THE OBSERVATIONAL METHOD AND DRILLED SHAFT ACCEPTANCE CRITERIA

Presented by:
Conrad W. Felice, Ph.D., P.E., P. Eng.
Ken Faught
Tim Kovacs, P.E.

LACHEL FELICE & Associates, Inc.
11411 NE 124th Street, Suite 275
Kirkland, WA 98034
Tel: 425-820-0800
Email: cfelice@lachel.com

September 25, 2007
Boise Centre on the Grove—Boise, ID

Observational Method

The Observational Methods in ground engineering is a continuous, managed, integrated, process of design, construction control, monitoring and review that enables previously defined modifications to be incorporated during or after construction as appropriate. All these aspects have to be demonstrably robust. The objective is to achieve greater overall economy without compromising safety

Presentation Outline

- Background
- Example projects
- Summary

Presentation Outline

Western Bridge Engineers' Seminar

- **Background**
- Example projects
- Summary

Background

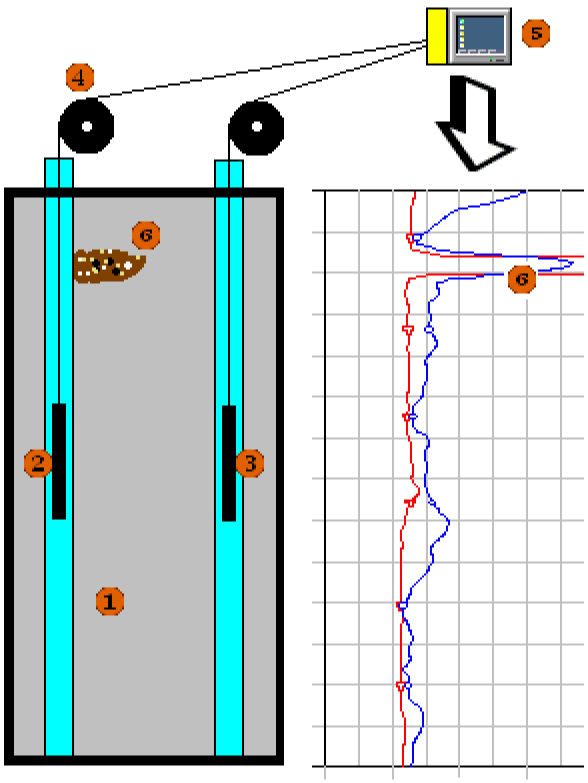
Quality assurance: Integrity testing

Purpose:

- **To verify the drilled shaft structural integrity**
- **To determine the extent and location of defects.**
  - **These defects include: internal voids, perimeter integrity, transverse cracks, soil intrusions, and weak concrete or grout.**

Background

Cross hole sonic logging



Integrity testing:
- In accordance with ASTM 6760
- Defect analysis and impact
- Foundation design
- Inspection
- Construction engineering
- Mitigation planning and design

Background

Ultrasonic wave propagation in an isotropic media

$$C = \sqrt{\frac{E(1-\nu)}{\rho(1+\nu)(1-2\nu)}}$$

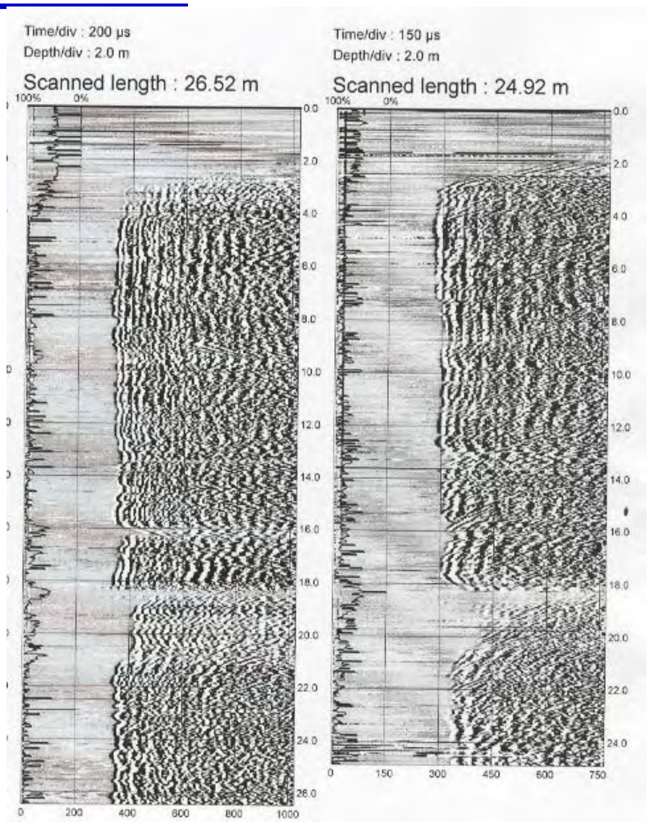
C: Stress wave speed
E: Young's modulus
ρ: Mass density of concrete
v: Poisson's ratio
t: travel time
L: Distance between transducers

$$t = \frac{L}{C} \Rightarrow t = \frac{L}{\sqrt{\frac{E(1-\nu)}{\rho(1+\nu)(1-2\nu)}}}$$

Background

Ultrasonic velocity ratings for concrete structures

Velocity (meters per second)	*Structure Condition*
4,575 and above	excellent
3,660 to 4,575	good
3,050 to 3,660	questionable
2,135 to 3,050	poor
below 2,135	very poor



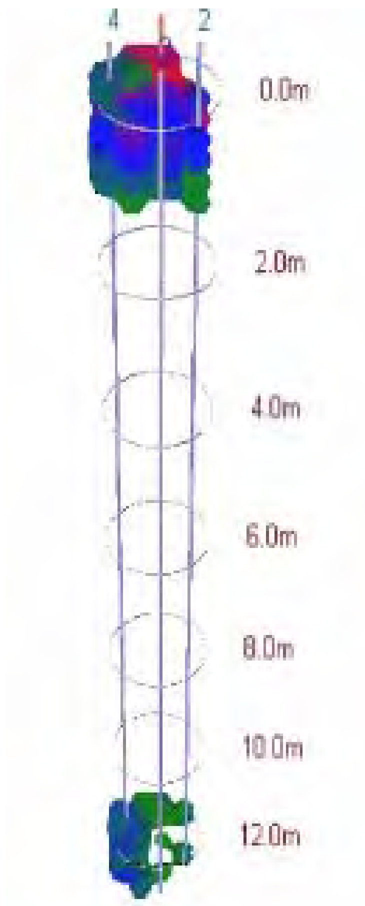
Bungey, J.H. (1980). "Validity of Ultrasonic Pulse Velocity Testing of In-Place Concrete for Strength," ***Nondestructive Testing International*****, Volume 13, No. 6, December.**

Background

Western Bridge Engineers' Seminar

Factors effecting CSL results

- **Measurement errors**
- **Concrete admixtures**
- **Curing temperatures**
- **Mix dependent**
- **Site conditions**
- **Construction means and methods**



Background

Concrete Condition Rating Criteria

Rating	CSL Results
Good (G)	No signal distortion or decrease in signal velocity of 10% or less from a measured signal velocity of nominally, 13,100 ft/s
Questionable (Q)	Minor signal distortion and a lower signal amplitude with a decrease in signal velocity between 10% and 20%. Results indicative of minor contamination, intrusion and/or questionable quality concrete.
Poor/Defect (P/D)	Severe signal distortion and much lower signal amplitude with a decrease in signal velocity of 20% or more. Results indicative of contamination, intrusion and/or poor quality concrete.
No Signal (NS)	No signal was received. Highly probable that an intrusion or other severe defect has absorbed the signal (assumes good bonding at the tube-concrete interface).
Water (W)	A measured signal velocity of nominally 5,000 ft/s. This is indicative of a water intrusion or of a water filled gravel intrusion with few or no fines present

Background

Definitions

- **Acceptance: The shaft has met the tolerances put forth in the specifications and based on construction observations and NDT results, the shaft is expected to perform as designed under service loads.**
- **Defect: An anomaly that can potentially weaken a shaft such that it will not perform as designed under service loads.**
- **Rejection: The Engineer will determine if a shaft if to be rejected based on the acceptance criteria. Rejection of a shaft is a consequence of inferior workmanship/construction practices, failure to meet specified tolerances or that a defect exists in the shaft which will result in inadequate or unsafe performance under service loads. Repairs and or an approved mitigation measures will be required.**
- **Unacceptable: During the approval process, questionable issues have been observed or recorded and are to be addressed by the contractor. A decision that a shaft is unacceptable will be based on an integrated process of construction observations and NDT results.**

Background

Western Bridge Engineers' Seminar

Definitions

- Acceptance: The shaft has met the tolerances put forth in the specifications and based on construction observations and NDT results, the shaft is expected to perform as designed under service loads.
- Defect: An anomaly that can potentially weaken a shaft such that it will not perform as designed under service loads.
- Rejection: The Engineer will determine if a shaft if to be rejected based on the acceptance criteria. Rejection of a shaft is a consequence of inferior workmanship/construction practices, failure to meet specified tolerances or that a defect exists in the shaft which will result in inadequate or unsafe performance under service loads. Repairs and or an approved mitigation measures will be required.
- Unacceptable: During the approval process, questionable issues have been observed or recorded and are to be addressed by the contractor. **A decision that a shaft is unacceptable will be based on an integrated process of construction observations and NDT results.**

Background

Decisions

- **Anomaly/Flaw: Unusual patterns, a quantity that indirectly measures voids or soft spots in the concrete. Could be a structural defect.**

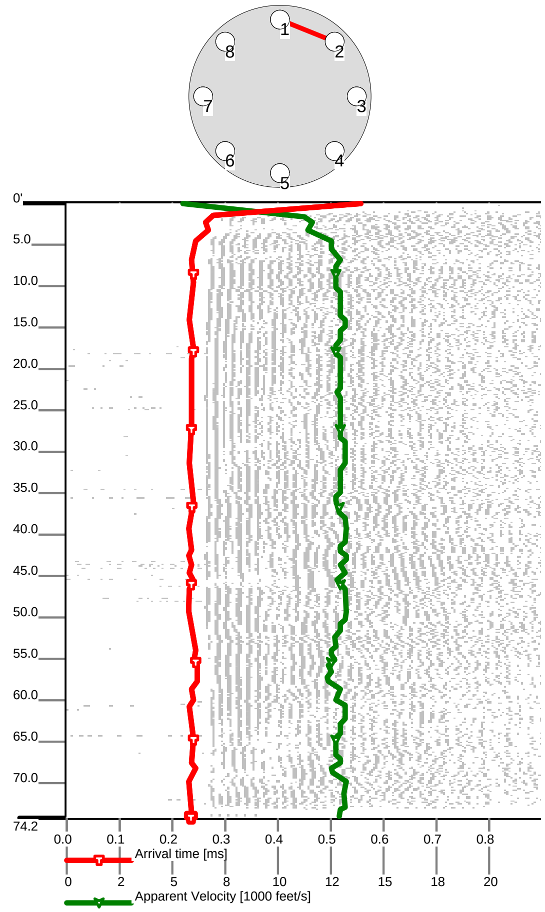
- **Defect: An anomaly that can potentially weaken a shaft such that it will not perform as designed under service loads.**

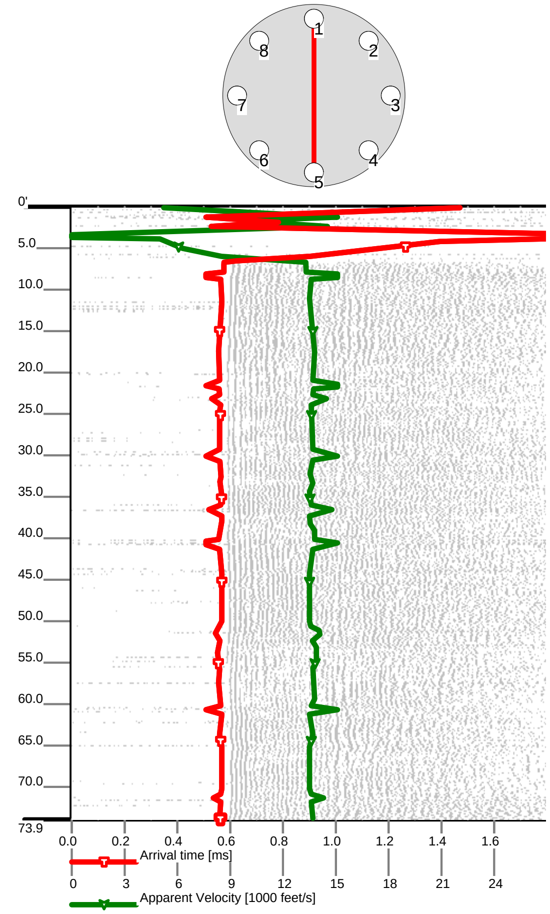
Presentation Outline

Western Bridge Engineers' Seminar

- Background
- **Example projects**
- Summary

Example project

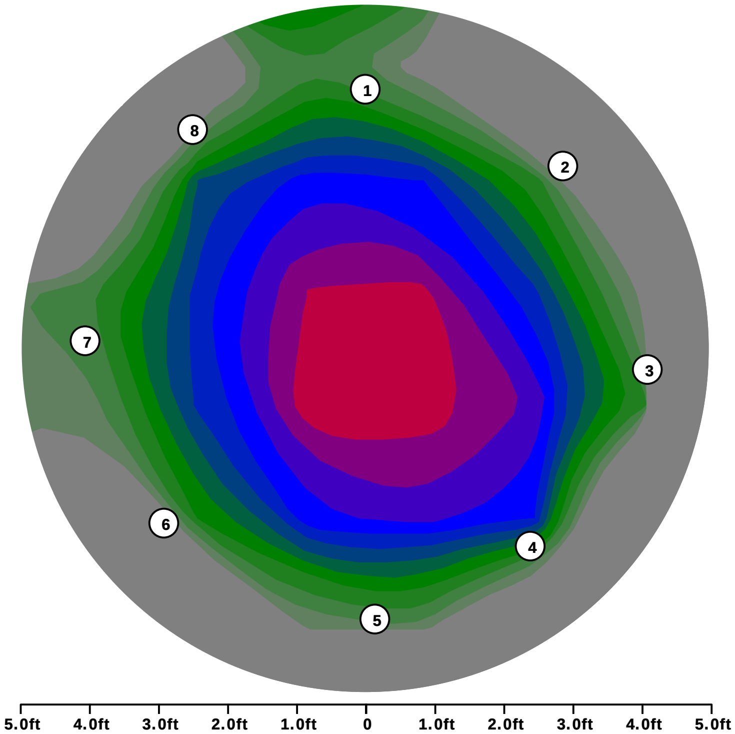




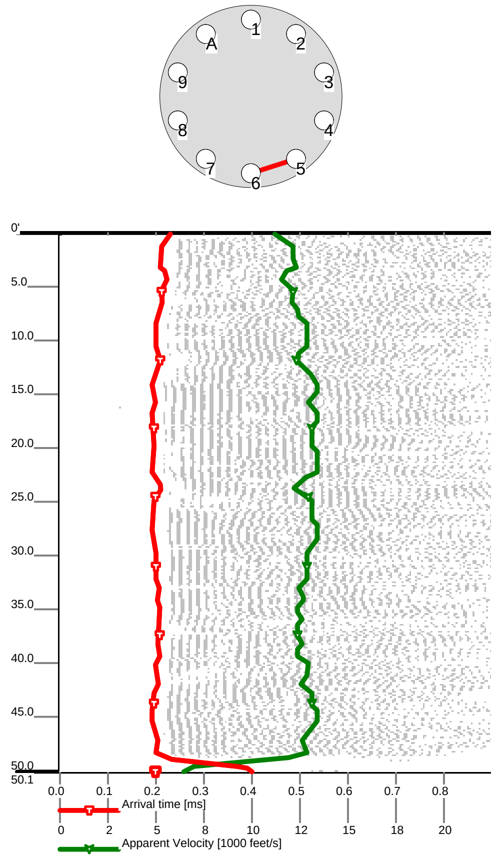
Drilled shaft parameters

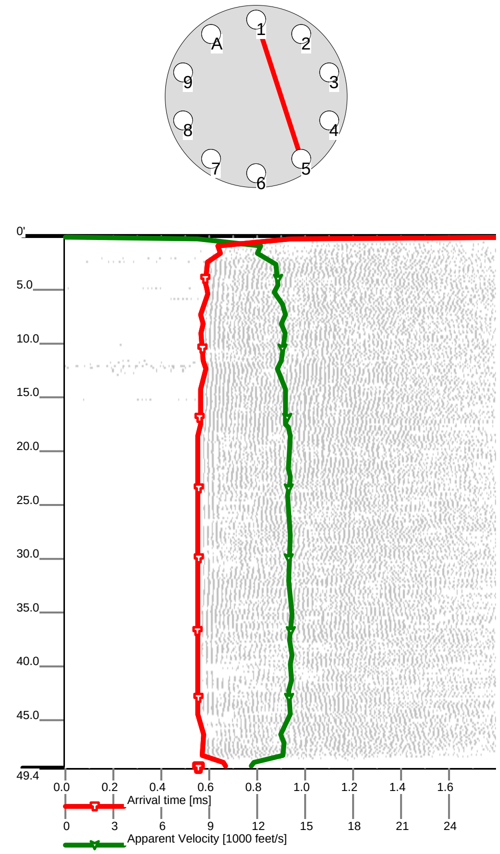
- Diameter: 10 ft
- Length: 72 feet
- Method: Oscillator
- Concrete strength: 4,000 psi
- End bearing (rock socket)

Example project



Example project: How many profiles are enough?



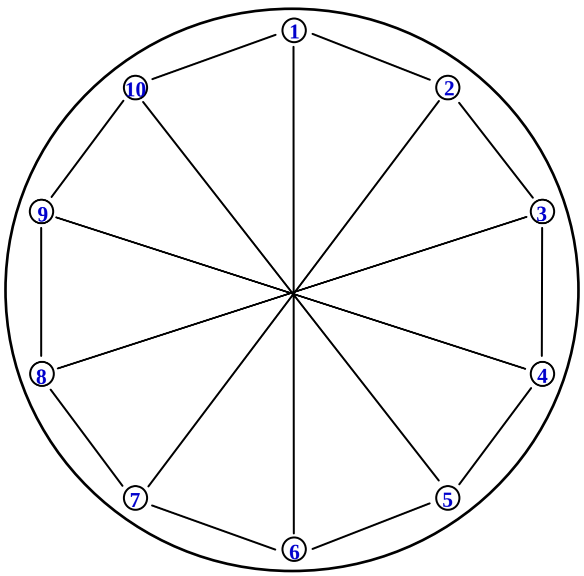


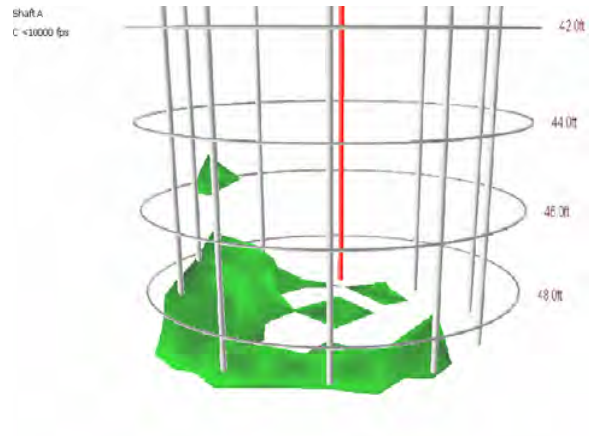
<u>Drilled shaft parameters</u>

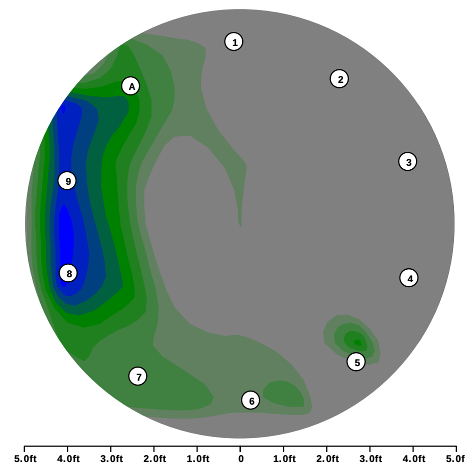
- **Diameter: 10 ft**
- **Length: 49 feet**
- **Method: Auger**
- **Concrete strength: 4,000 psi**
- **End bearing in glacial till**

Example project: How many profiles are enough?

Standard test pattern (15 profiles)



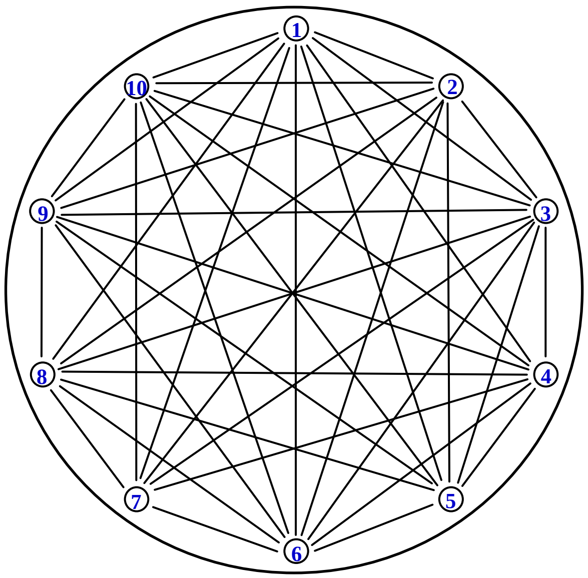


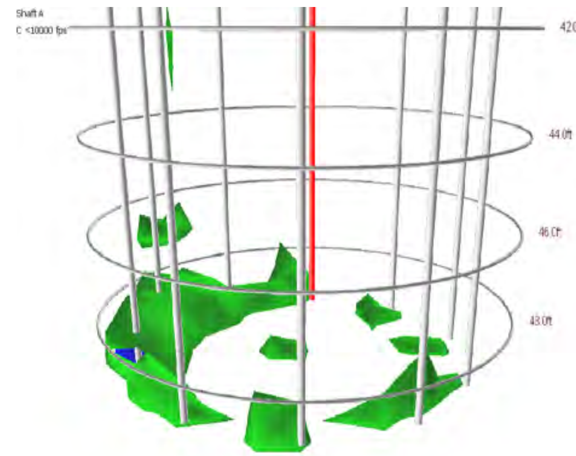


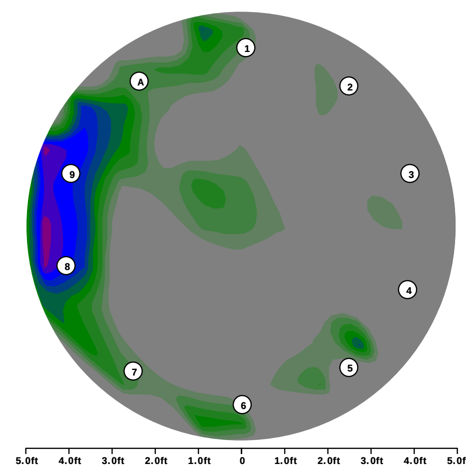
Horizontal view is at 48.5 ft. depth

Example project: How many profiles are enough?

All possible profiles (45 ea)



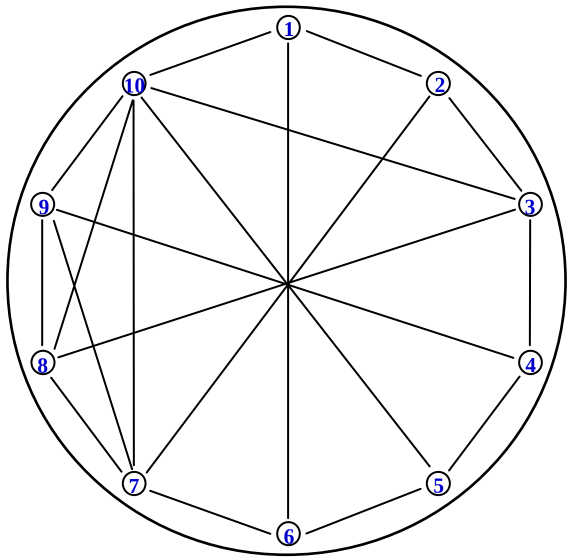


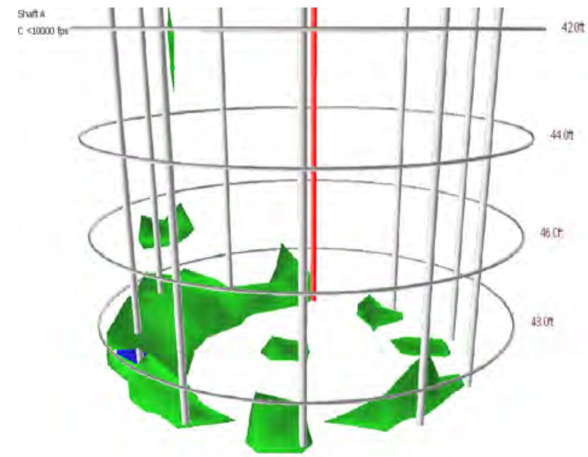


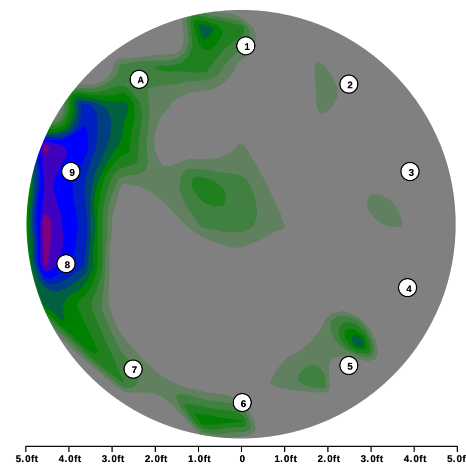
Horizontal view is at 48.5 ft. depth

Example project: How many profiles are enough?

Standard pattern plus four selected profiles (19 ea)

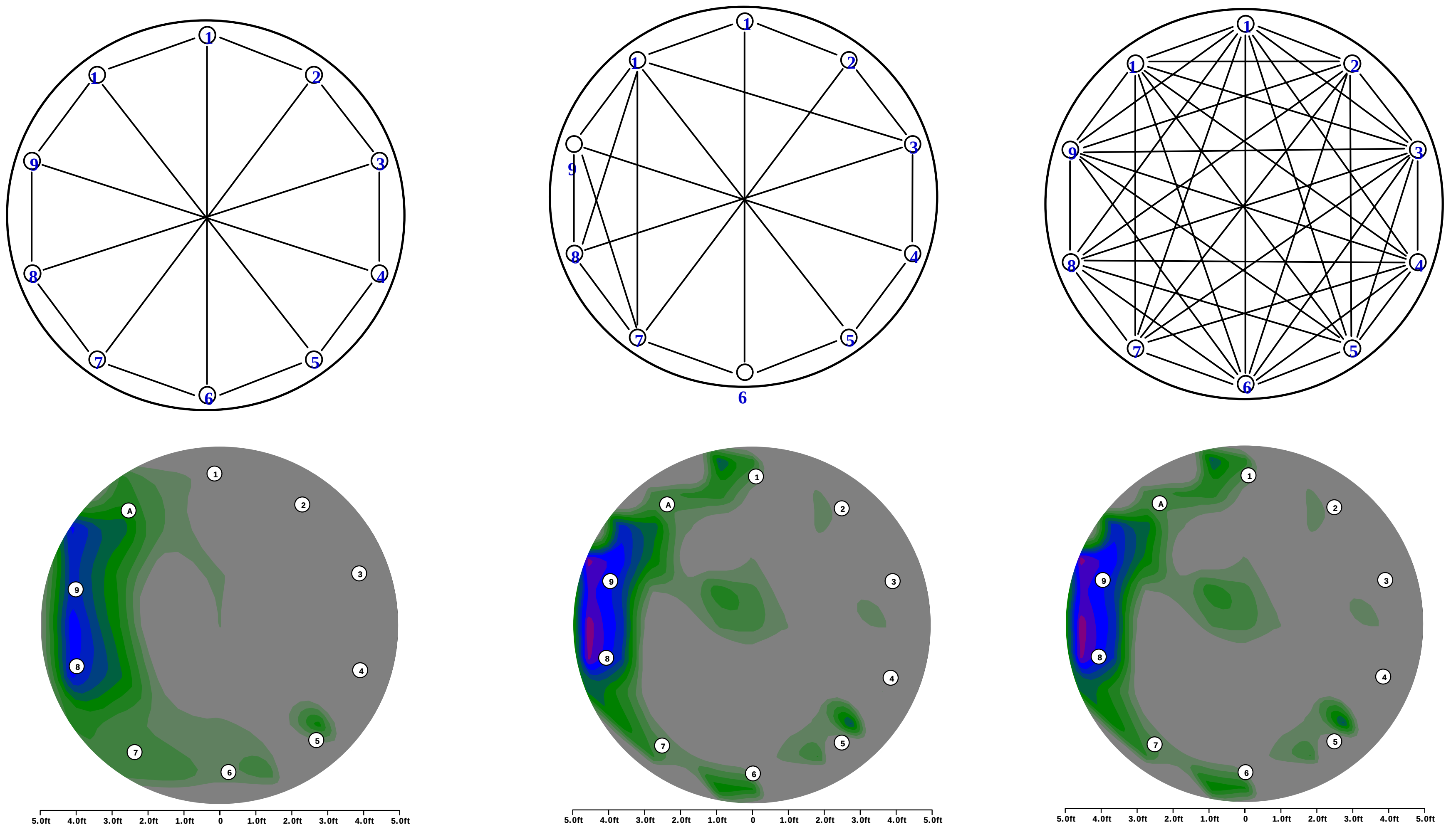






Horizontal view is at 48.5 ft. depth

Example project: How many profiles are enough?



Example project: How many profiles are enough?

Recommendation

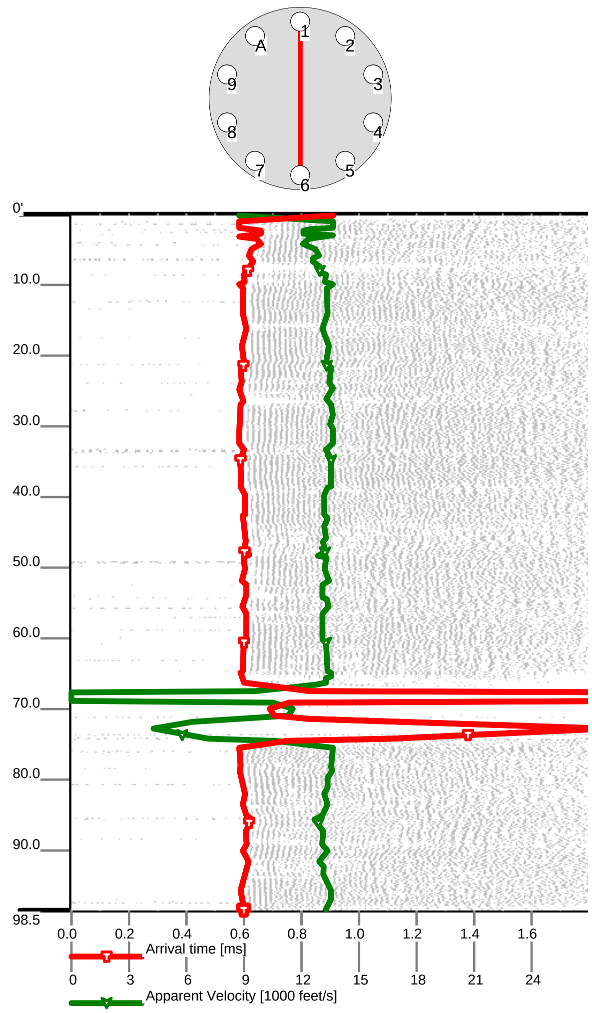
Minimum specification:

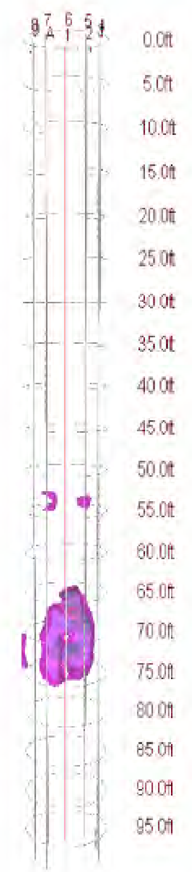
- **Perimeter profiles**
- **Major diagonals**
- **As needed**
  - **Select additional profiles to testing based on initial data**
  - **Tomography**

Example project: Remediation

Drilled shaft parameters

- Diameter: 10 ft
- Length: 96 feet
- Method: Oscillator
- Concrete strength: 4,000 psi
- Artesian conditions
- End bearing

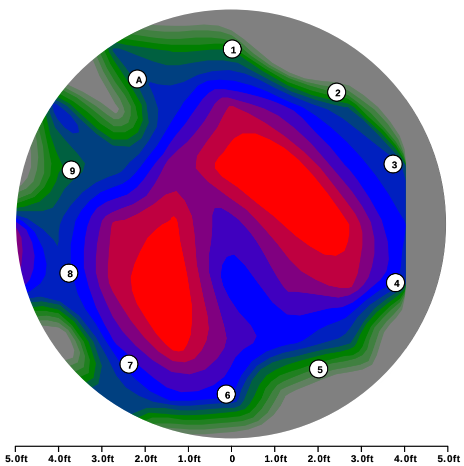


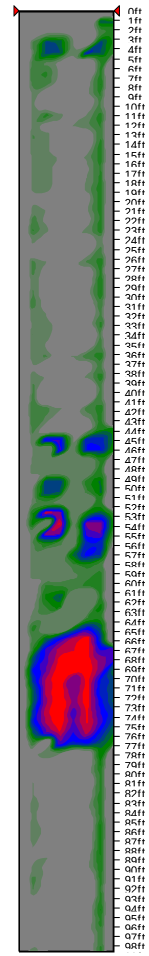


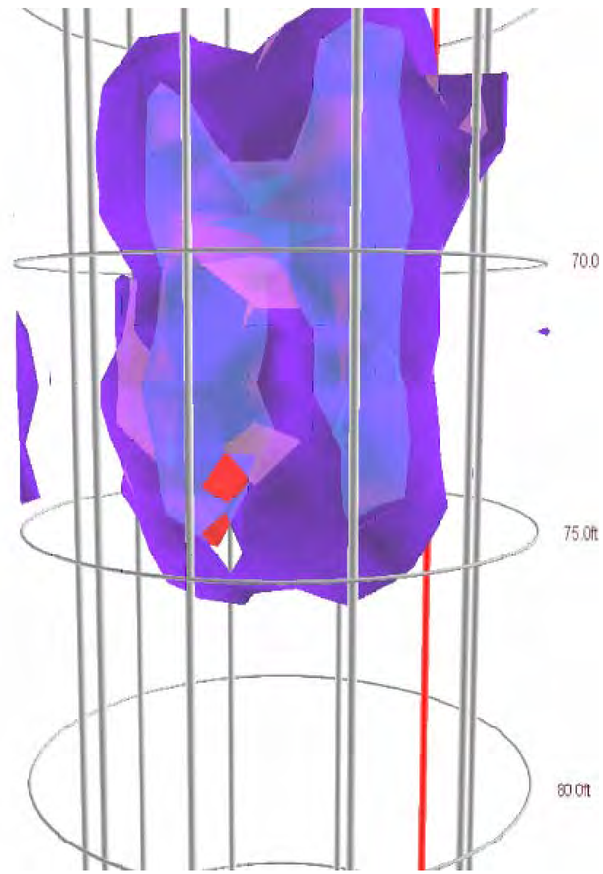
Example project: Remediation

Remedial actions

- Core to confirm
- Washing and flushing
- Mini-pile installation
- Pressure grouting





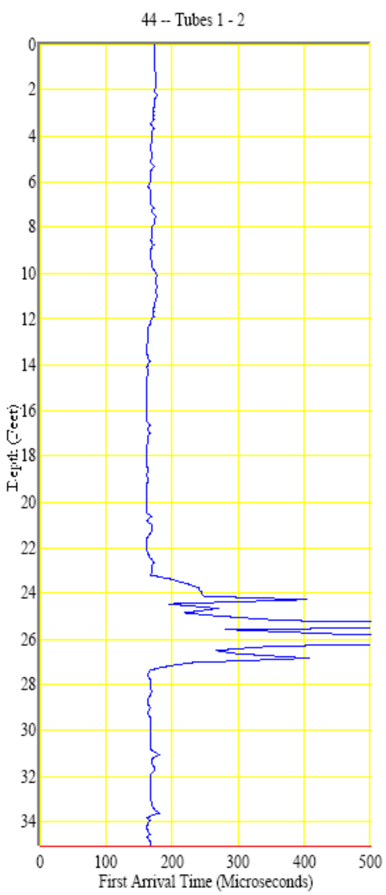


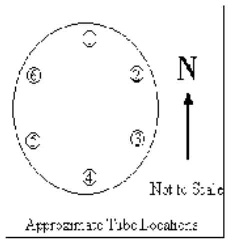
Example project

<u>Drilled shaft parameters</u>

- **Diameter: 6 feet**
- **Length: 35 feet**
- **Method: Auger**
- **Concrete strength: 4,500 psi**
- **Rock socket**

Example project





Tube Spacing :	29.50	inches
Signal Gain :	200	
Threshold :	1.50	
At Depth of	2.02	ft
Velocity	14100	ft/sec
First Arrival Time	174	us
Signal Energy	501.76	V-us

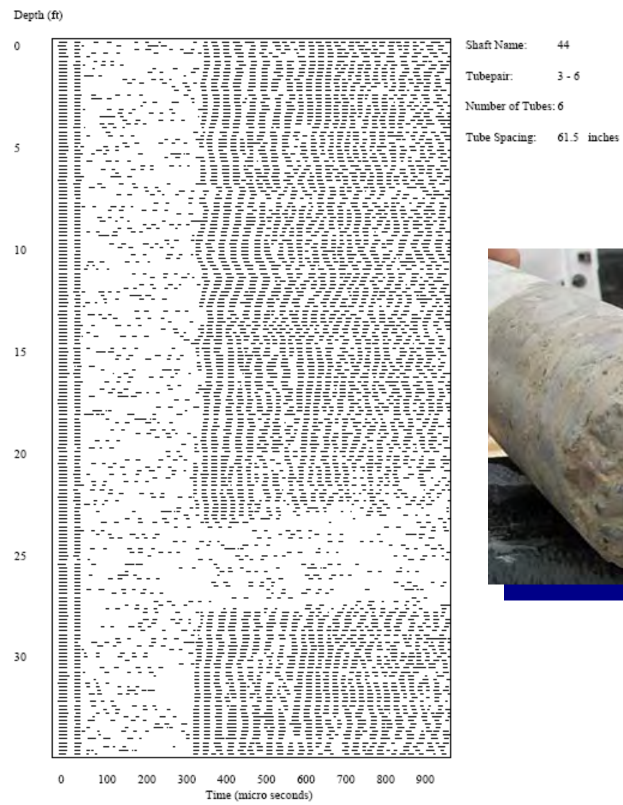
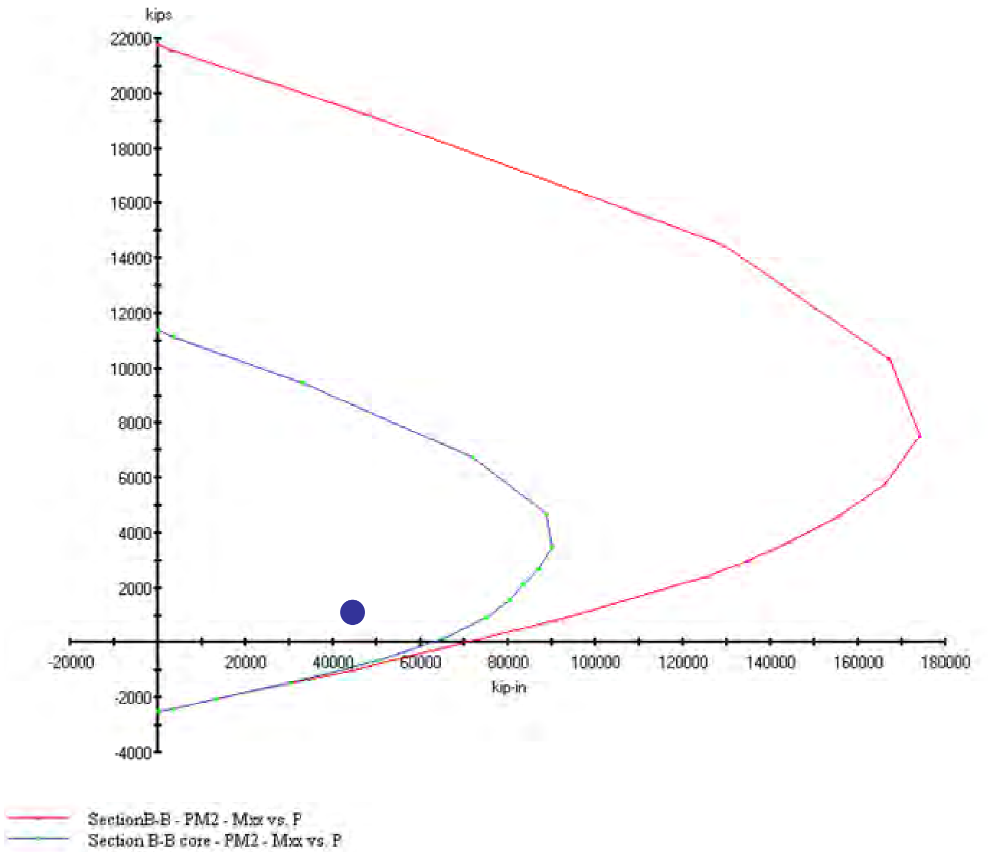
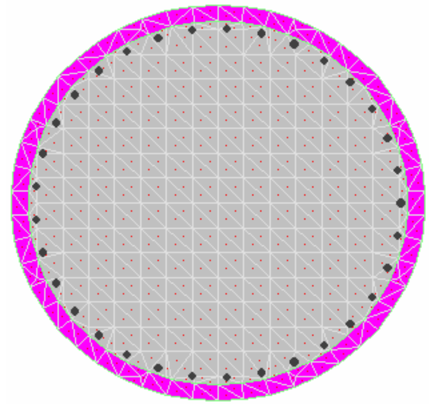


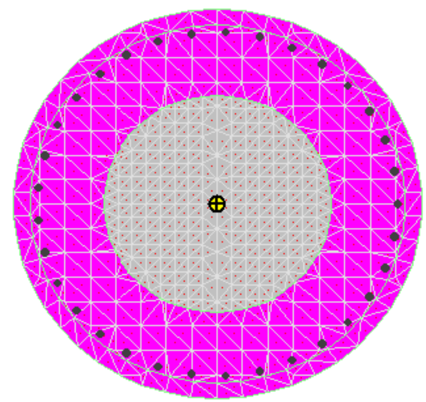
Figure A.0

Example project





As-designed



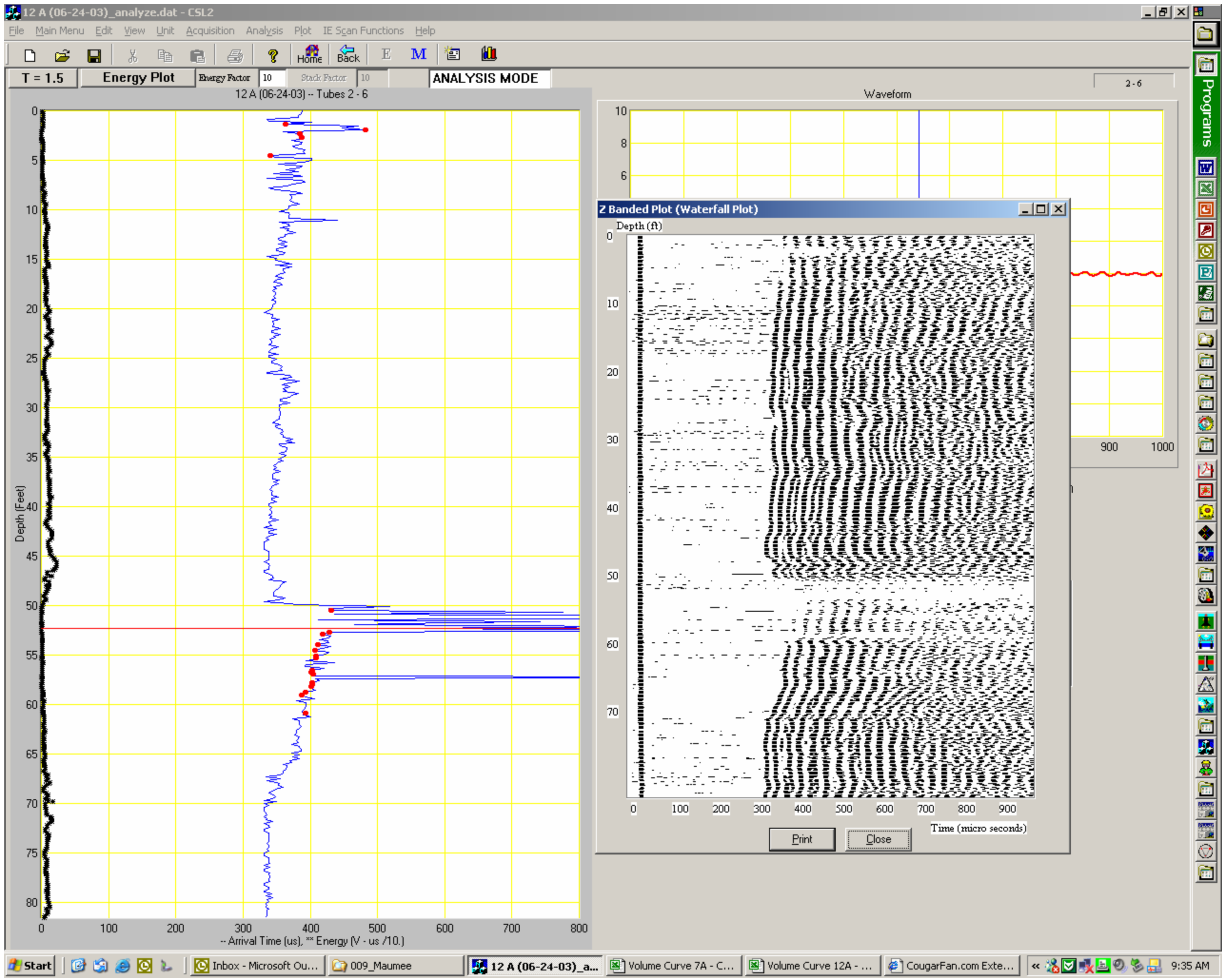
As-constructed

Example project

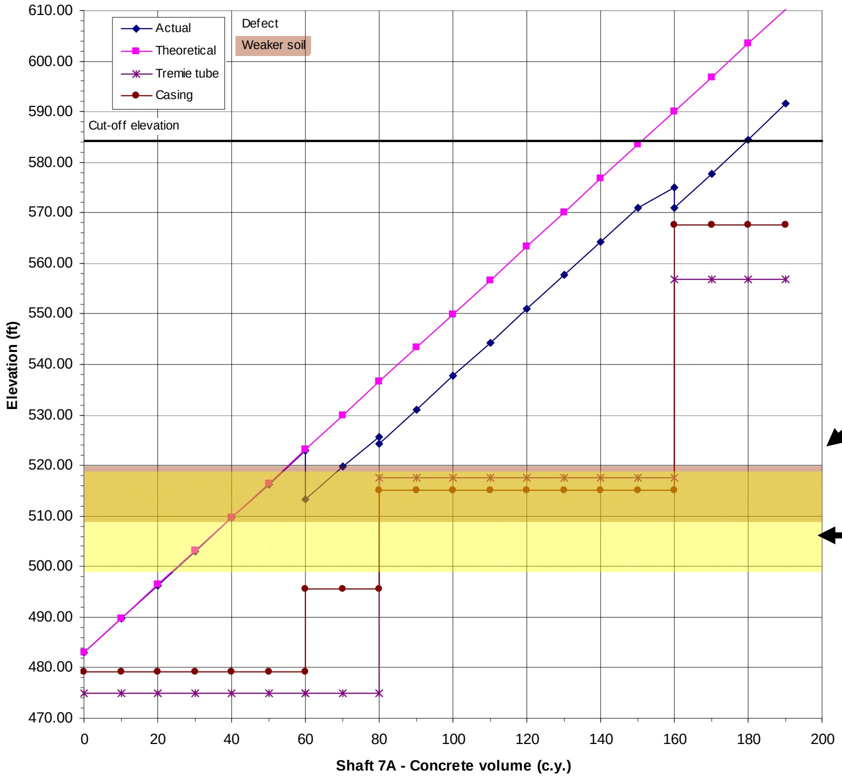
Drilled shaft parameters

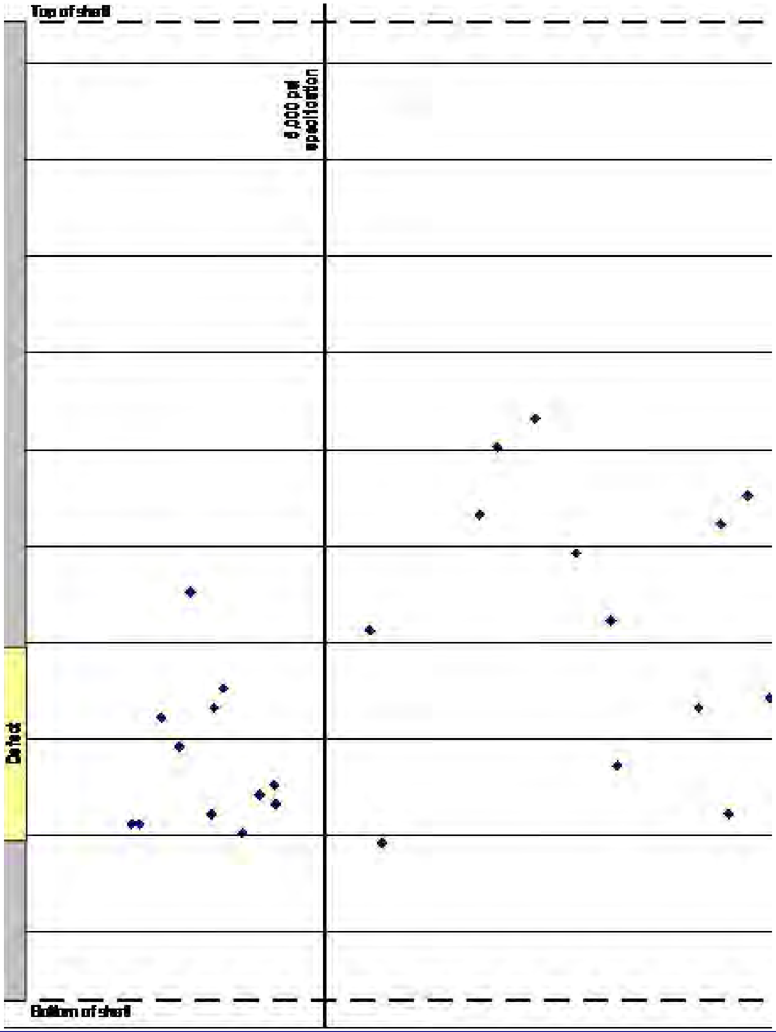
- **Diameter: 7-8 ft.**
- **Length: 100 ft.**
- **Method: Oscillator**
- **Concrete strength: 5000 psi**
- **End bearing on fractured rock**

Example project



Example project





Presentation Outline

Western Bridge Engineers' Seminar

- Background
- Example projects
- **Summary**

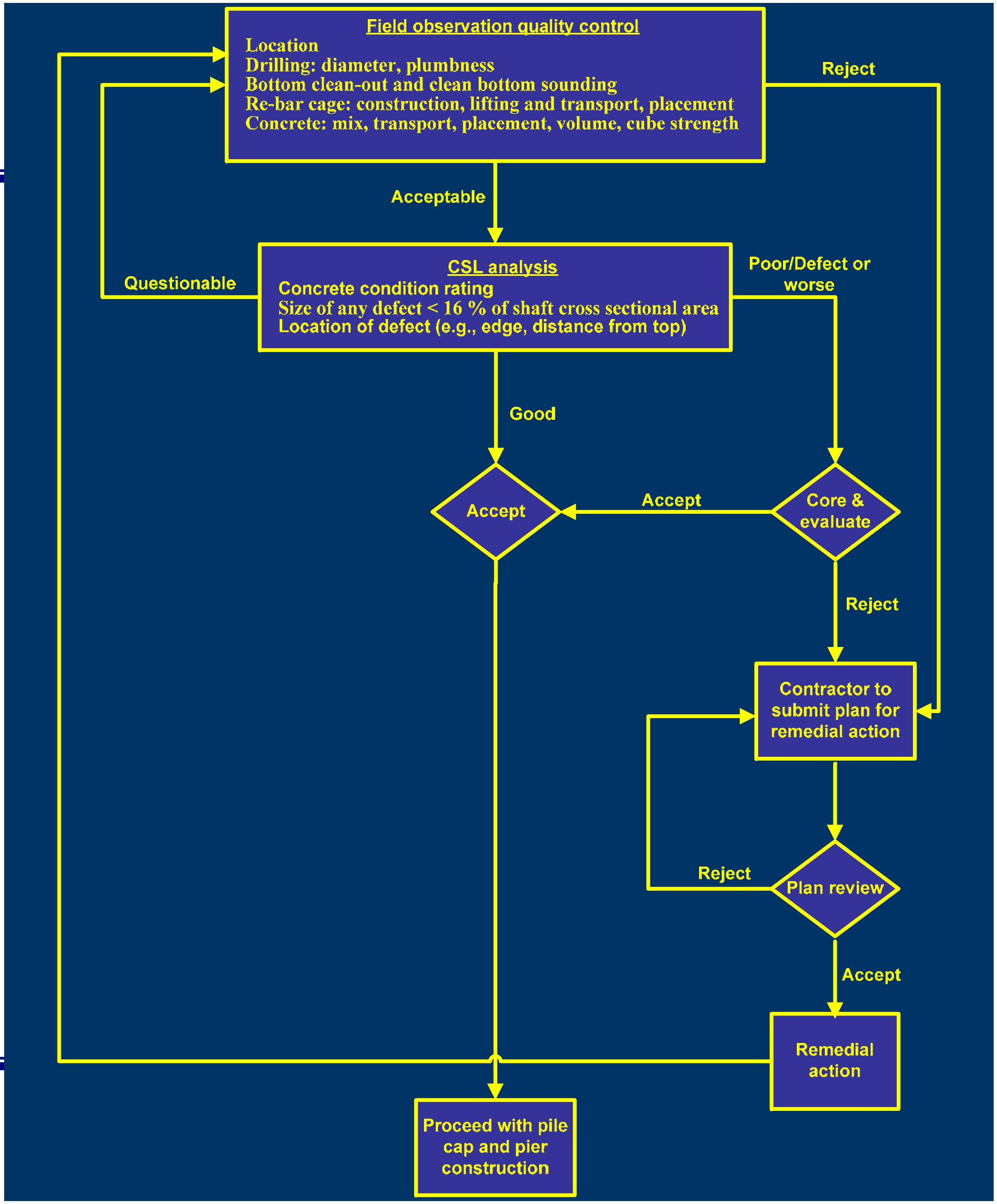
Summary

General statistics

Condition	Number of shafts	Percentage
Accepted without comment	727	91%
Accepted with anomaly	51	6%
Accepted after repairs	21	3%
Total	799	100%

Summary

Acceptance process

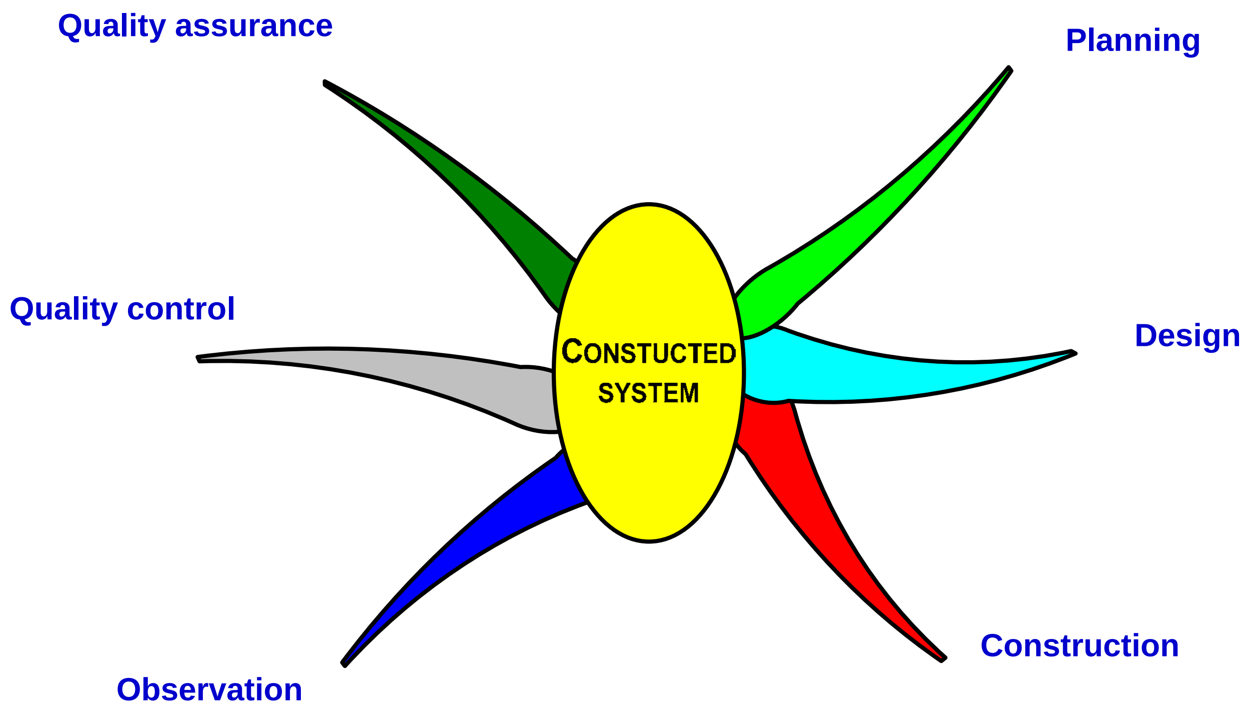


LACHEL FELICE & Associates
Geotechnics, Foundations, Underground Structures

Systems perspective: Observational Method

Team

- Owner
- Designer
- Contractor



Summary

The Direction of Our Profession

"Construction deserves more attention in design." (Peck, 1973)

Summary

- **Apply the observational method**
- **Not every observed anomaly is a defect that must be repaired**
- **Demand complete construction records**
- **NDT should be treated as part of the system**
- **Tools are available to assess the impact of anomalies on capacity**
- **Owners and designers should place more value on integrity testing technique and thereby avoiding overly conservative foundation systems.**

Western Bridge Engineers' Seminar
Practical Solutions for Today's Challenges in Bridge Engineering

Western Bridge Engineers' Seminar

Questions

LACHEL FELICE & Associates, Inc.
Kirkland, Washington
www.lachel.com

LACHEL FELICE & Associates
Geotechnics, Foundations, Underground Structures

Geotechnics, Foundations, Underground Structures