TIP – Verification of Pile Integrity and Capacity

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PÅLDAG 17

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It is obvious why we test; we cannot afford failures

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Thermal Integrity Profiling

Measures the elevated temperatures during the hydration process to determine pile integrity

Temperature during curing is directly related to concrete quality, volume, and radius (cover)

- Reductions in temperature indicate necking, inclusions, or poor quality concrete
- Increases in temperature indicate bulges or increased concrete cover

Variance in temperature between diametrically opposite wires indicates cage alignment/cover issues

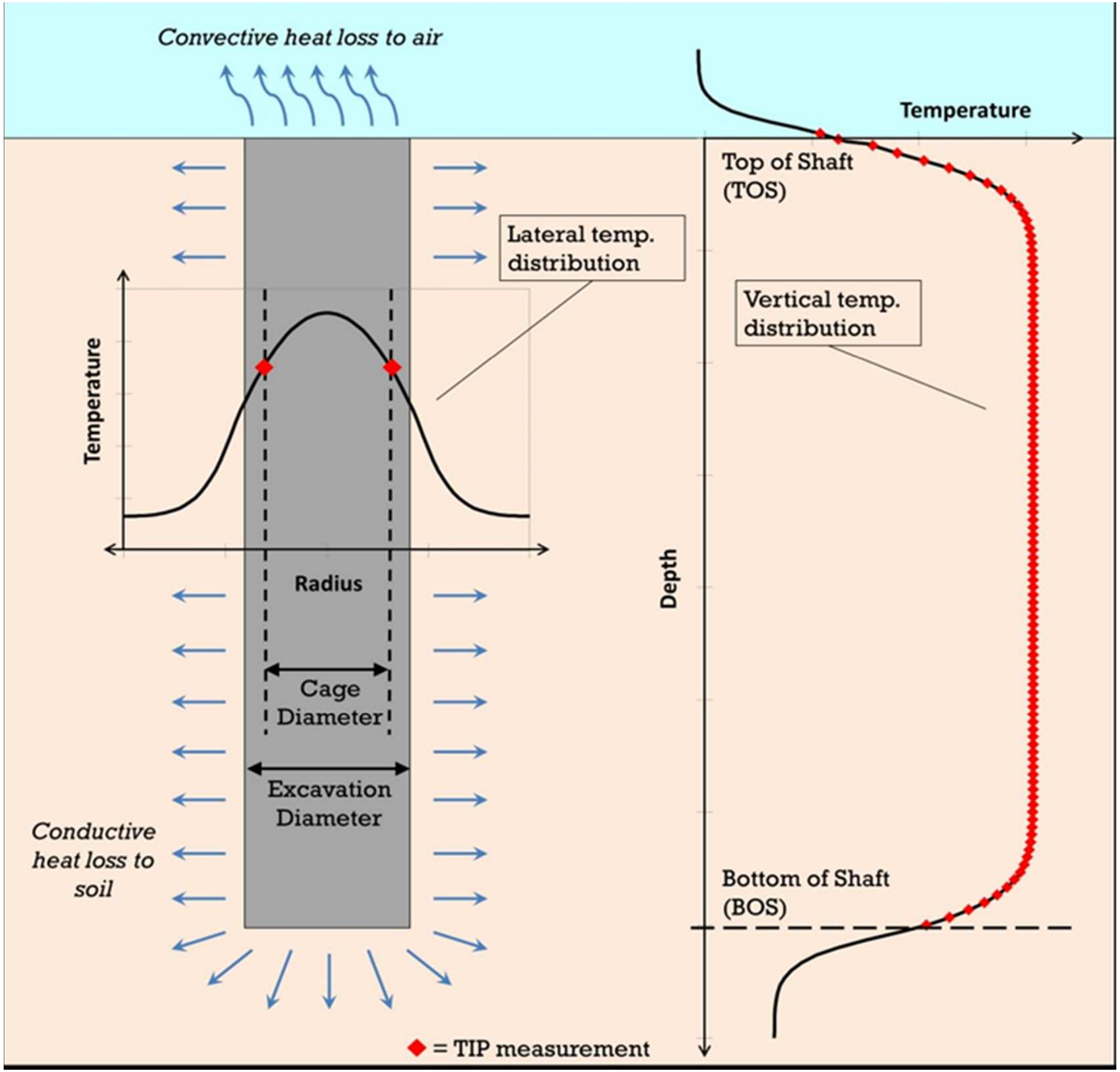
Acquiring Volume data allows temperature to be converted to radius

Thermal Integrity Profiling

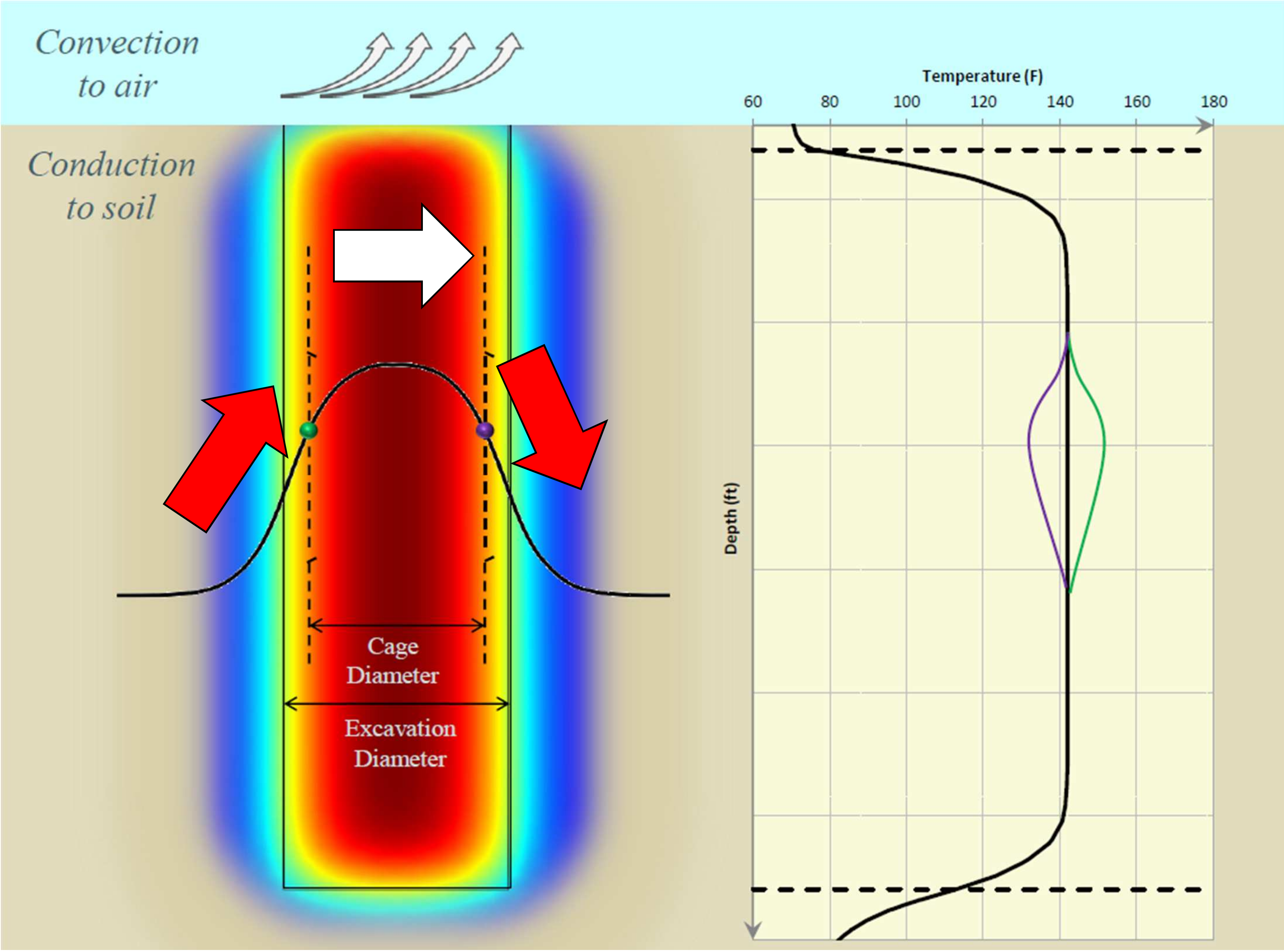
- Thermal Integrity Profiler evaluates concrete both inside and outside the cage
  - Assessing both cover and alignment

(100% testing – entire section)

- Evaluates shaft during curing (as early as 12 hrs. depending upon mix design and pile diameter)
  - Allows construction to progress much faster
  - Significant cost savings can be achieved if we can save many days or weeks on a project
- ASTM D7949

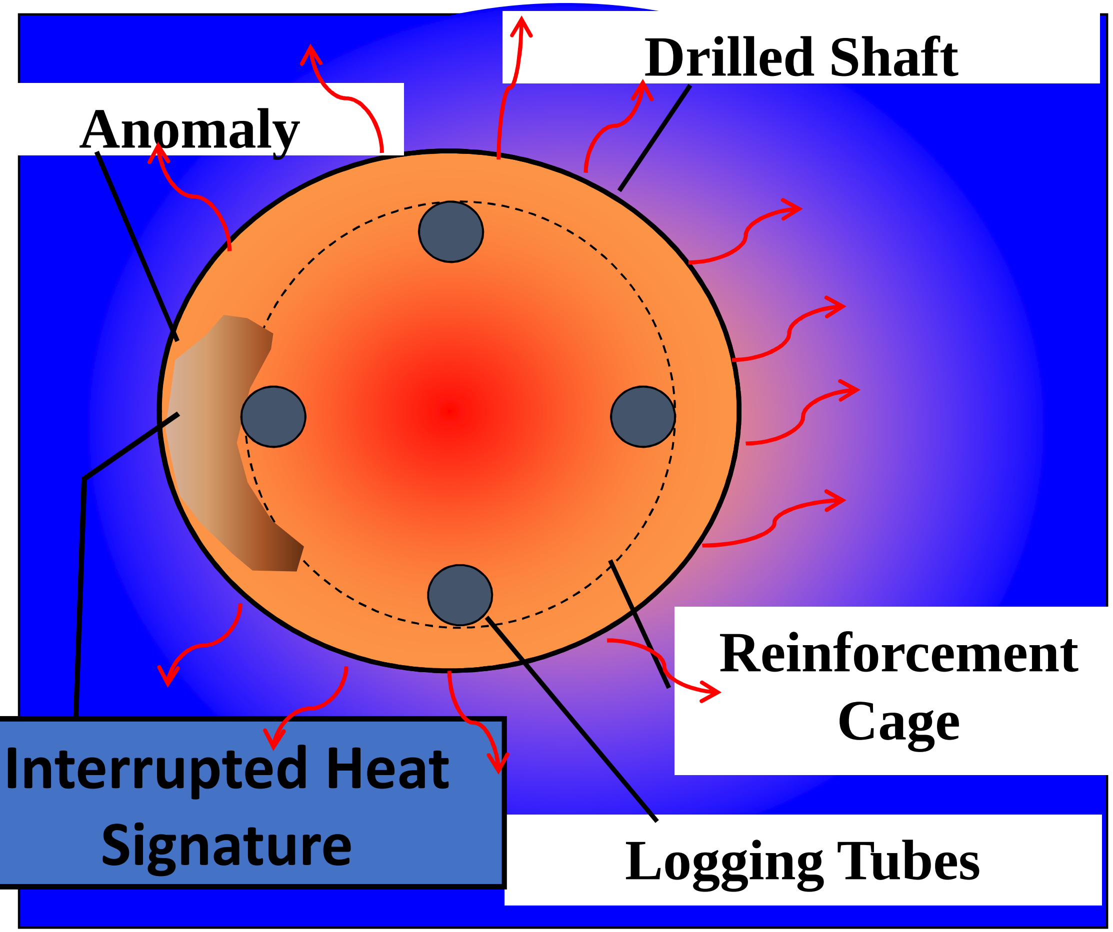


Convective heat loss to air
Temperature
Top of Shaft
(TOS)
Lateral temp.
distribution
Vertical temp.
distribution
Temperature
Radius
Depth
Cage
Diameter
Excavation
Diameter
Conductive
heat loss to
soil
Bottom of Shaft
(BOS)
= TIP measurement

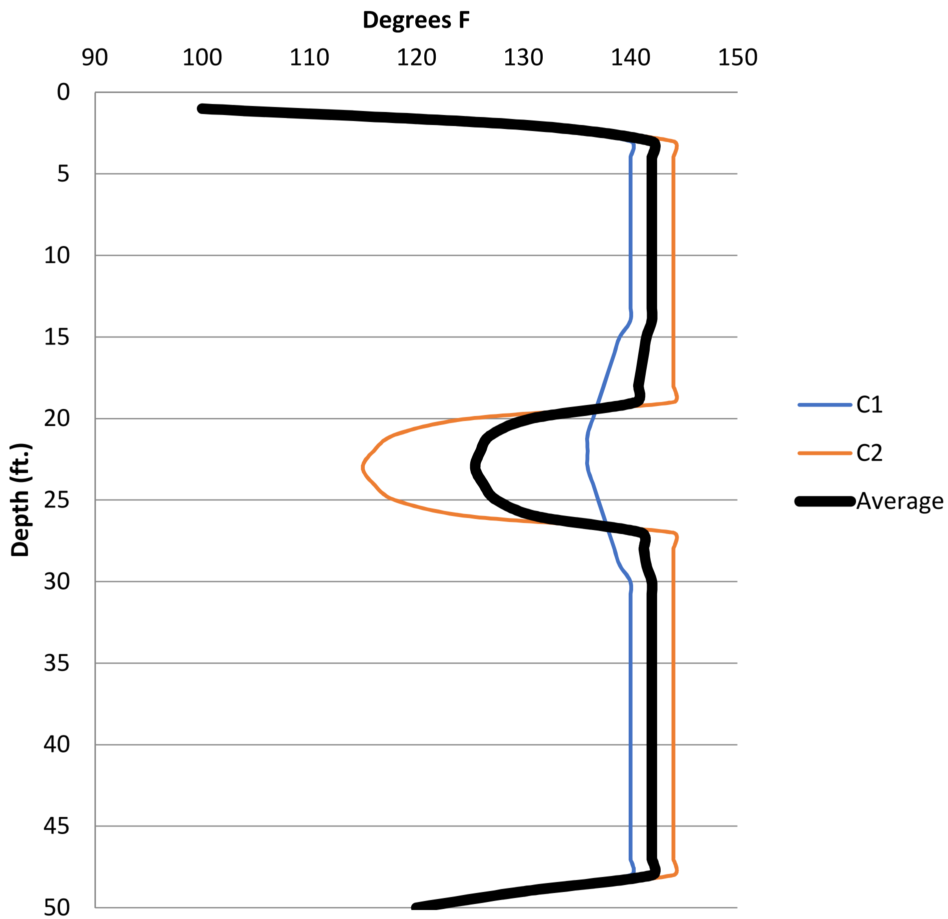


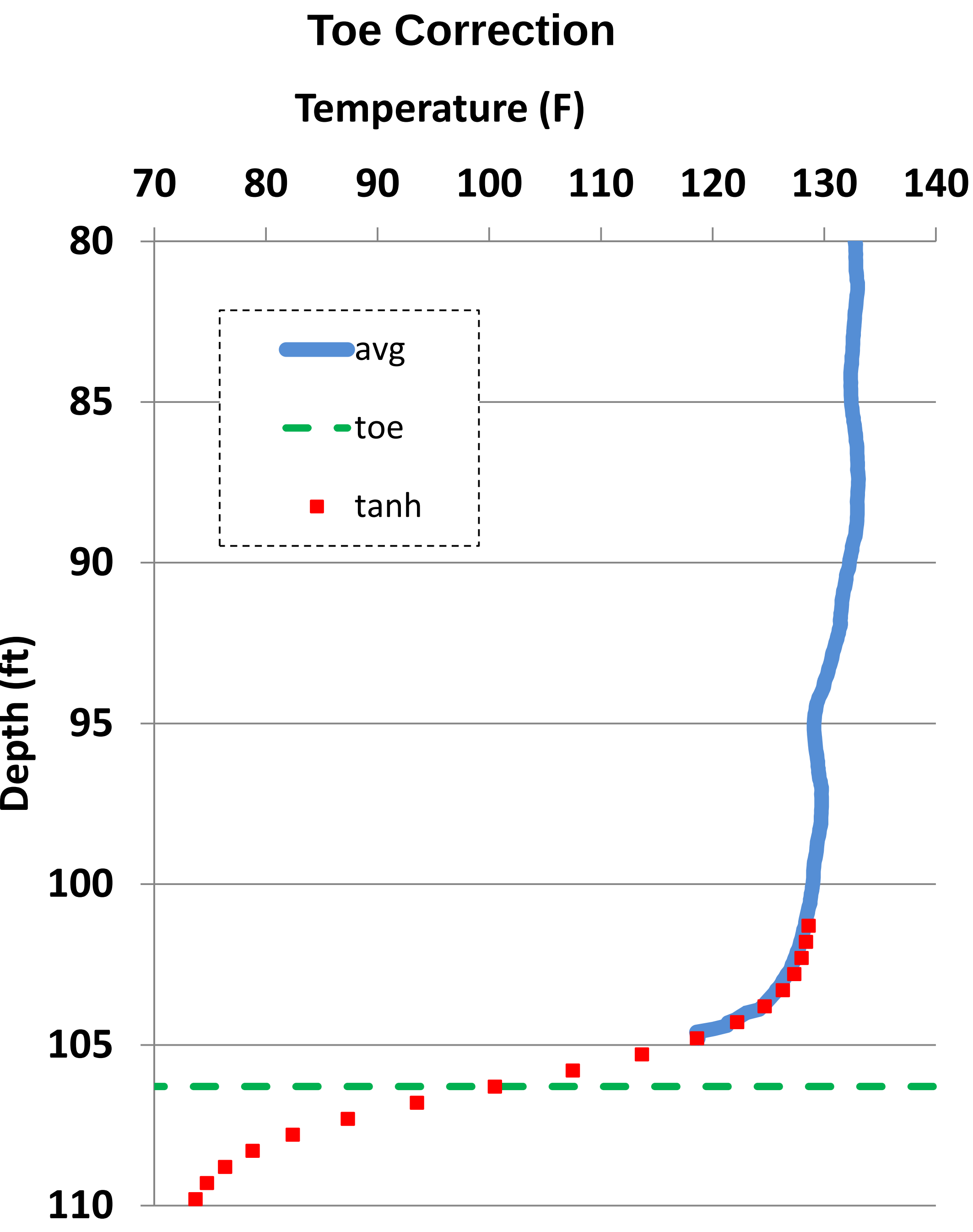
Convection
to air
Conduction
to soil
Cage
Diameter
Excavation
Diameter
Temperature (F)
60
80
100
120
140
160
180
Depth (ft)

Thermal Integrity Profile

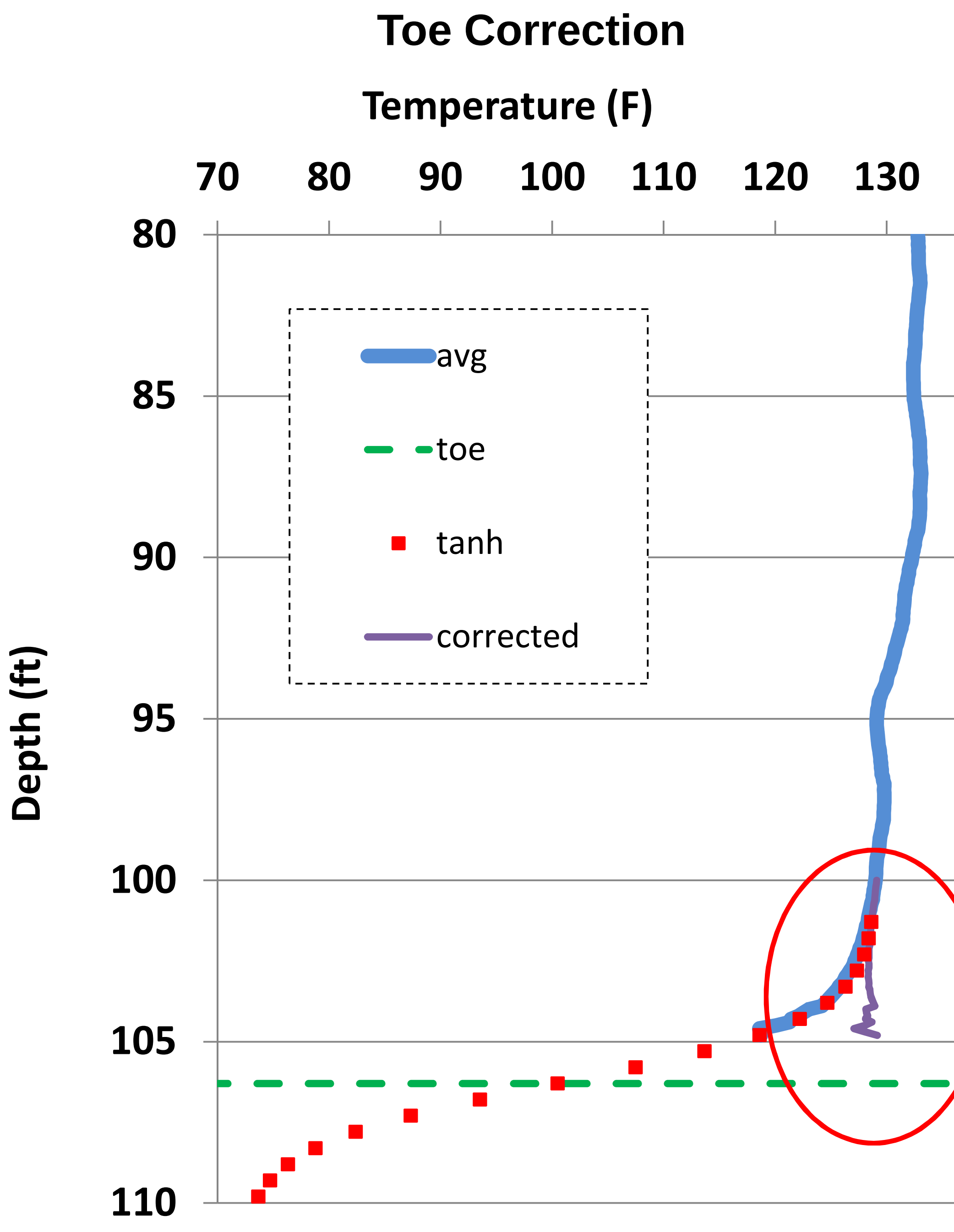


Data Interpretation - Local Defect near C2



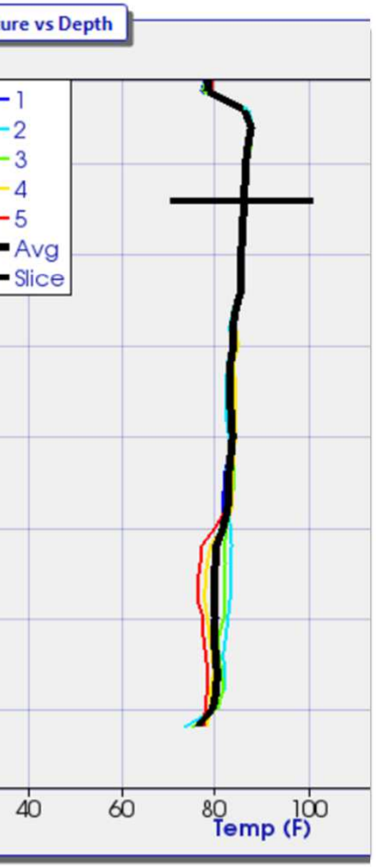


Toe Correction
Temperature (F)
70
80
90
100
110
120
130
140
Depth (ft)
80
85
90
95
100
105
110
avg
toe
tanh

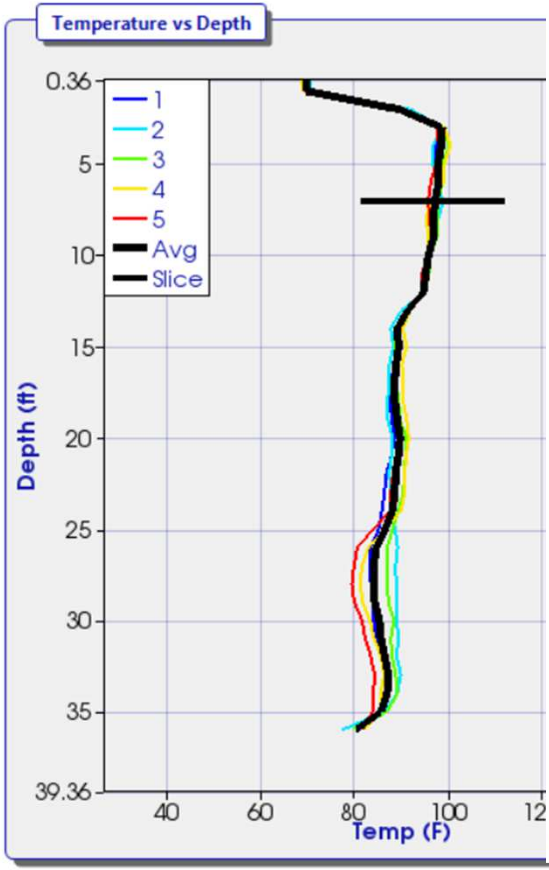


Toe Correction
Temperature (F)
70
80
90
100
110
120
130
Depth (ft)
80
85
90
95
100
105
110
avg
toe
tanh
corrected

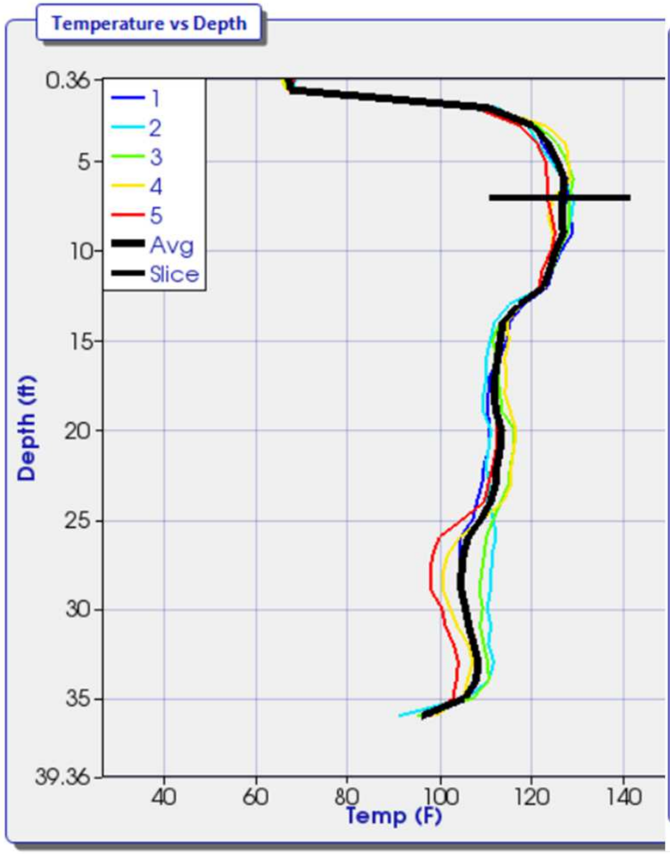
Thermal Integrity Profiling



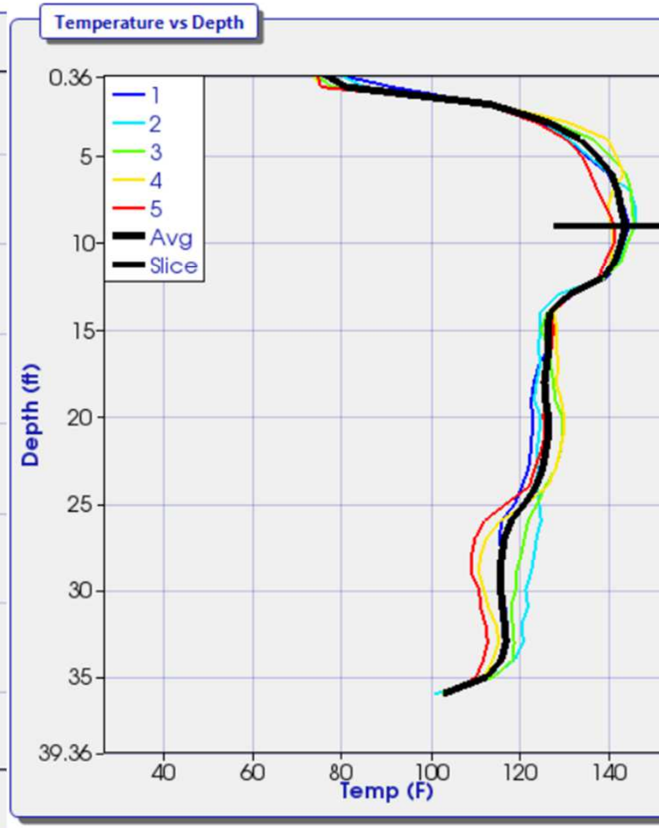
1 hour



4.5 hours

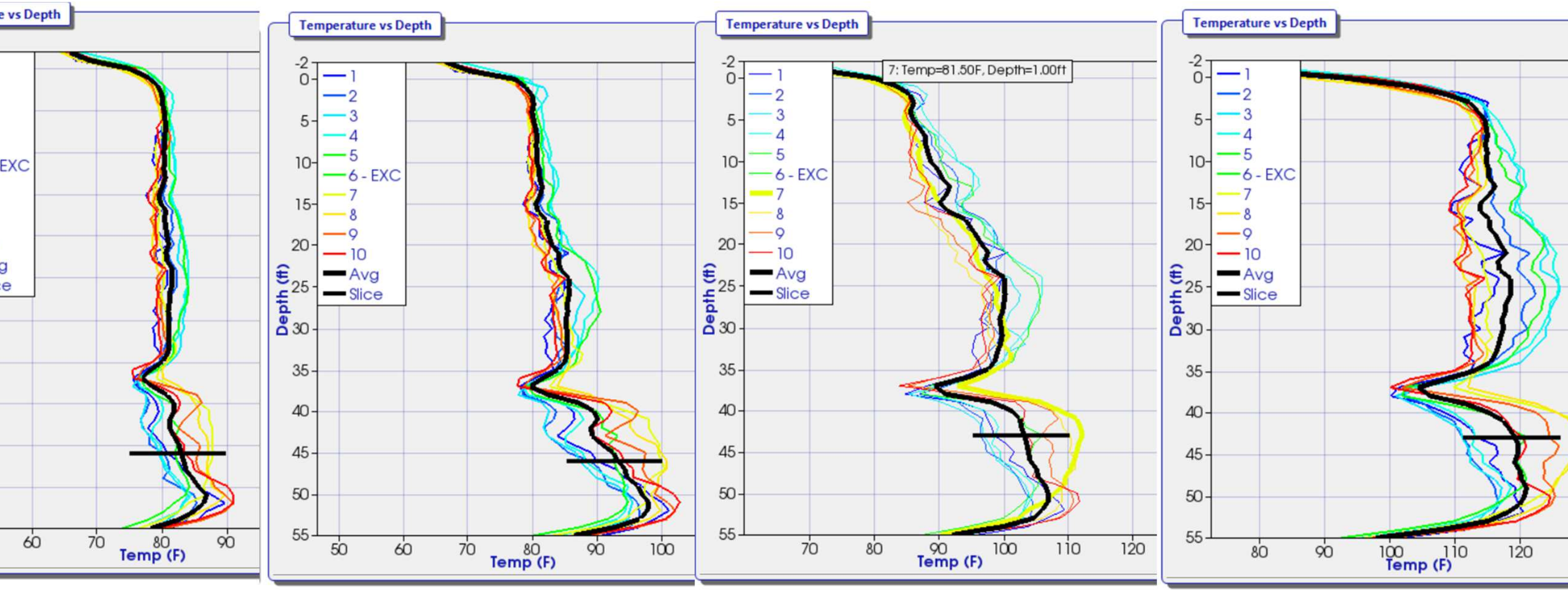


8 hours



18 hours

Thermal Integrity Profiling



2 hours 4.5 hours 8 hours 18 hours

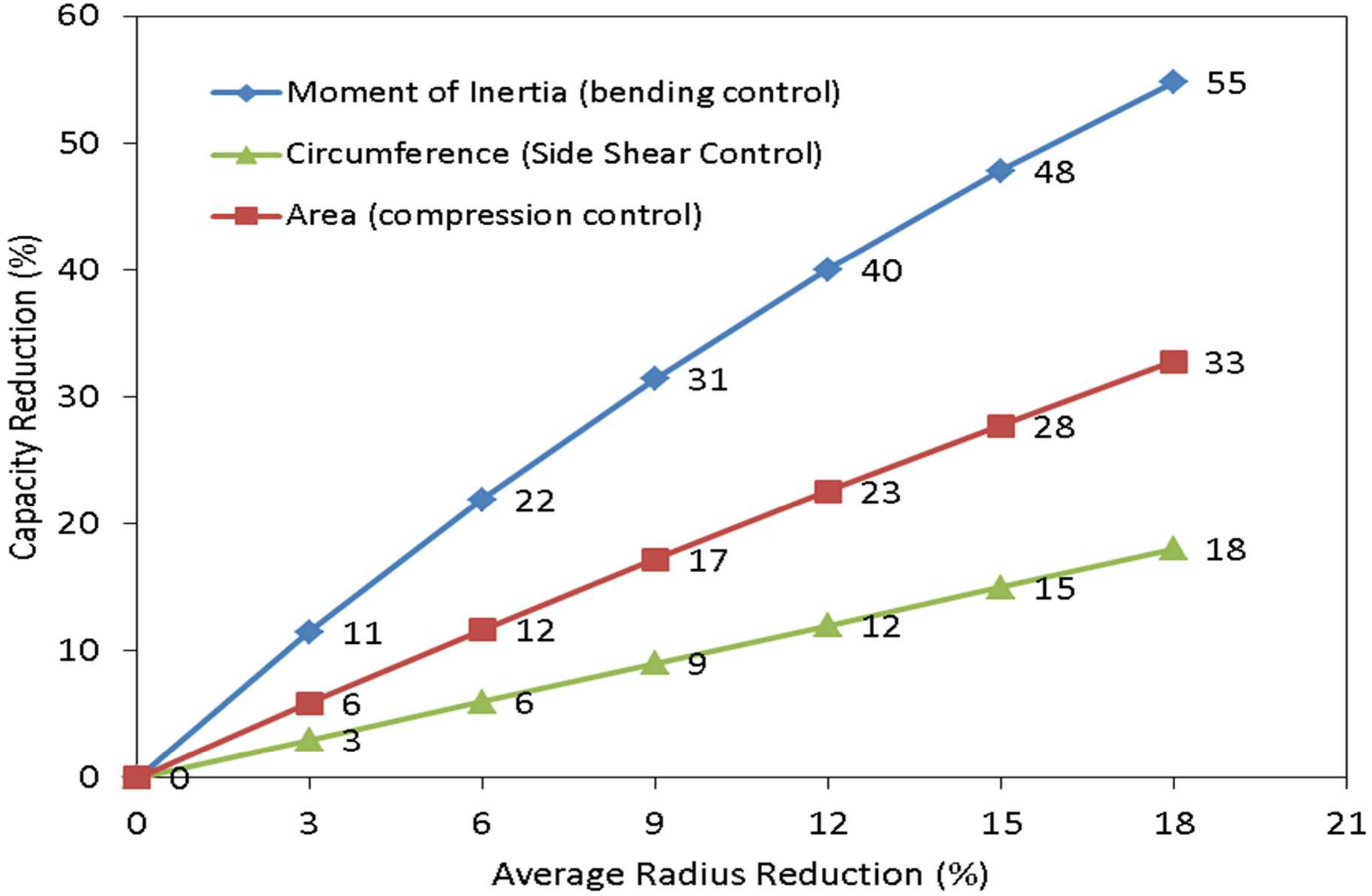
TIP Testing Equipment

- Thermal Wire® cable
  - Embedded in grout or concrete
  - Digital sensors sample temperature data
- TAP or TAG Box
  - Data collection with TAP
  - Data collection and transmission to cloud
- TIP Main Unit
  - Project set up
  - Download data from TAP box
  - View field results

Acceptance Criteria

- Load carrying requirements can be controlled by:
  - Geotechnical side shear
  - Structural bending
  - Compression
- These are directly related to:
  - Circumference surface area of the shaft
  - Moment of inertia
  - Cross sectional area
- Radius Reduction approach will affect each differently:
  - Reduction has linear relation to circumference
  - Reduction has fourth power relation to moment of inertia
  - Reduction has squared relation to area

Radius Reduction vs. Capacity Reduction



Acceptance Criteria

Radius Reduction	Bending Capacity Loss	Compression Capacity Loss	Side Shear Reduction	Cover Loss (4 inch cover, 6ft dia. shaft)
3%	11%	6%	3%	1.08in
6%	**22%**	**12%**	**6%**	**2.16in**
>6%	>22%	>12%	>6%	>2.16in

Satisfactory (S)

0 to 6% Radius Reduction <u>and</u>
Local Cover Criteria Met

Anomaly (A) Requiring further evaluation

Radius Reduction > 6% <u>or</u>
Local Cover Criteria Not Met

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I-5 Bridge over Puyallup River
Tacoma, Washington

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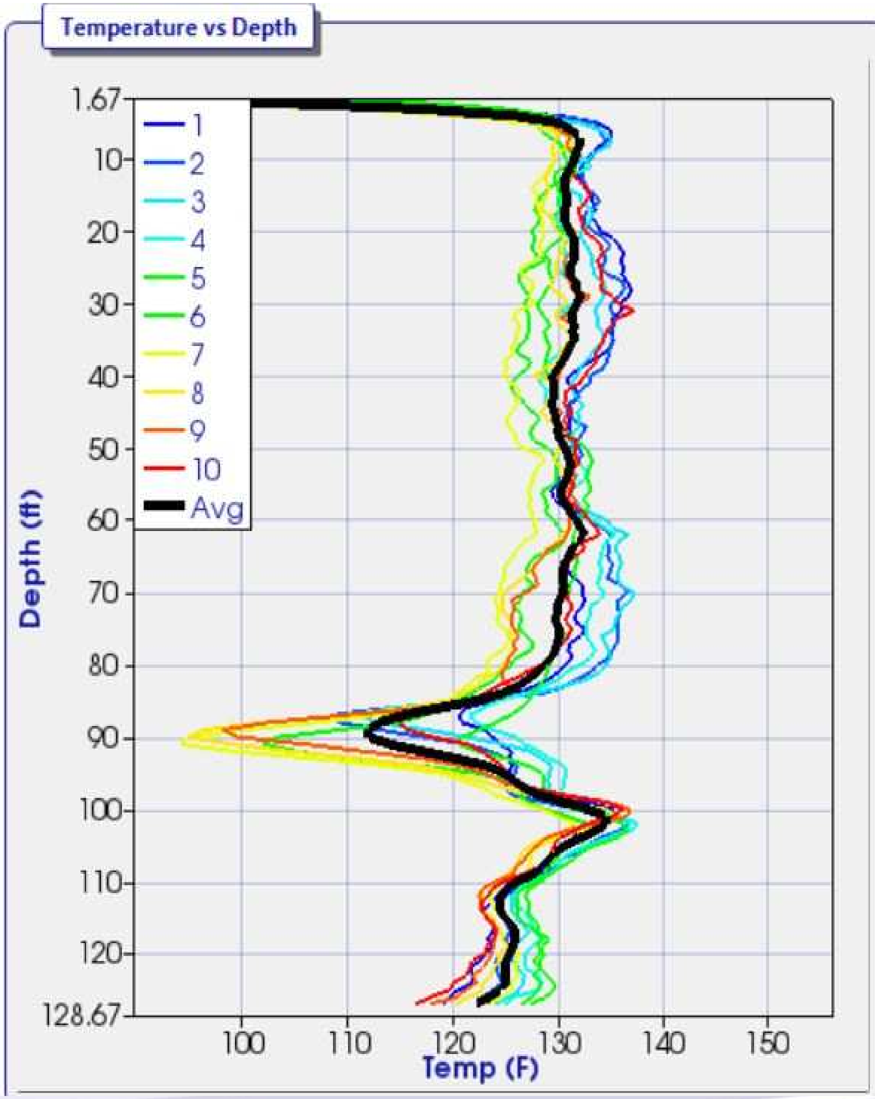
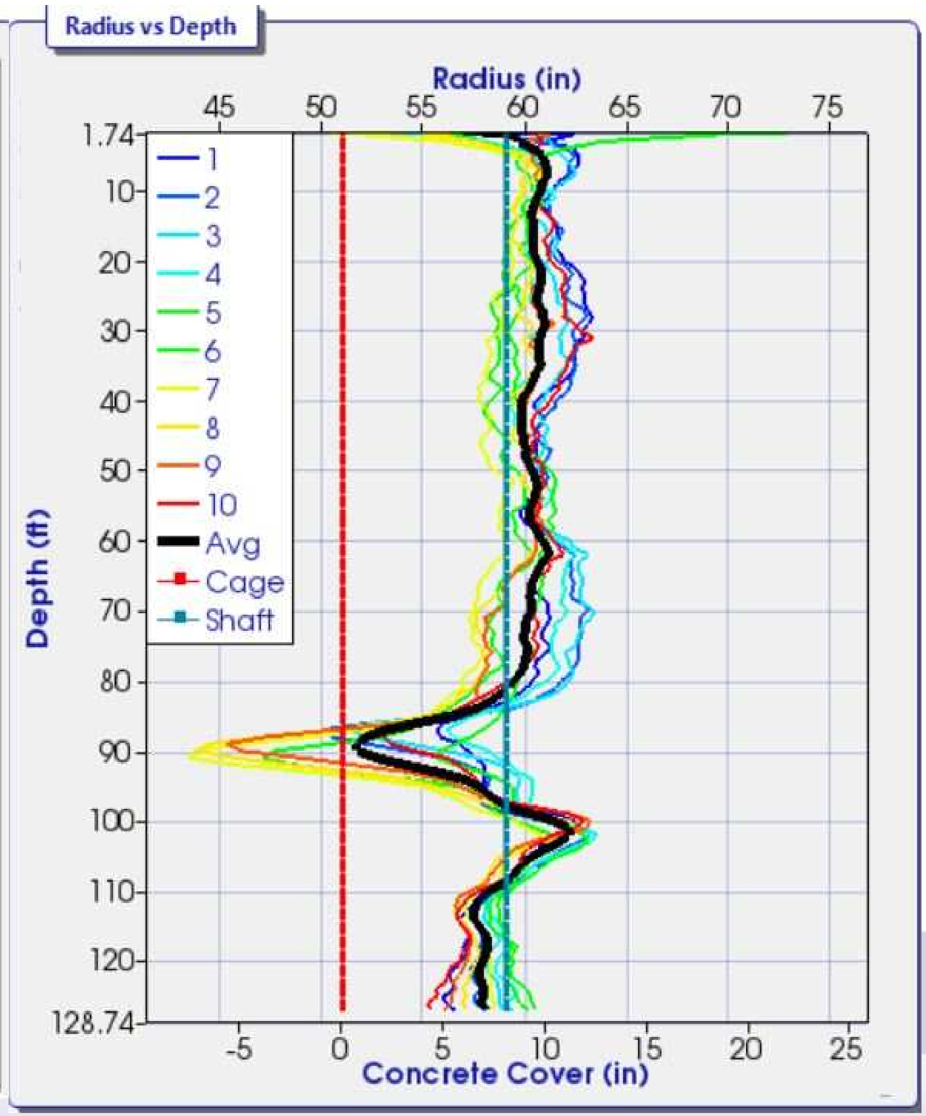
TIP Example 1

- Wet cast Shaft in Washington State
- 3m diameter
  - 10 TIP wires installed
- Cage Diameter 2.6m
- 38.4m shaft length
- TIP testing begins immediately after casting
  - Data recorded during pour as well as cure
- Data recorded for approximately 90 hours after casting
- Shaft peak temperature occurs approximately 40 hours after casting
- Shaft analysis done at time of one half peak temperature (20 hours)

TIP Data at Peak Temperature





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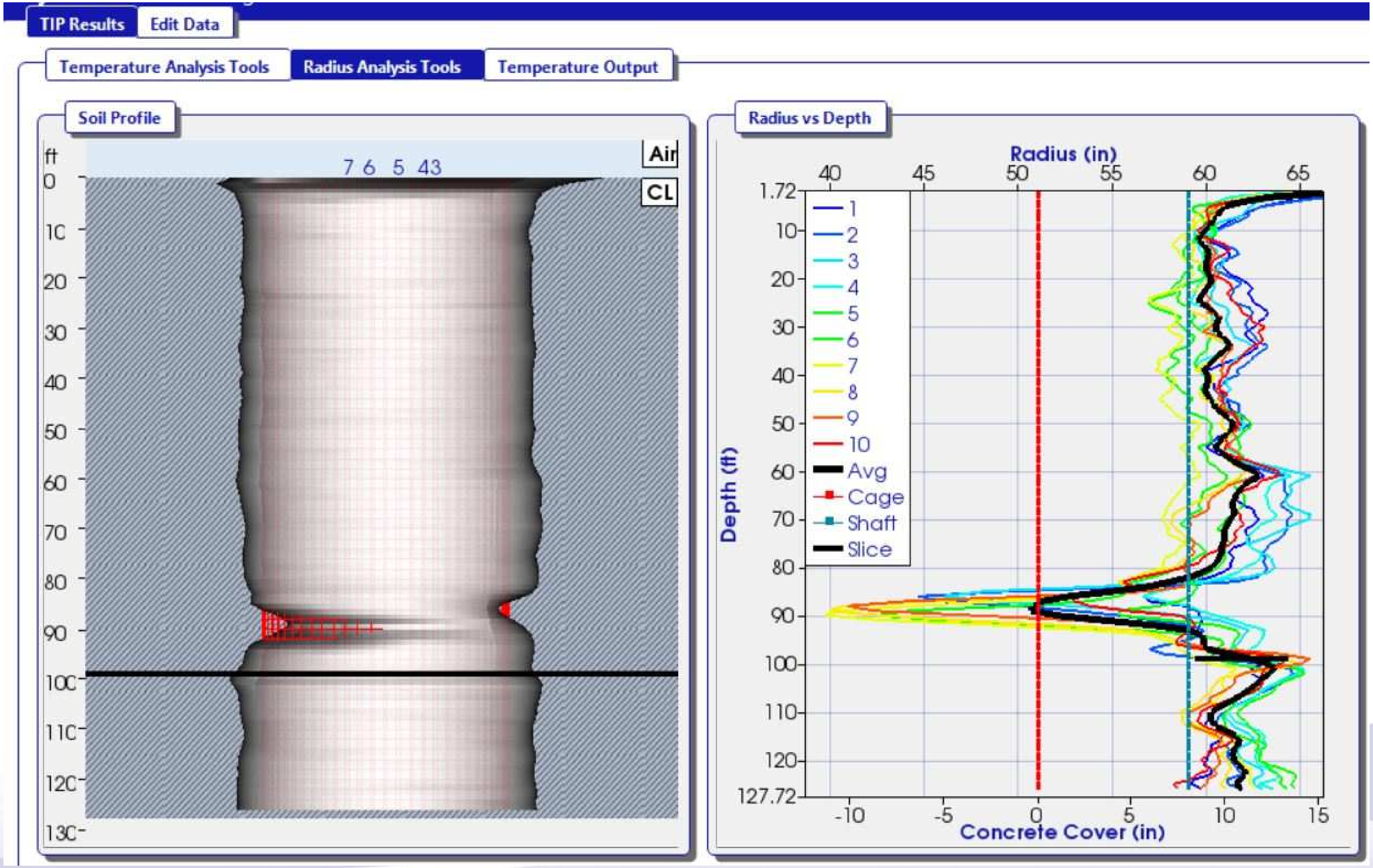
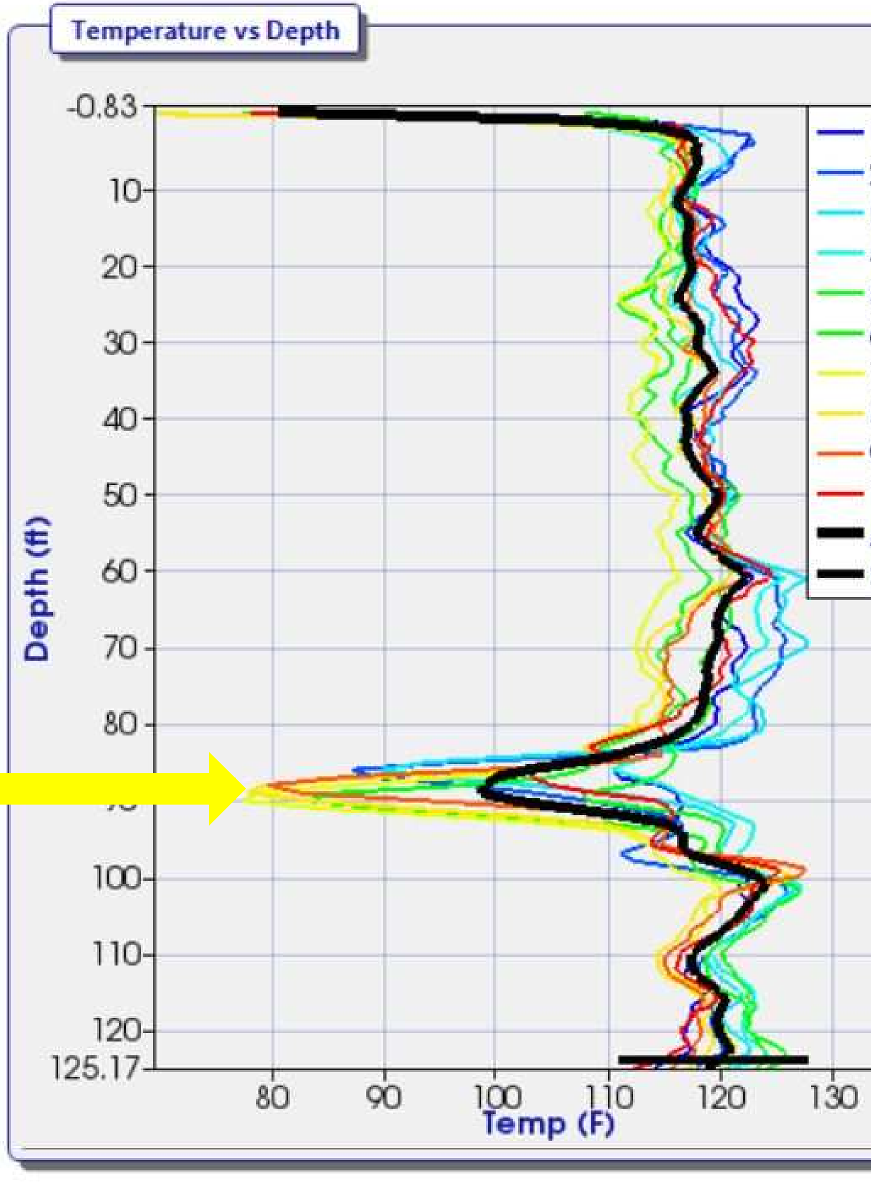
TIP Data at one half Peak Temperature



Coring Results at approximately 90’ depth

- Coring result close to wires 7 and 8, where largest reduction occurred
- Coring confirms TIP test results
- Zone was hydro-blasted and pressure grouting was performed



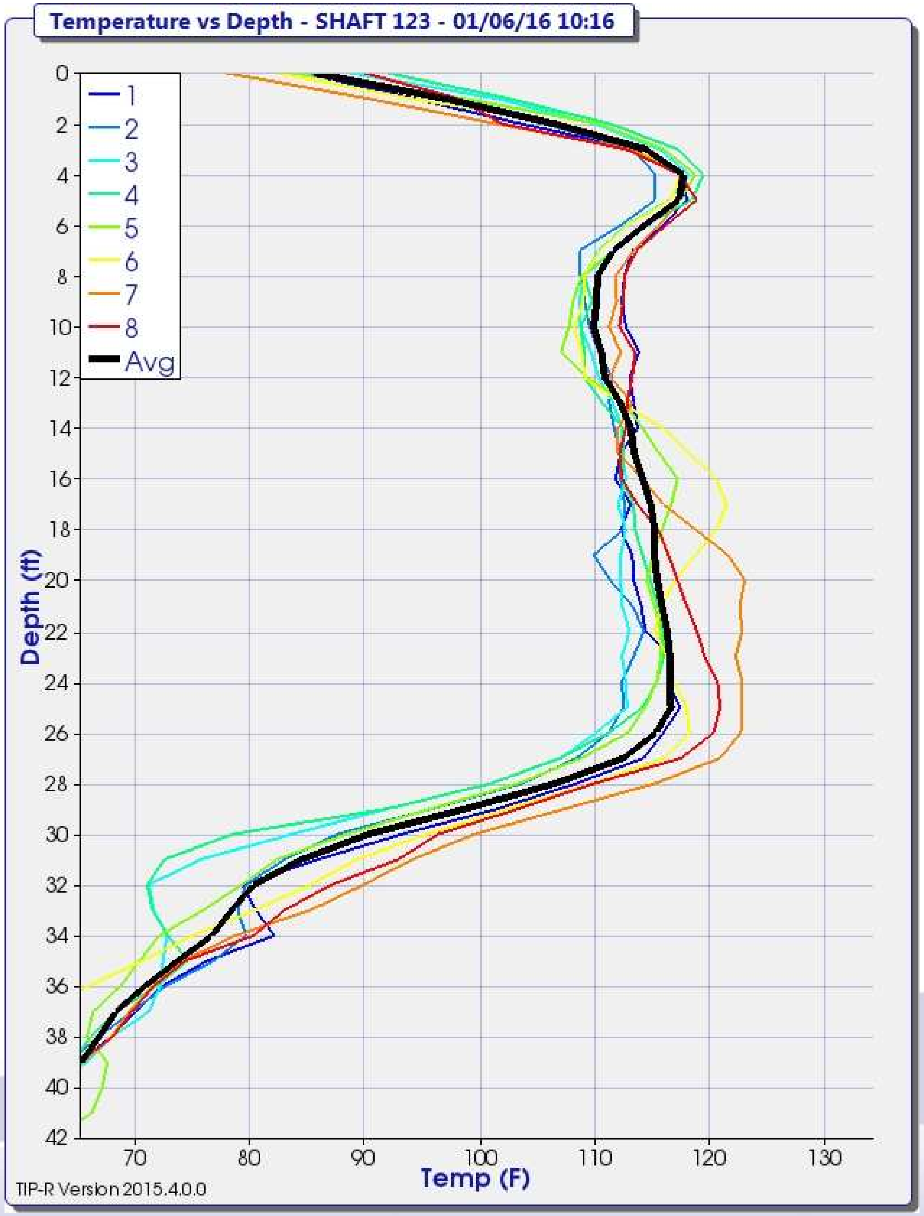
TIP Results and Acceptance Criteria

- Shaft shows a local reduction near wires 6 through 9
  - Design radius = 1.5m
  - Local effective radius at wires 7 & 8 = 1.02m
  - Reduction in Local Radius = 32.2%
    - Clearly greater than 6% Reduction in our Criteria
  - Cover is also reduced to zero in these regions
    - Anomaly extends inside the reinforcing cage
    - Below minimum cover requirement
  - Shaft fails <u>BOTH</u> the radius reduction criteria <u>AND</u> the cover criteria
  - This is considered an anomaly which requires further evaluation
  - Coring and remediation is done in several locations in the shaft

Example 2: Free fall concrete into wet base

Shaft Details:
Diameter 2.4m
Length 12.8m

What is wrong with this shaft?



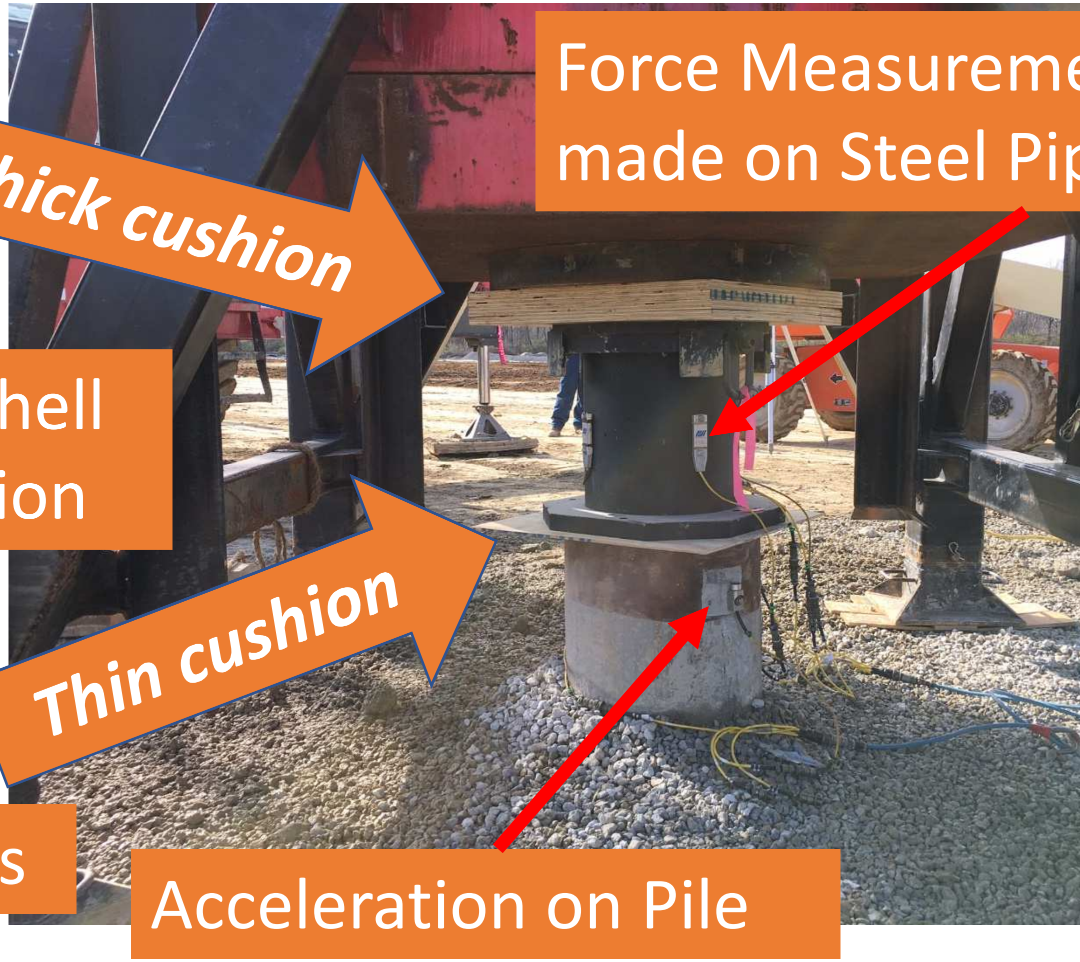
- Engineer requested that contractor to use tremie (request denied)
- Concrete placed free fall method
- Reportedly 1.5m of water present at the base prior to placement
- Core revealed collapsed shaft and contaminated concrete

Dynamic Testing Drilled Shafts

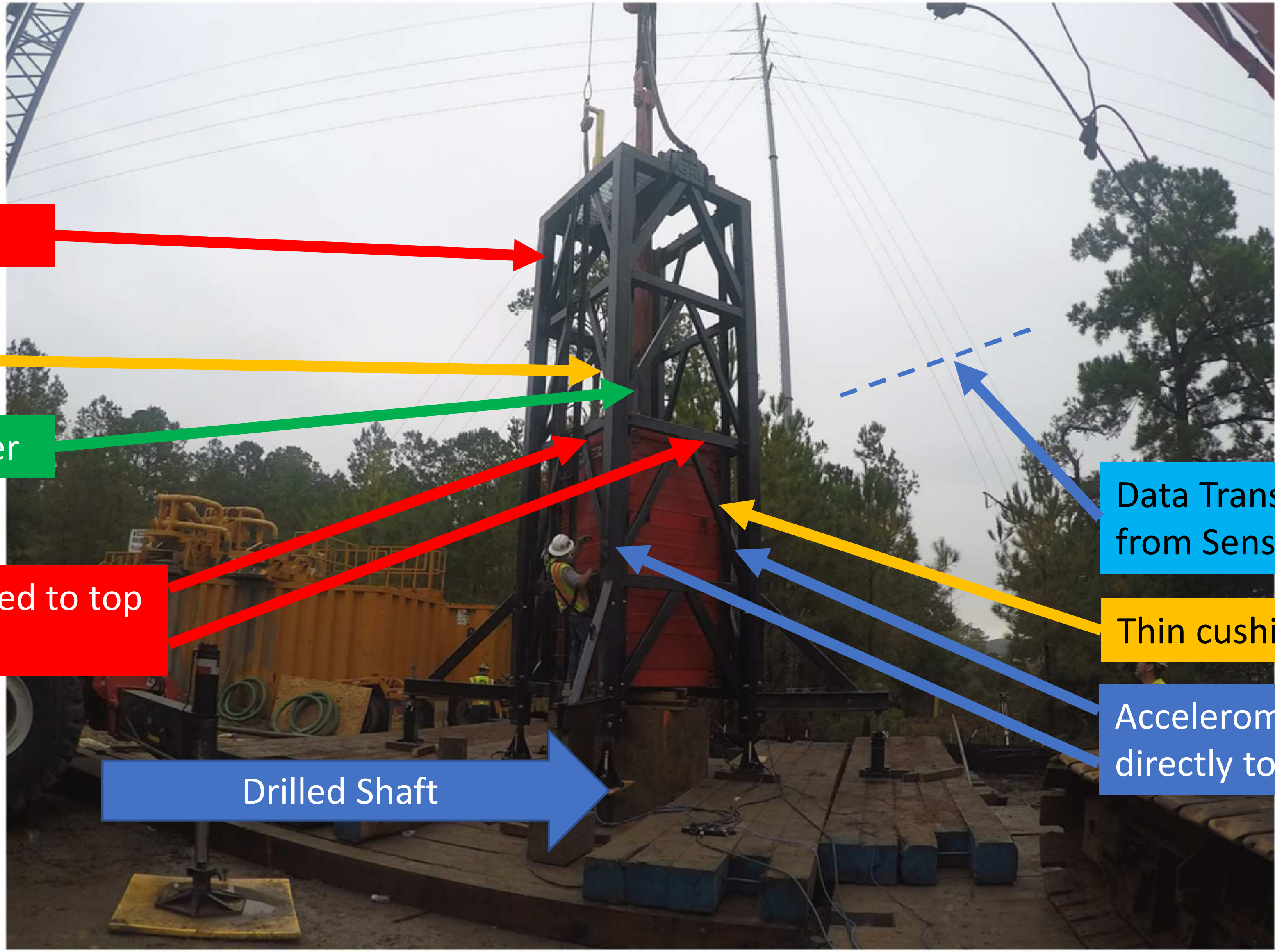
- Build up Pile Top and use a plywood cushion
  - Reduces Excavation
  - Protects Reinforcing
  - Remove after Testing
- Use Steel Top Transducer
  - Strain sensors attached to steel pipe
    - Eliminates uncertainties in Area and Modulus
  - Accelerometers attach directly to the Drilled Shaft
- Drop Weight 1%, 2%, … 5% of Ru
  - 2% helps to activate end bearing

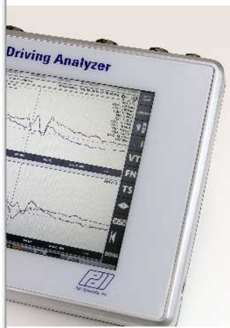
Built-up Section

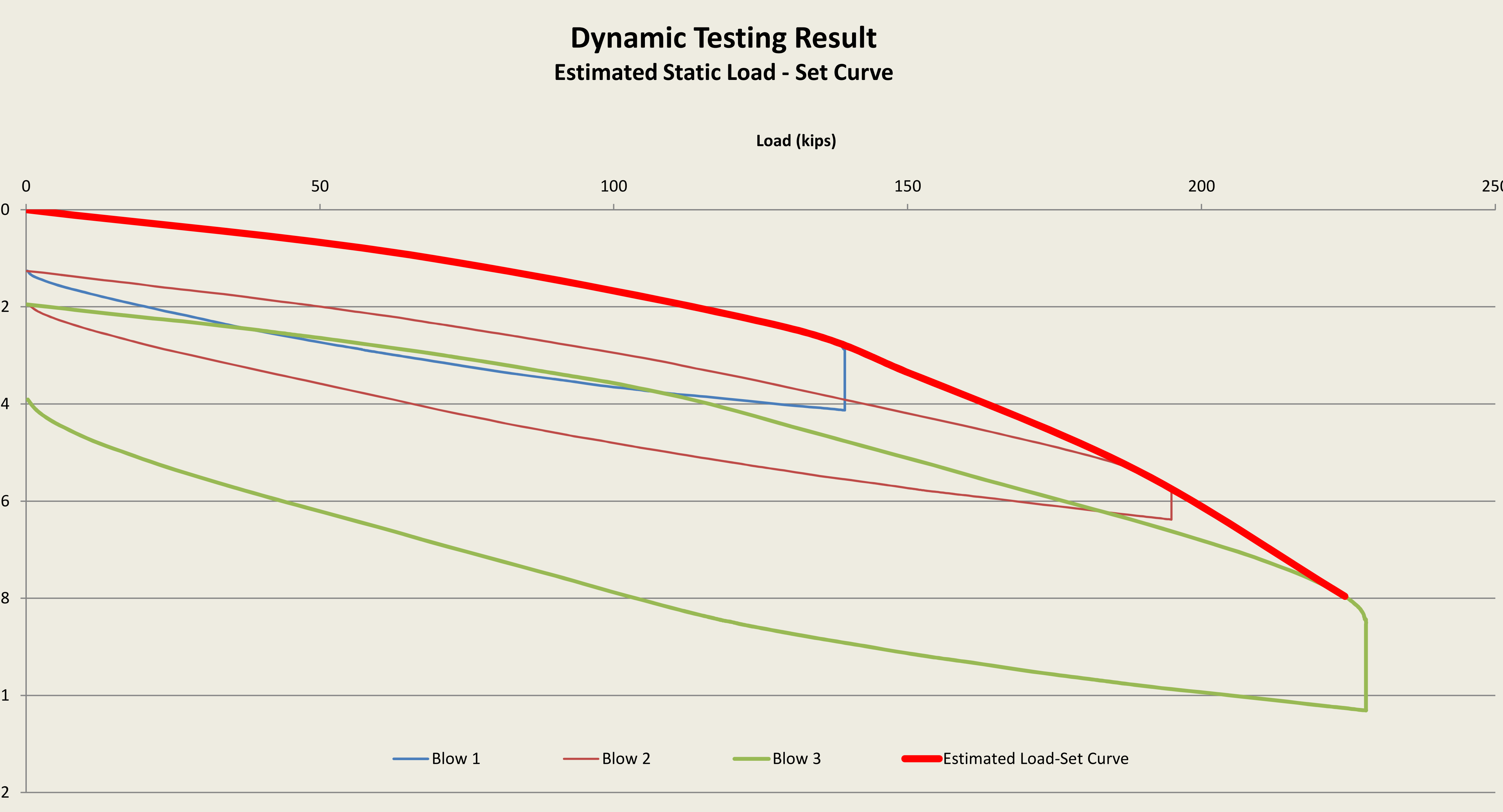
Use of Load Cell



Drilled Shaft Testing



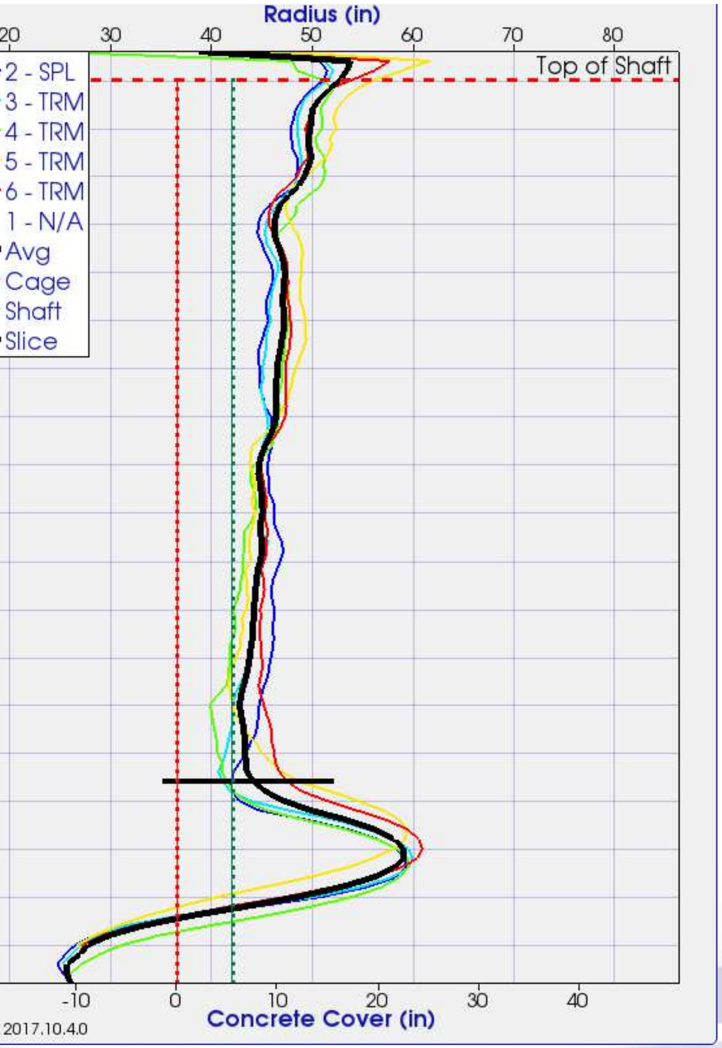




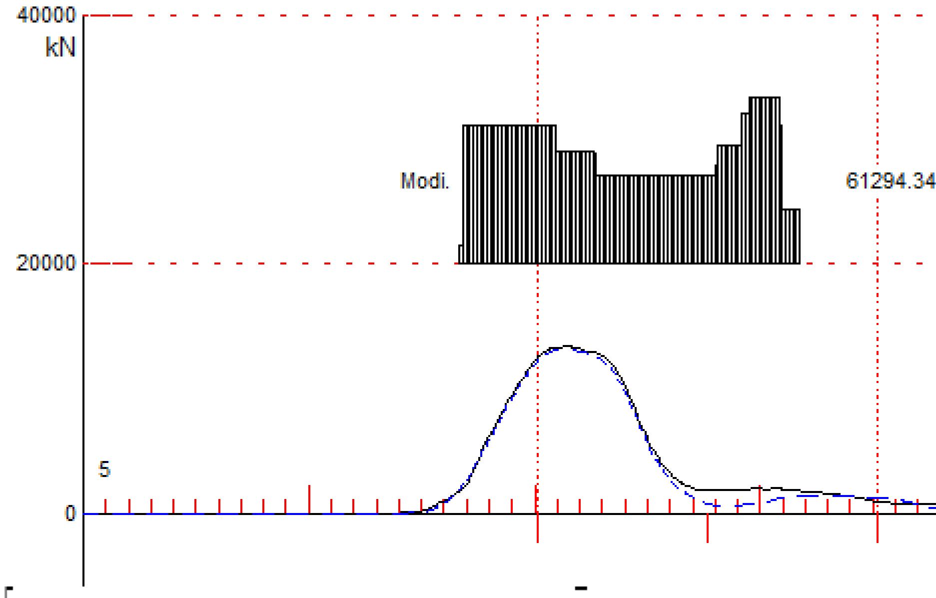
Dynamic Testing Result
Estimated Static Load - Set Curve
Load (kips)
0
50
100
150
200
250
0
2
4
6
8
1
2
Blow 1
Blow 2
Blow 3
Estimated Load-Set Curve

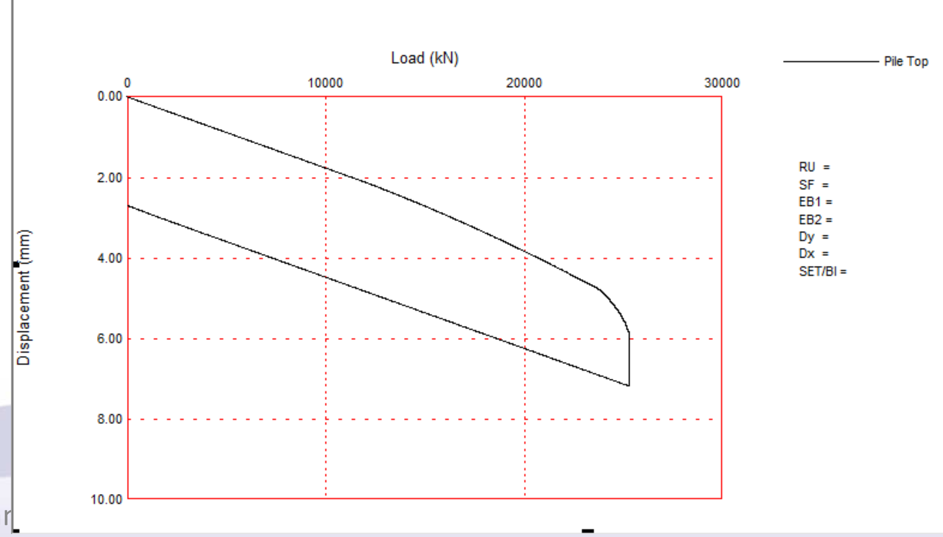
CAPWAP and TIP on a 2.1 m diameter drilled shaft

TIP Measurements



CAPWAP impedance





Conclusions

- TIP is being used frequently for testing drilled shafts and ACIP/CFA piles
- TIP can evaluate the entire cross-section including the area outside the reinforcing cage
- An acceptance criteria based upon cover and radius is possible with TIP
- The minimum cover specs for a project can be verified
- Dynamic Testing is being done regularly on Drilled Shafts
  - TOP Transducer eliminates errors due to unknown area and modulus
- When doing a dynamic test on a drilled shaft, TIP can provide additional information to help with the CAPWAP analysis

Thank You

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