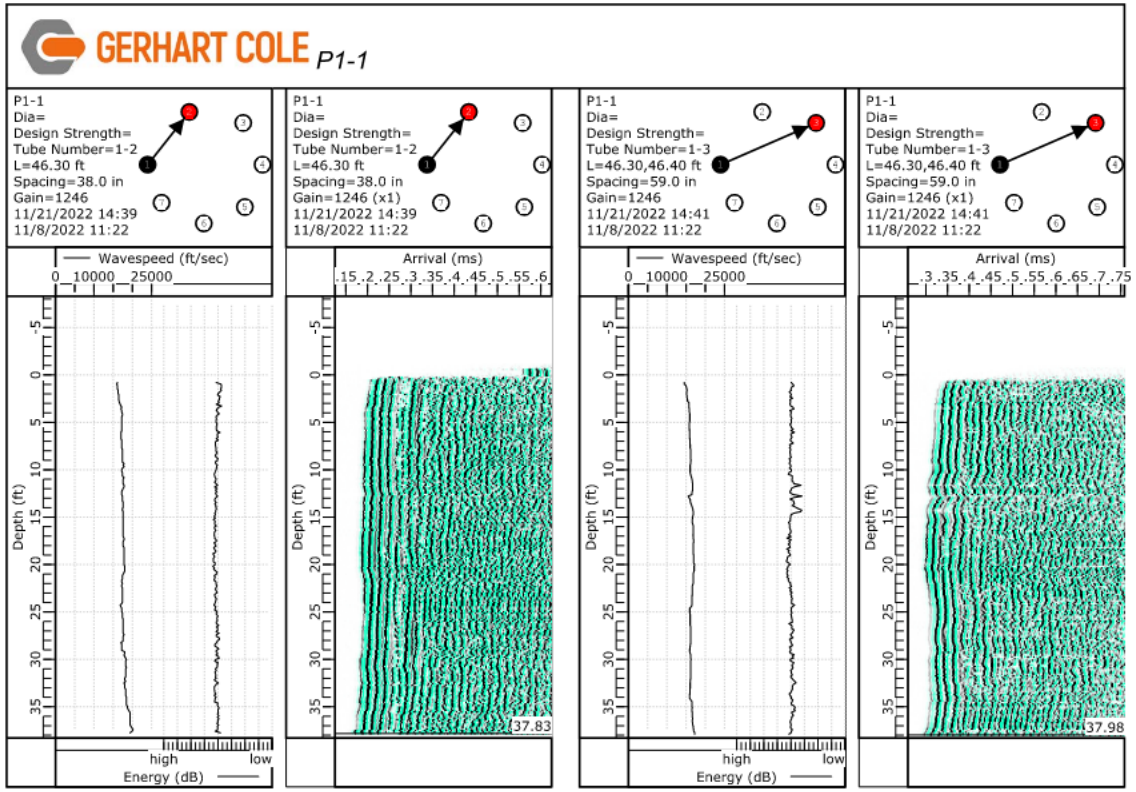
TIP & CSL Test Results - Shaft P1-1

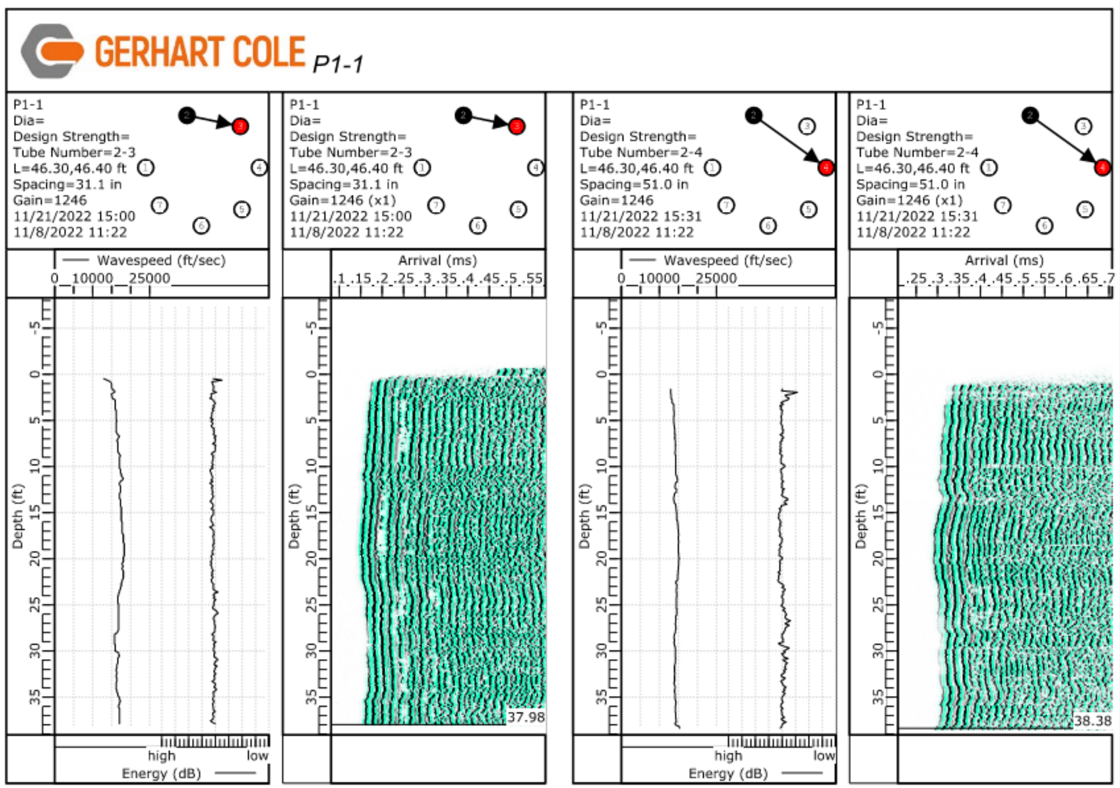
- TIP testing indicated potentially lower quality concrete at a depth of 20-26ft.



TIP & CSL Test Results - Shaft P1-1

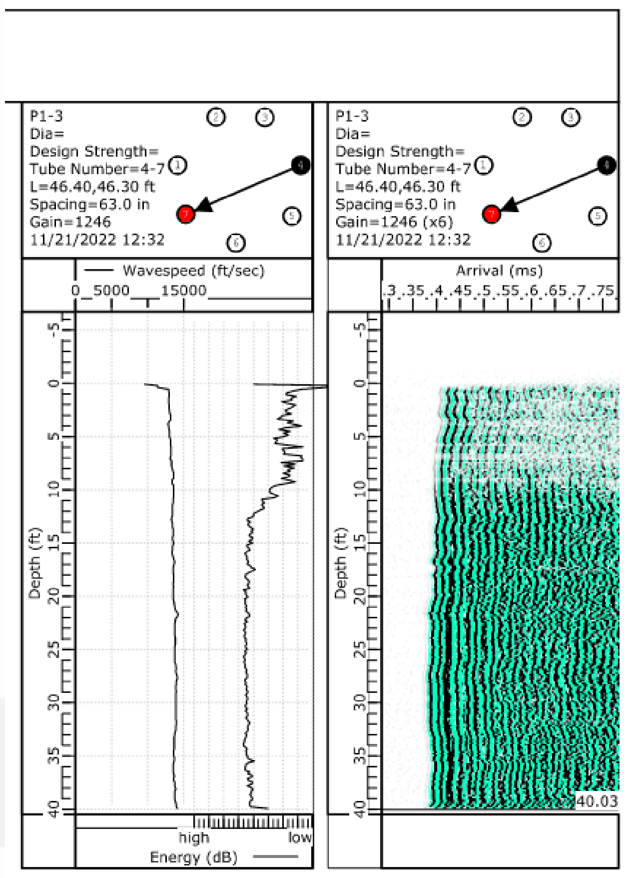
- CSL test results did not corroborate the potentially lower quality concrete between 20-26ft and gave good results

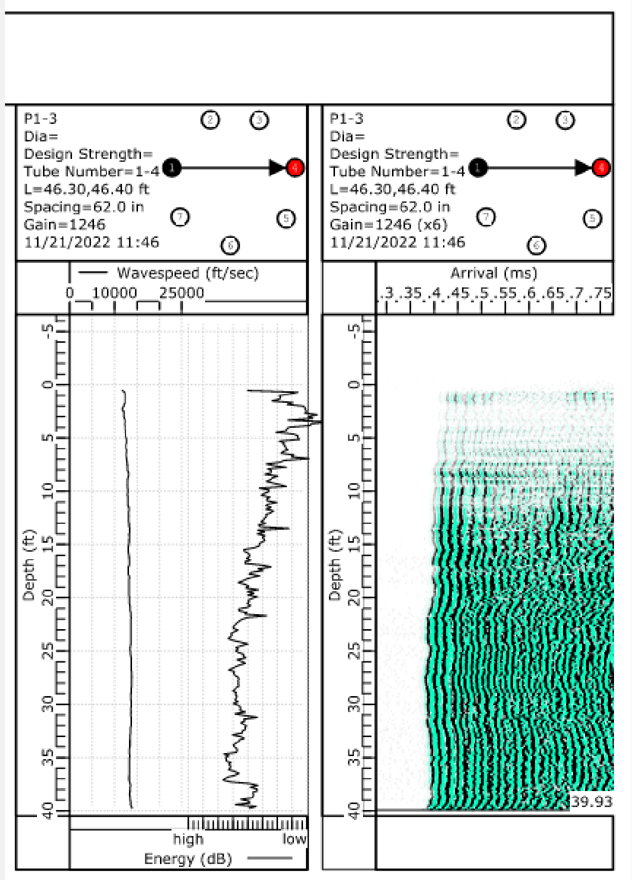


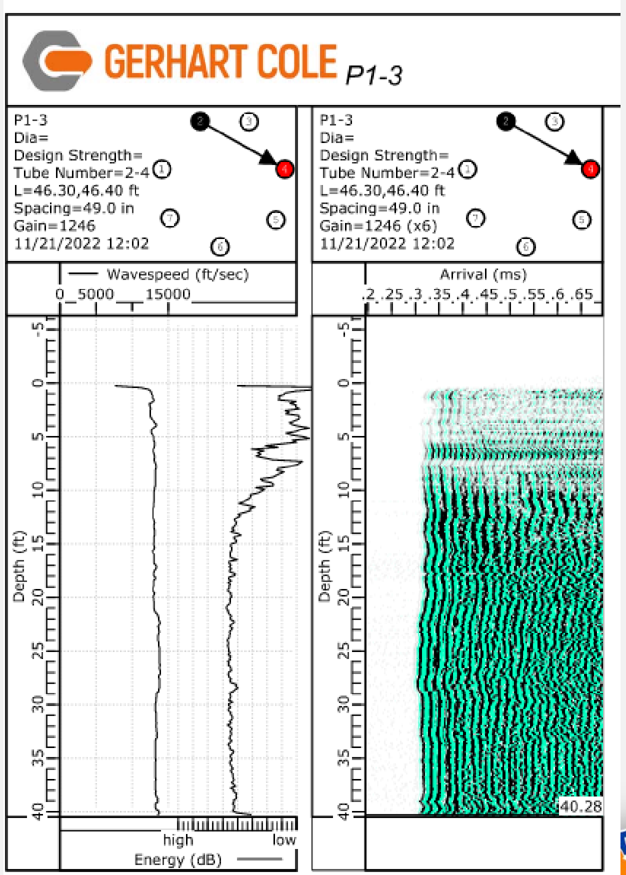


TIP & CSL Test Results - Shaft P1-3

- CSL results indicated signal loss in several of the waterfall diagrams
  - All relating to tube 4 in the top 10 feet

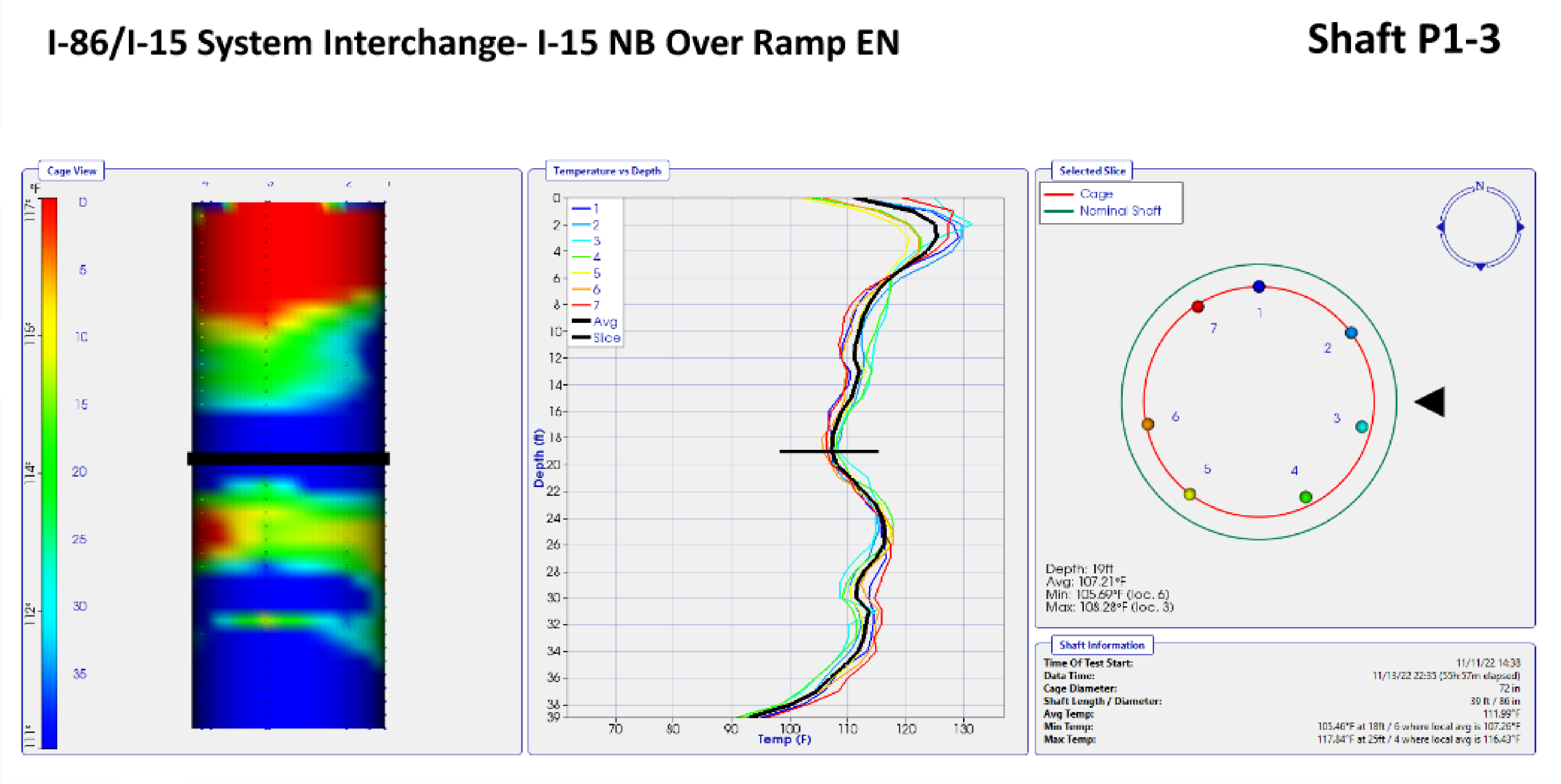






TIP & CSL Test Results - Shaft P1-3

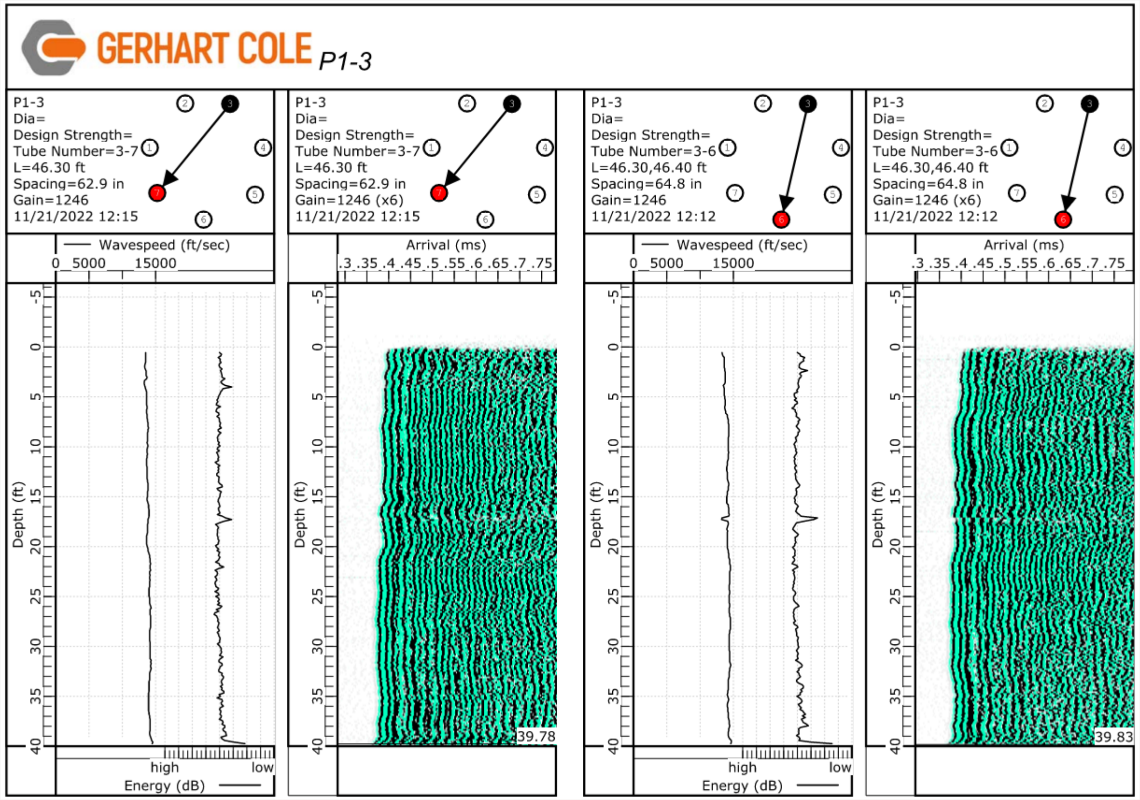
- TIP testing did not corroborate this signal loss



TIP & CSL Test Results – Shaft P1-3

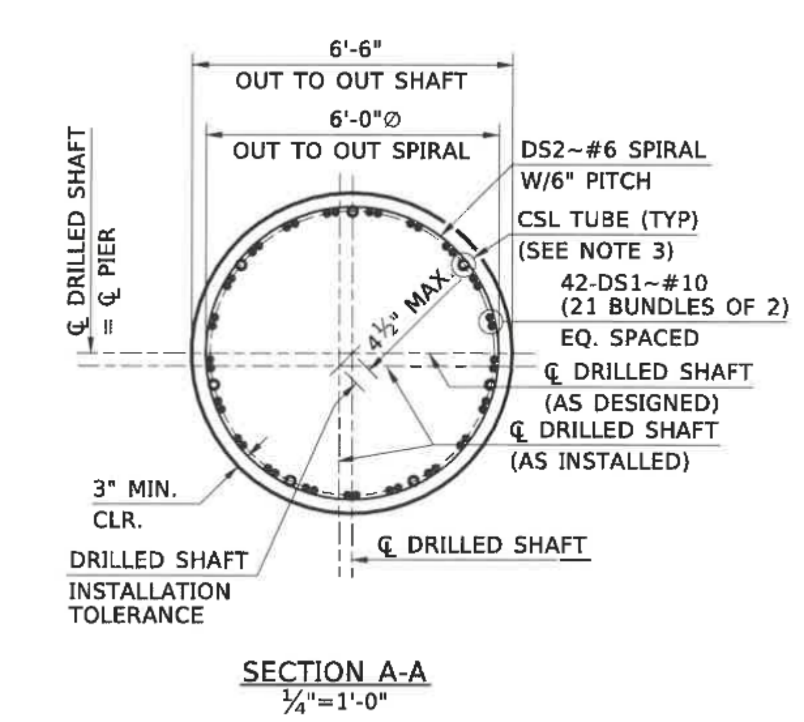
- Water was not placed in CSL tube prior to concrete pour
  - This can cause debonding of the CSL tube to the concrete, which can result in signal loss
- CSL testing between other tubes did not agree with tube 4 results

Shaft was accepted as is

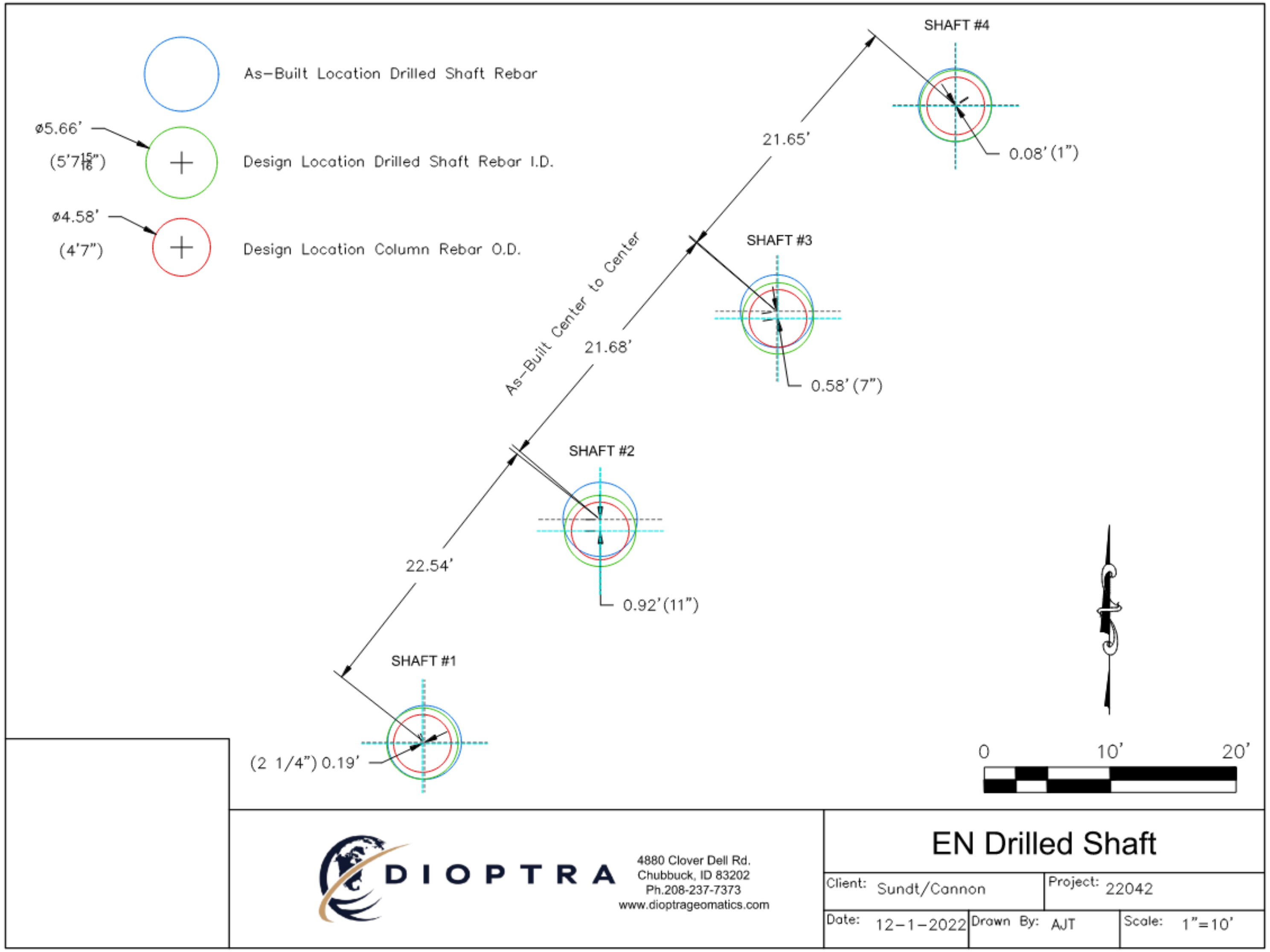


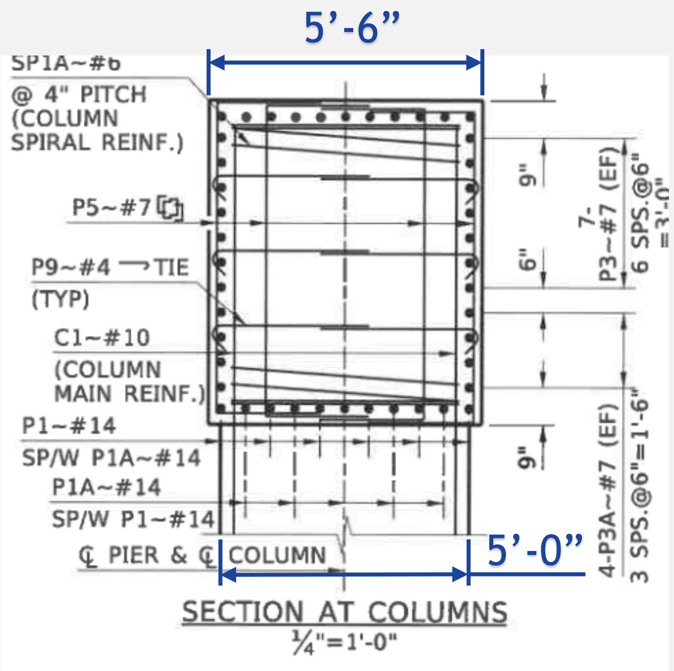
Drilled Shaft Location Issues

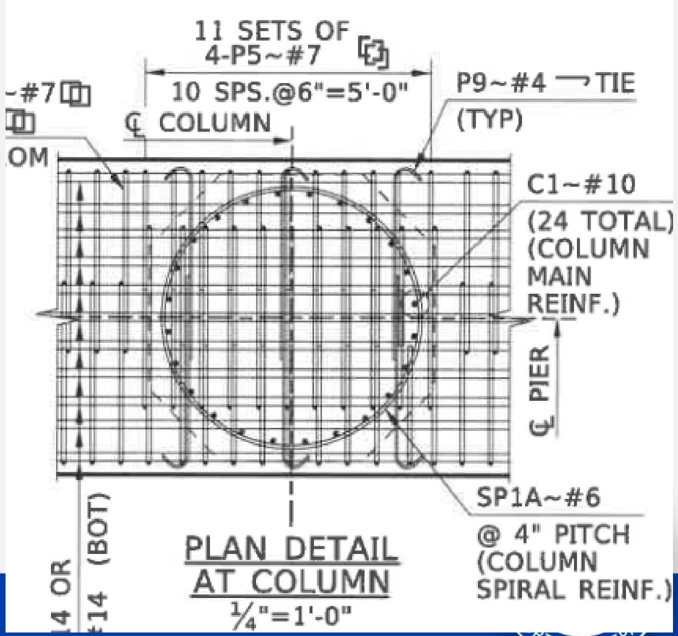
- Horizontal placement tolerance 4.5” on plans
- NB over EN Bridge –
  - Two Shafts out of location 7” & 11”



Drilled Shaft Location Issues







Drilled Shaft Location Issues - Considerations

- Option 1 – Make the cap wider

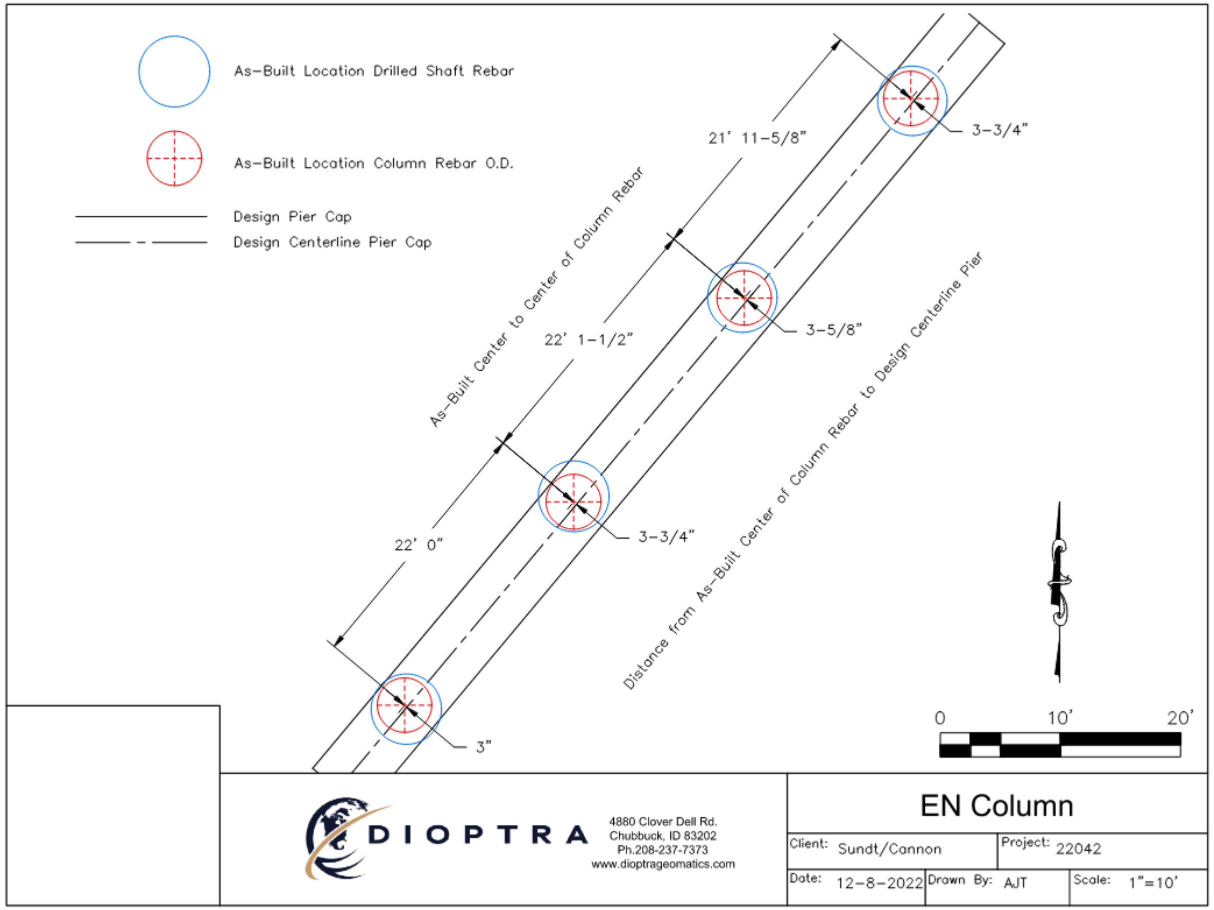
Positives	Negatives
Easier to fit longitudinal rebar	Cap Rebar Changes
Bearing locations stay the same relative to cap	More Concrete = More Mass
More flexibility for column locations	More Analysis

- Option 2 – Shift the entire cap

Positives	Negatives
Cap Rebar stays the same	Challenge to fit longitudinal rebar
Structure Mass and loads are similar	Bearing locations change relative to cap CL
Less Detailing Changes	Some Additional Analysis – Cap Torsion

Drilled Shaft Location Issues - Solution

- Contractor proposed option 2 (Cap Shift) with ITD's approval
- ITD Bridge ran reanalysis to confirm design still acceptable



Location Issues - Lessons Learned

- Design
  - Make future caps wider than 3” on each side of column
  - Increase allowable placement tolerance, 4.5” was reasonable, but our specifications are normally 6”
  - Consider smaller longitudinal rebar in the cap, #14s are hard to thread through column cages
- Construction
  - Double check survey – survey as close to drilling date as possible
  - Potentially survey shaft cage before placing concrete
  - Allow contractor to come up with solutions – this is what they are best at
  - Work together to come up with solutions – we are all on the same team

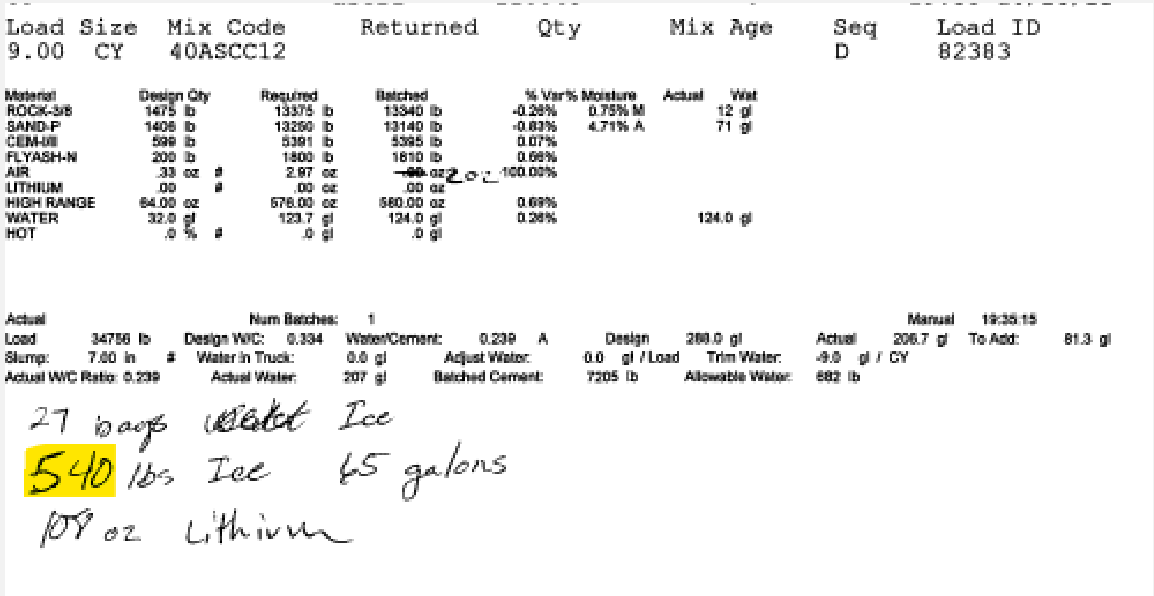
Concrete Placement in Extreme Temperatures

- ITD Concrete Specification
- Max Concrete Temp. 80° at time of placement
- Min Concrete Temp. 50° at time of placement
- Max Internal Curing Temp.

I-15/I-86 System IC Drilled Shaft Concrete Placement						
		Date	Air Temperature	Concrete Temperature	Max Internal Temps °F	Yards
	Test Shaft 1	September 1, 2022	94°	78°		90
Bridge 1	Drilled Shaft 1	October 25, 2022	43°	52°	145°	73
Bridge 1	Drilled Shaft 2	October 31, 1933	44°	55°	143°	60
Bridge 1	Drilled Shaft 3	November 3, 2022	28°	50°	146°	63
Bridge 1	Drilled Shaft 4	November 11, 2022	26°	52°	146°	63
Bridge 2	Drilled Shaft 5	January 20, 2023	17°	49°	195°	64
Bridge 2	Drilled Shaft 6	January 23, 2023	18°	53°	150°	65
Bridge 2	Drilled Shaft 7	January 26, 2023	24°	53°	120°	64
Bridge 2	Drilled Shaft 8	January 28, 2023	27°	53°	144°	64

Hot Weather Concrete - Ice

- Test Shaft
  - Used Ice to cool down loads
    - 400-1000lbs of ice used
- Drilled Shafts 1-3
  - Used Ice to cool down loads
    - 540-750lbs of ice used
  - Placement in afternoon to night



Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
9.00 CY	40ASCC12				D	82383

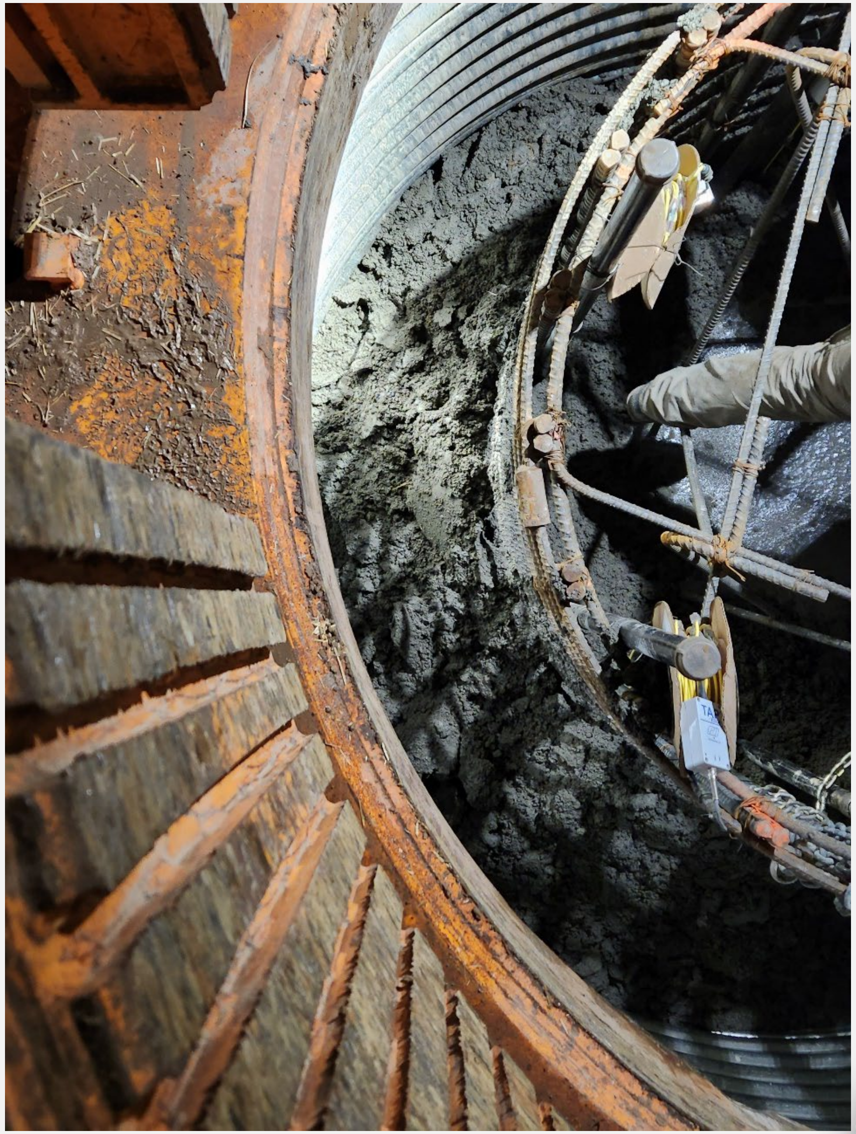
Material	Design Qty		Required	Batched	% Var	% Moisture	Actual Wat
ROCK-3/8	1475 lb		13375 lb	13340 lb	-0.26%	0.75% M	12 gl
SAND-P	1406 lb		13250 lb	13140 lb	-0.83%	4.71% A	71 gl
CEM-I/II	599 lb		5391 lb	5395 lb	0.07%		
FLYASH-N	200 lb		1800 lb	1810 lb	0.56%		
AIR	.33 oz	#	2.97 oz	~~.00~~ oz 2 oz	100.00%		
LITHIUM	.00	#	.00 oz	.00 oz			
HIGH RANGE	64.00 oz		576.00 oz	580.00 oz	0.69%		
WATER	32.0 gl		123.7 gl	124.0 gl	0.26%		124.0 gl
HOT	.0 %	#	.0 gl	.0 gl			

Actual Num Batches: 1 Manual 19:35:15
Load 34756 lb Design W/C: 0.334 Water/Cement: 0.239 A Design 288.0 gl Actual 206.7 gl To Add: 81.3 gl
Slump: 7.00 in # Water in Truck: 0.0 gl Adjust Water: 0.0 gl / Load Trim Water: -9.0 gl / CY
Actual W/C Ratio: 0.239 Actual Water: 207 gl Batched Cement: 7205 lb Allowable Water: 682 lb

27 bags Ice
540 lbs Ice 65 galons
109 oz Lithium

Cold Weather Concrete - Flash Freeze

- Drilled Shaft #3
  - Ambient temperature at pour: 28°
  - Concrete Temperature: 50°
  - In place Concrete Temperature: 27°



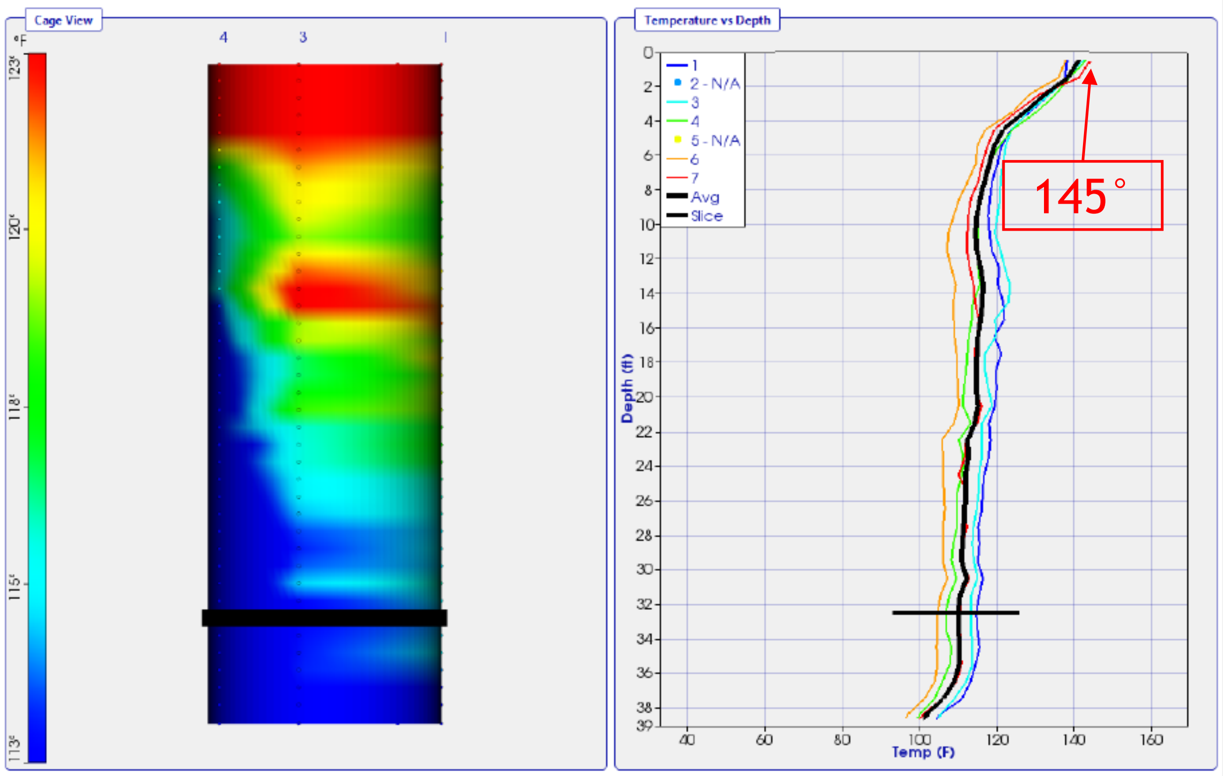
Cold Weather Concrete – Lessons Learned

- Cold Weather Plan
  - Heat enough to where steel is warm but not too hot
  - Between a set of trucks, put heat back on.
  - Cover after placement and heat.

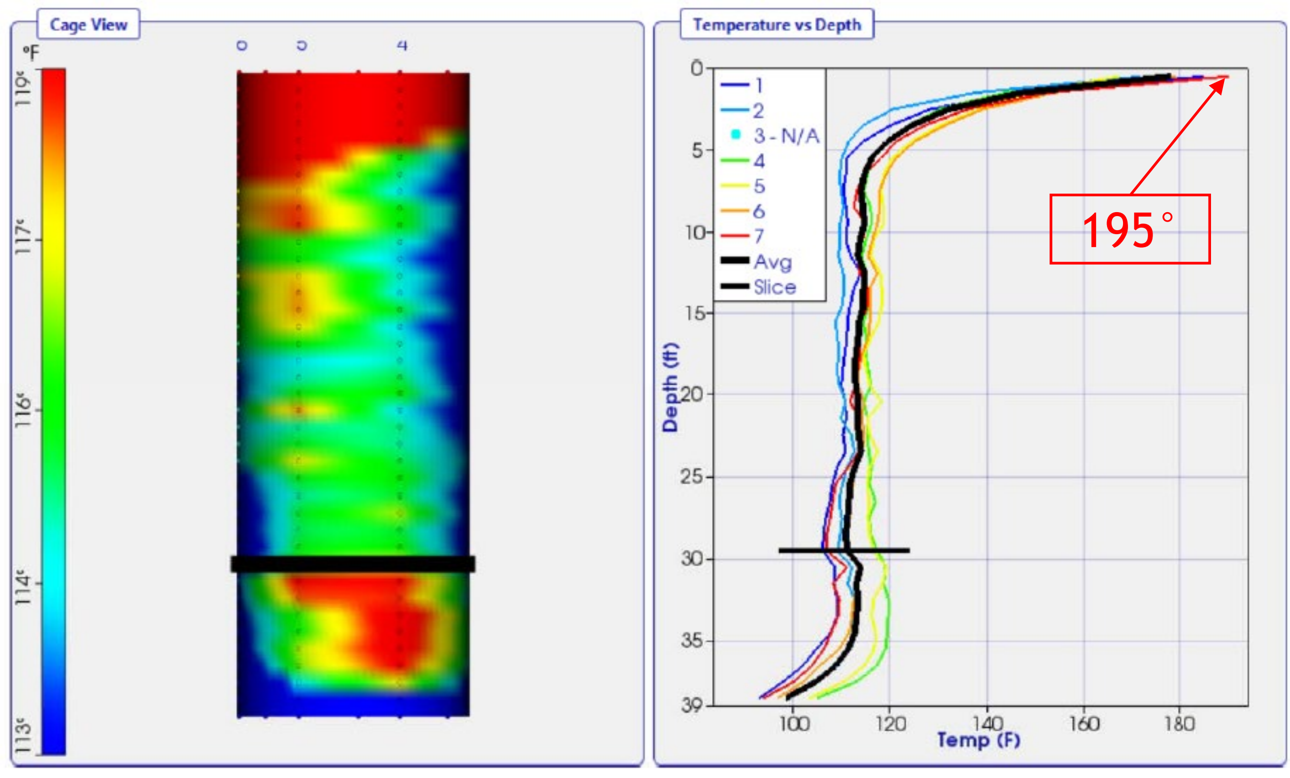
Concrete Cured how hot?

Concrete Cured how hot?

Shaft P1-3

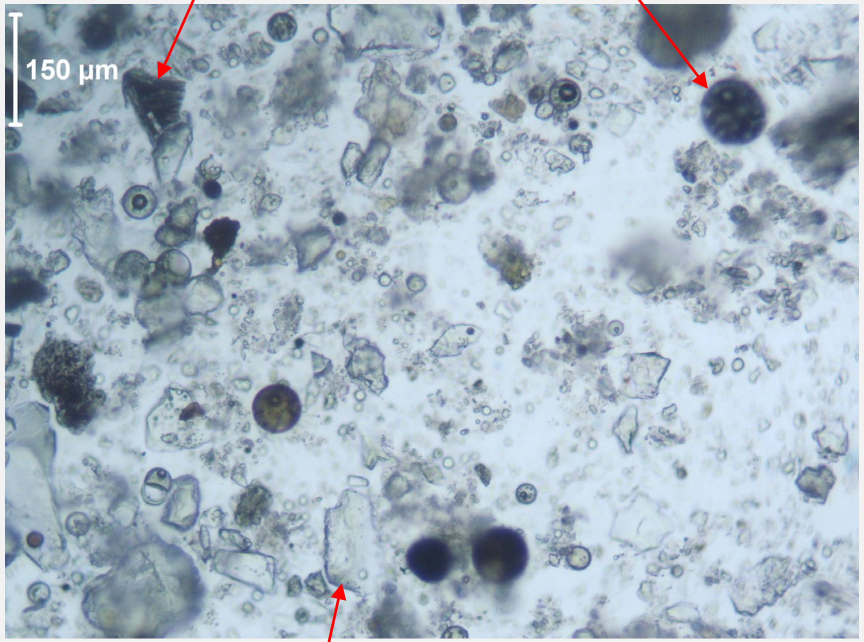


Shaft P1-1



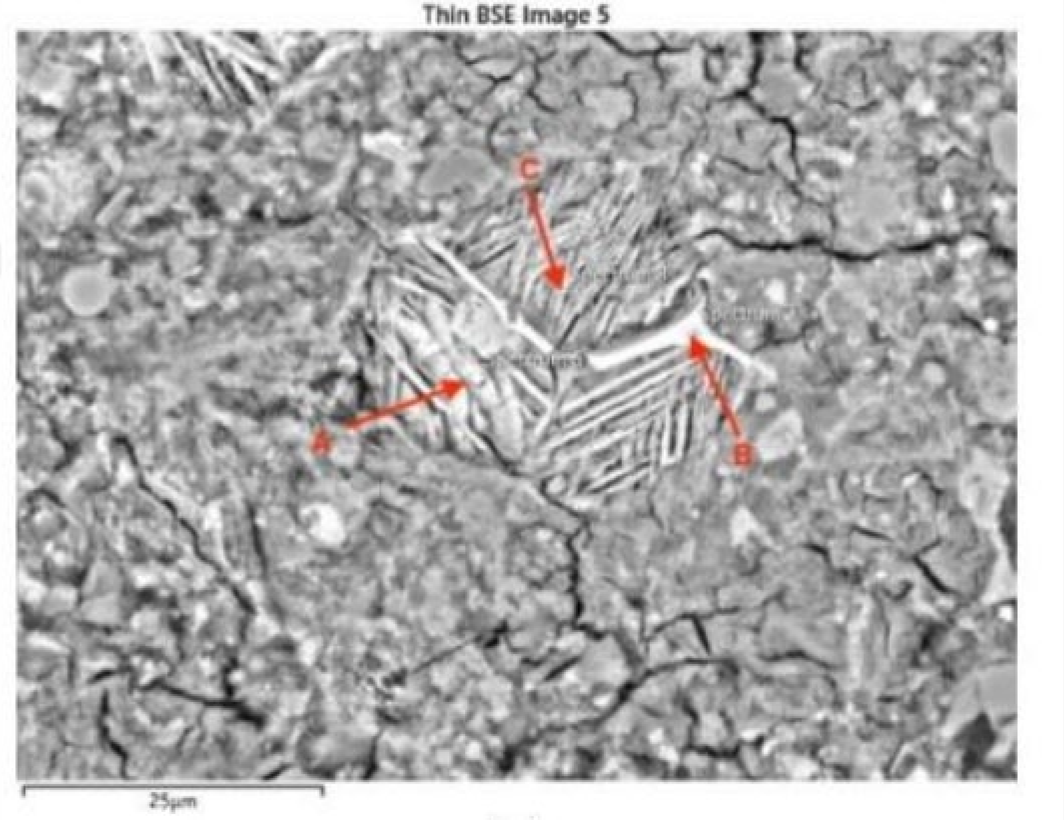
Testing the Concrete

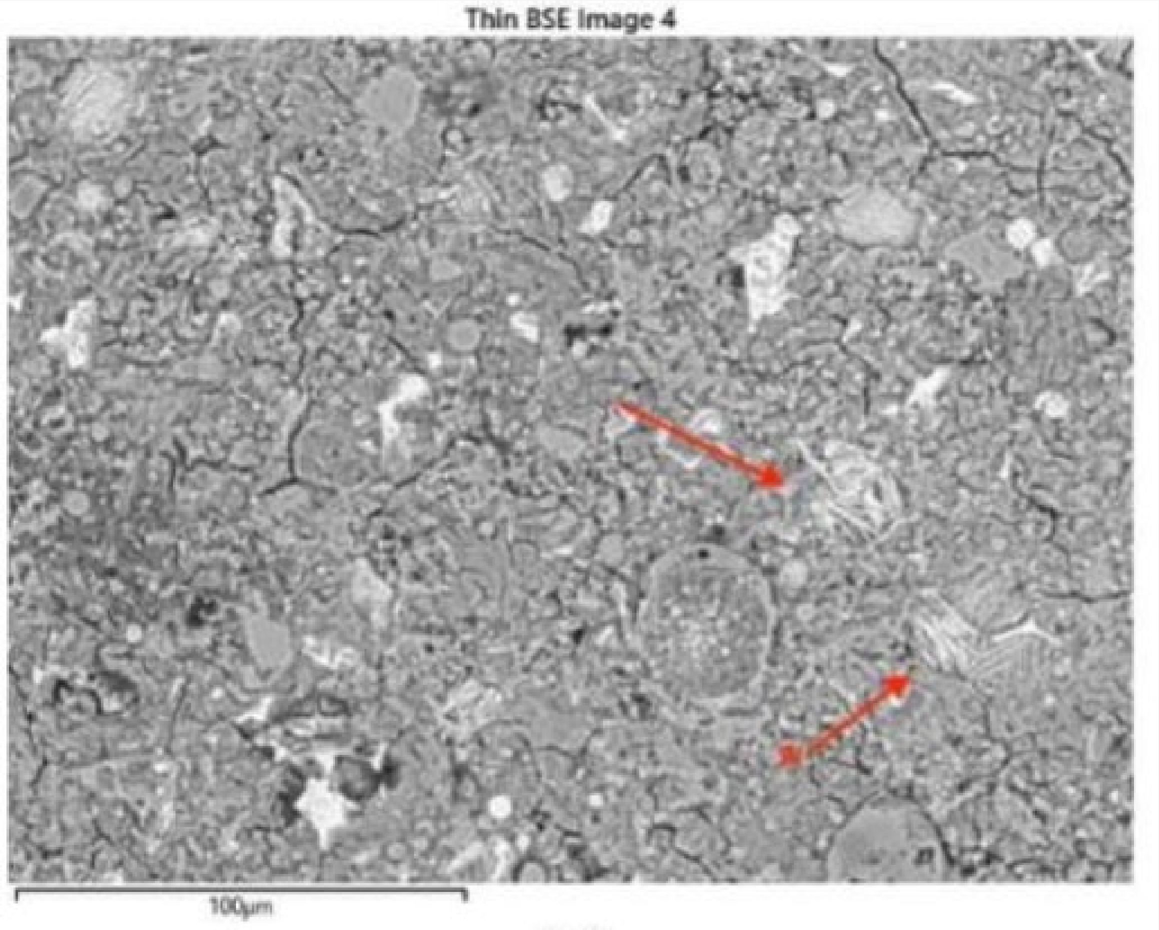
Figure A3. Photographs of the polished section of Shaft 1A.



Petrographic Analysis

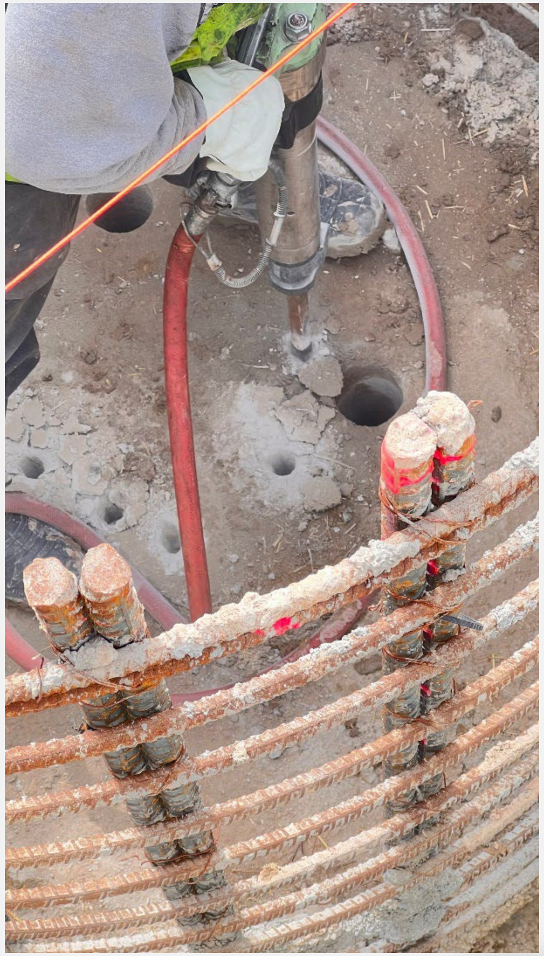
Delayed Ettringite Formation (DEF)





Concrete Placement – Lessons Learned

- Internal Temperature Probes in the Center are Valuable
- Watch Steel Casing temperatures
- Temperature control is Key
- If something looks off, take the time to investigate



Summary of Lessons Learned

- **Everybody** makes mistakes
- Don't be afraid of change
- Act quickly - problems don't age well
- We are all on the same team
- Know your contract/specifications

Questions?

I-86/1-15 System IC

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