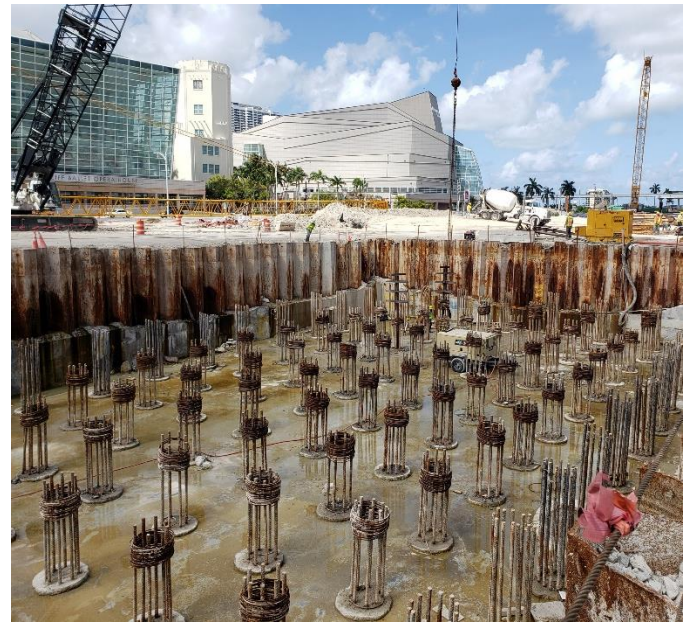# Estimating the As-Placed Grout Volume of Auger Cast Piles
BED25-977-04

GRIP 2023

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Auger Cast Piles

Auger cast piles are constructed using a full-length auger, providing excavation stability without using mechanical or hydrostatic support.

Once drilled, grout (sand, cement, water mix) is pumped through the hollow auger stem during auger extraction to create a continuously grouted column.

Image source: (**left**) Geotechnical Engineering Circular (GEC) No. 8 (2007) (**right**) FDOT

Installation Process

(A) drilling (B) grouting (C) pile grouting complete and (D) reinforcement cage placement

Image source: Adapted from Geotechnical Engineering Circular (GEC) No. 8 (2007)
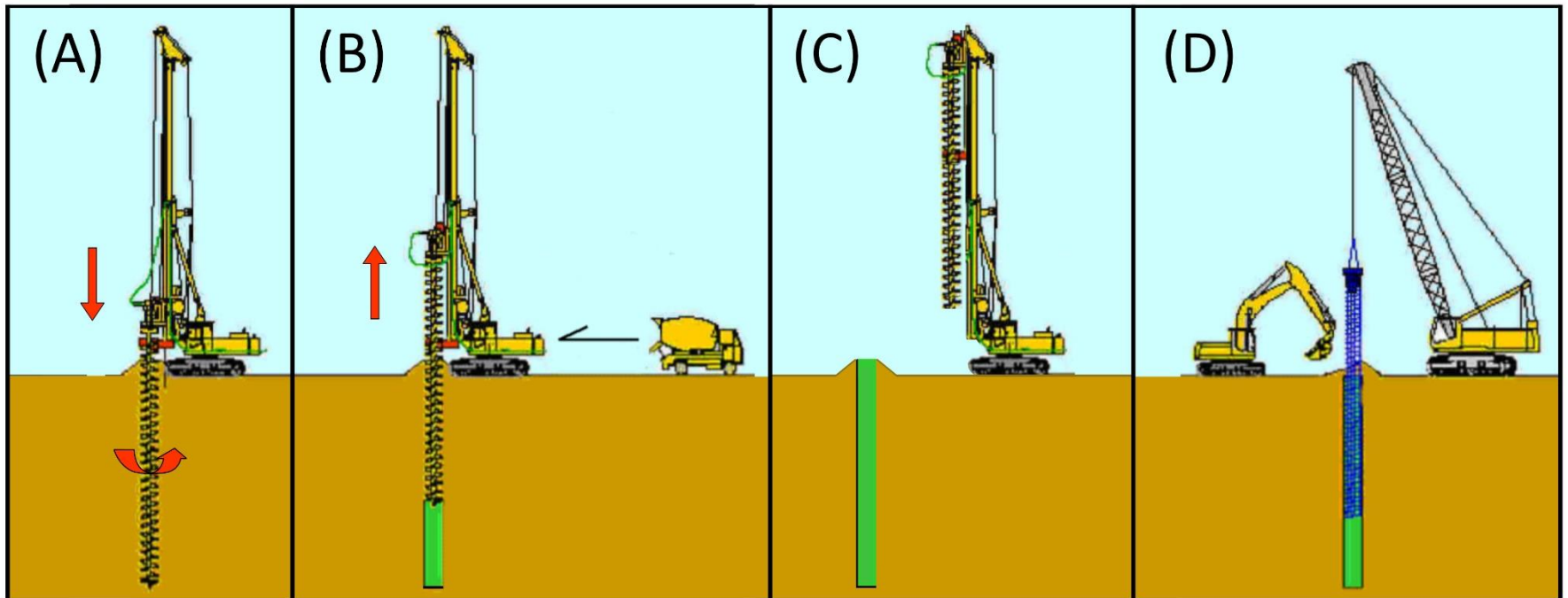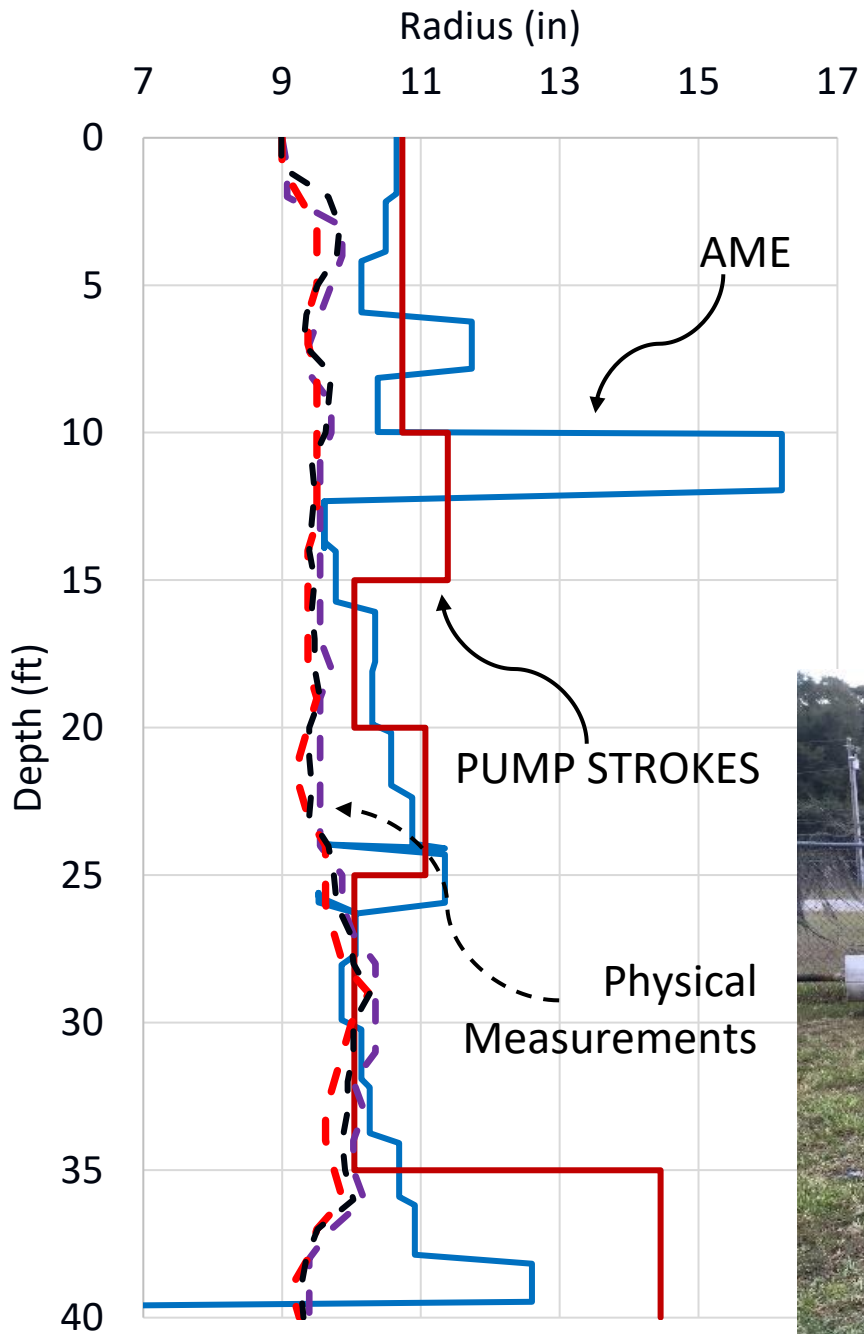
Grout Volume Monitoring

Grout volume is monitored by **(1)** a magnetic flow meter and **(2)** counting pump strokes and using pump calibration (cuft/stroke)

Image source: **(left)** ACIP Pile Installation Monitoring, Full-scale Load Testing, and Extraction program – DFI (2017) and **(right)** Geotechnical Engineering Circular (GEC) No. 8 (2007)

Pumped volume vs measured pile size

Grout Volume Definitions

- **Volume 1:** Priming Volume, grout volume required to prime grout pump, fill all hoses, and fill the hollow auger stem.

- **Volume 2:** Initial Head Volume, grout head required by FDOT 2020 Standard Specifications for Road and Bridge Construction, Section 455-44.2. Volume equivalent to the corresponding volume of 20ft of pile length or 20% of total pile length (5ft or 10% for non-bridge foundations).

- **Volume 3:** Incremental Volume, 115% volume pumped into excavation as auger is extracted for each 5ft to ensure uniform grout distribution throughout the length of the pile. Volume 3 tracking ends at the moment of grout return.

- **Volume 4:** Finishing Volume, the grout volume pumped after grout return including a portion of finished pile volume and grout wasted at the ground surface as grout continues to be pumped as the auger is extracted after the time of grout return.

How can auger cast pile volume be calculated?

$$Pile\ Volume = Vol\ 2 + Vol\ 3 + Portion\ of\ Vol\ 4$$

- $Portion\ of\ Vol\ 4 = AFF * \pi r^2 L_{return}$

- $Pile\ Volume = Vol\ 2 + Vol\ 3 + AFF * \pi r^2 L_{return}$

$where: L_{return} = return\ depth$

$$AFF = Auger\ Fill\ Factor$$

Auger Fill Factor (AFF)

PORTION OF RETURN DEPTH EXCAVATION VOLUME ALREADY TRACKED

SOIL CUTTINGS

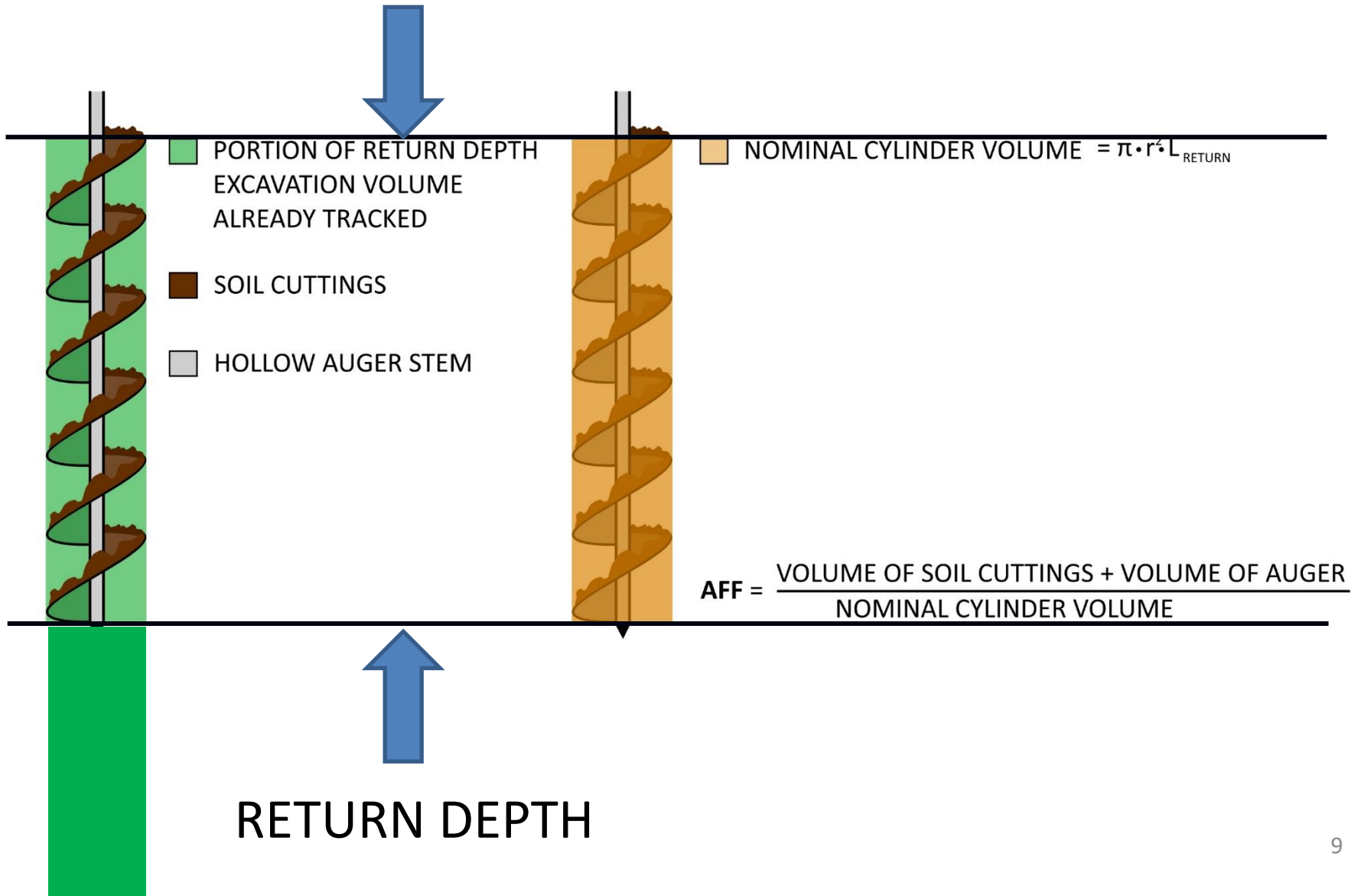HOLLOW AUGER STEM

NOMINAL CYLINDER VOLUME $= \pi \cdot r^2 \cdot L_{RETURN}$

$$AFF = \frac{VOLUME\ OF\ SOIL\ CUTTINGS + VOLUME\ OF\ AUGER}{NOMINAL\ CYLINDER\ VOLUME}$$

8

Auger Fill Factor (AFF)

PORTION OF RETURN DEPTH EXCAVATION VOLUME ALREADY TRACKED

NOMINAL CYLINDER VOLUME $= \pi \cdot r^2 \cdot L_{RETURN}$

SOIL CUTTINGS

HOLLOW AUGER STEM

$$AFF = \frac{VOLUME\ OF\ SOIL\ CUTTINGS + VOLUME\ OF\ AUGER}{NOMINAL\ CYLINDER\ VOLUME}$$

RETURN DEPTH

$$AFF = \frac{Volume_{Auger+soil}}{\pi r^2 L_{Return}} = \frac{\pi r^2 h}{\pi r^2 L_{Return}}$$

$$= \frac{h}{L_{Return}}$$
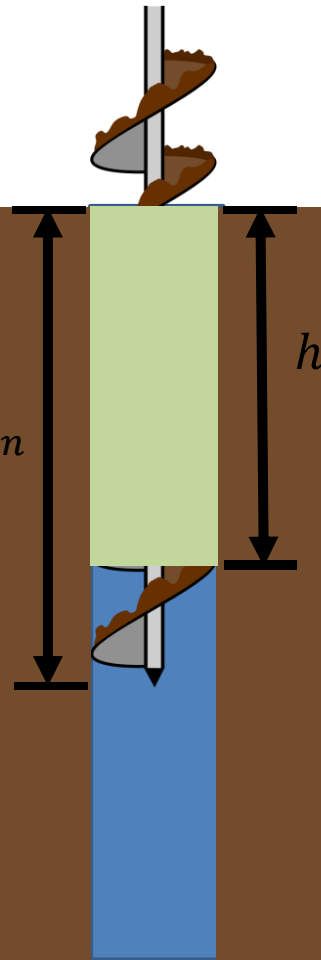
Types of soil adhesion

Soil cuttings adhere to auger stem

Hybrid soil cling mode

Soil cuttings sit on auger flights

Problem Statement

- Despite advances in grout volume monitoring systems and increased details in field inspection logs, the as-built volume of grout in the excavation remains largely unknown.

Objectives

- To obtain field data from ACIP pile projects to better correlate the measured grout volume to the as-built pile dimensions.
- To develop a more reliable method for estimating grout volume by identifying the variables that affect pile volume other than the simplistic approaches used to date.
  - Variables are likely to include but are not limited to: soil type, construction means/methods, and types of equipment.

Work Tasks

- Task 1: Previously Collected Data
- Task 2: Collection of New Data
- Task 3: Data Analysis
- Task 4a: Draft Final Report
- Task 4b: Closeout Meeting / Presentation
- Task 5: Final Report

Auger cast installation data received from the I-395/SR 836/I-95 expansion in Miami, FL.

Image source: (**left & right**) FDOT & Miami-Dade Expressway Authority (MDX 2017)
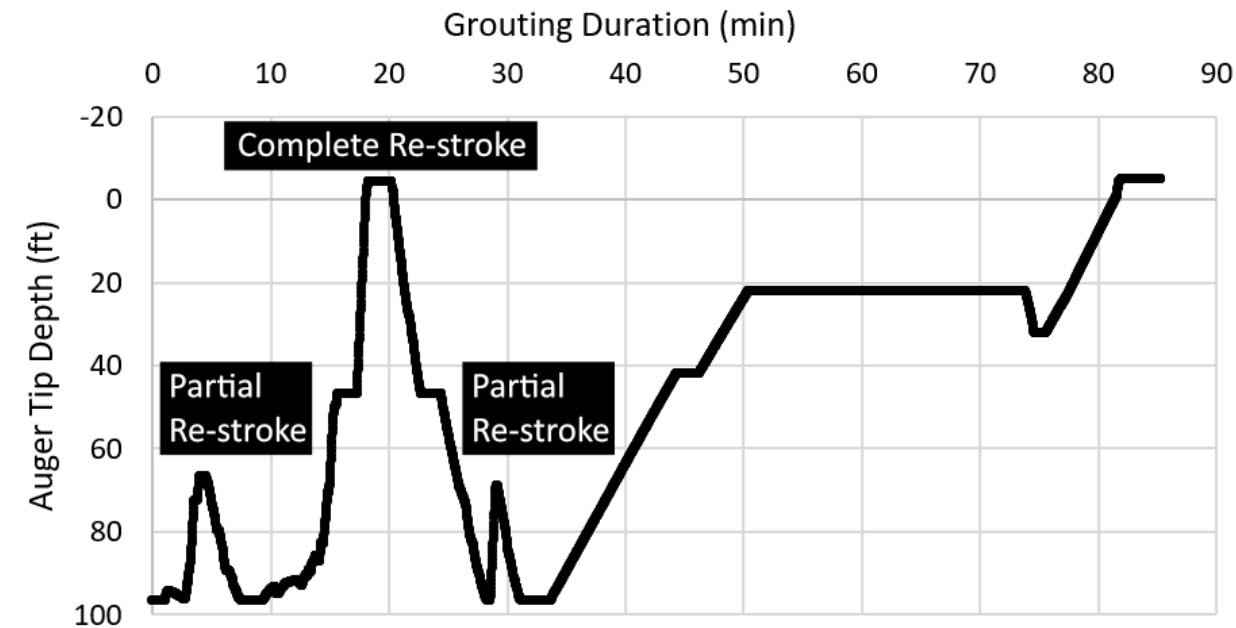
Analysis Performed

- Identification and recording of partial and complete auger re-stroking where pile excavation is left unsupported.

- Comparison of grout volumes as measured by **(1)** counting pump strokes (using corresponding cuft/stroke) and **(2)** magnetic flow meter measurements recorded by AME.
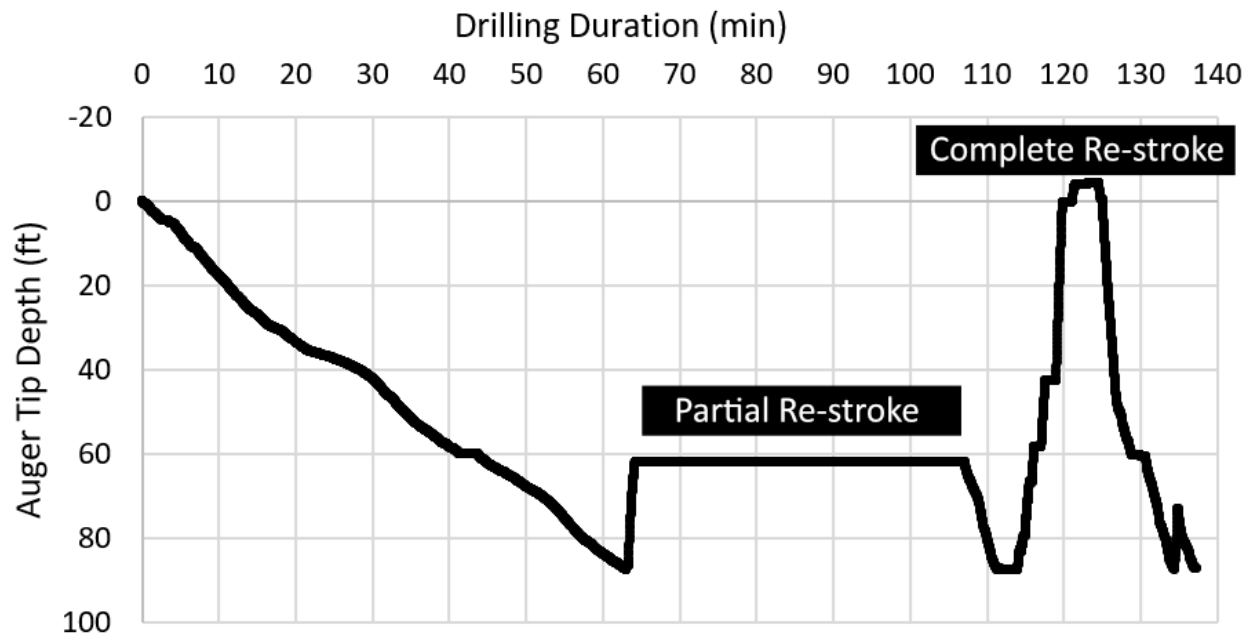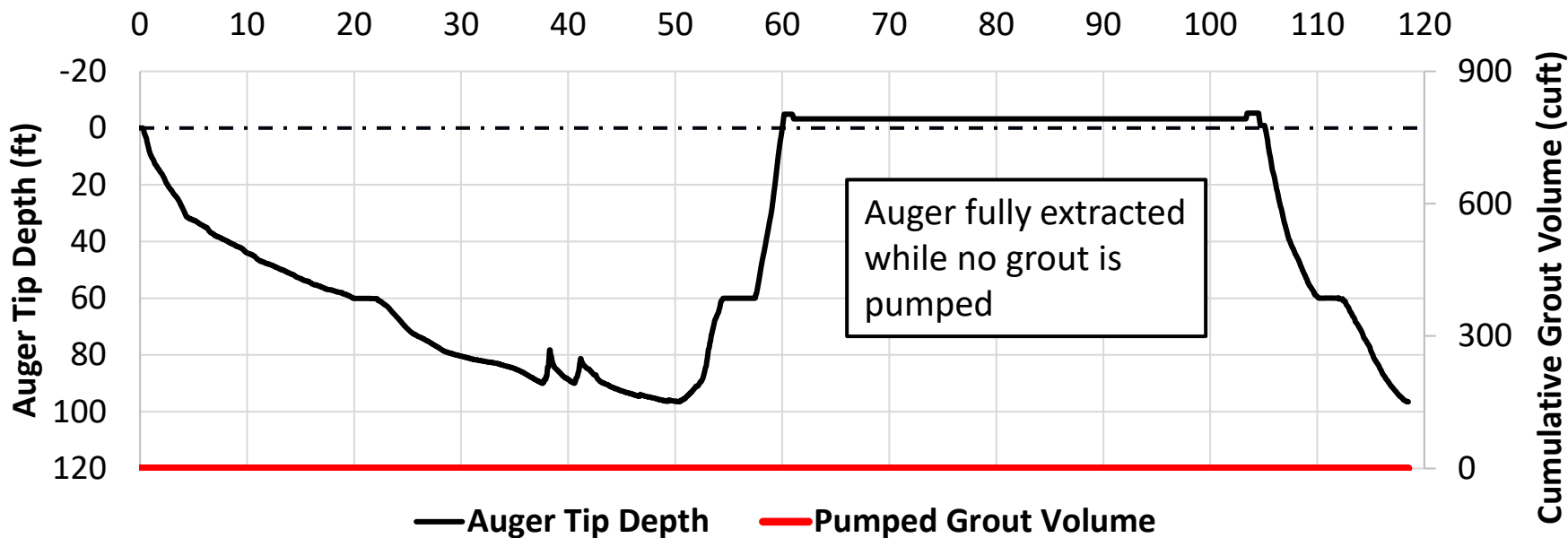
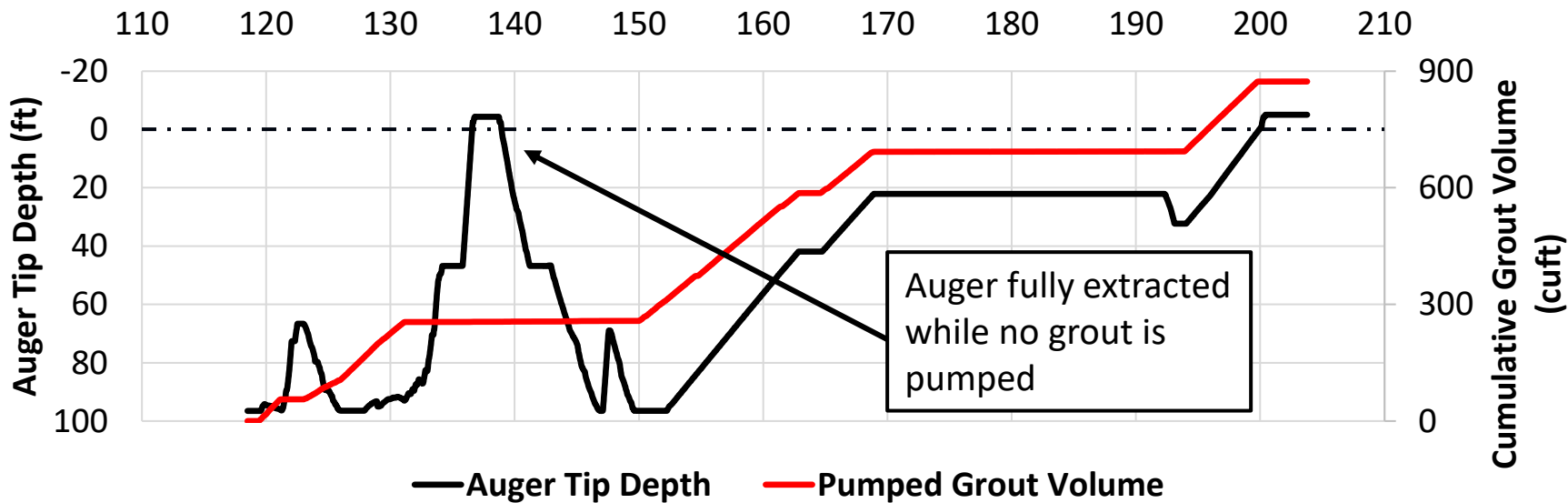Example partial and complete re-strokes, where excavation is unsupported.

Of 386 auger cast piles analyzed, 59.6% had at least one re-stroke.

Drilling: Time (min)

Auger Tip Depth (ft) / Cumulative Grout Volume (cuft)

Auger fully extracted while no grout is pumped

— Auger Tip Depth   — Pumped Grout Volume

Grouting: Time (min)

Auger Tip Depth (ft) / Cumulative Grout Volume (cuft)

Auger fully extracted while no grout is pumped

— Auger Tip Depth   — Pumped Grout Volume

Observed frequency of re-stroking

| Piles with at least one…	#	%	of	Total Piles Analyzed
Partial Re-stroke during Drilling	203	52.6%	of	386
Complete Re-stroke during Drilling	114	29.5%	of	386
Partial Re-stroke during Grouting	63	16.3%	of	386
Complete Re-stroke during Grouting	25	6.5%	of	386

Comparison of grout volume recording method for single auger cast pile, not within 3% agreement criteria per (FDOT, 2022).

$y = 0.9223x - 3.5645$

$R^2 = 0.9998$

$(AME\ Volume)/(Pump\ Stroke\ Volume) = 0.9223$

AME Flow Meter Volume (cuft)

Pump Stroke Volume (cuft)
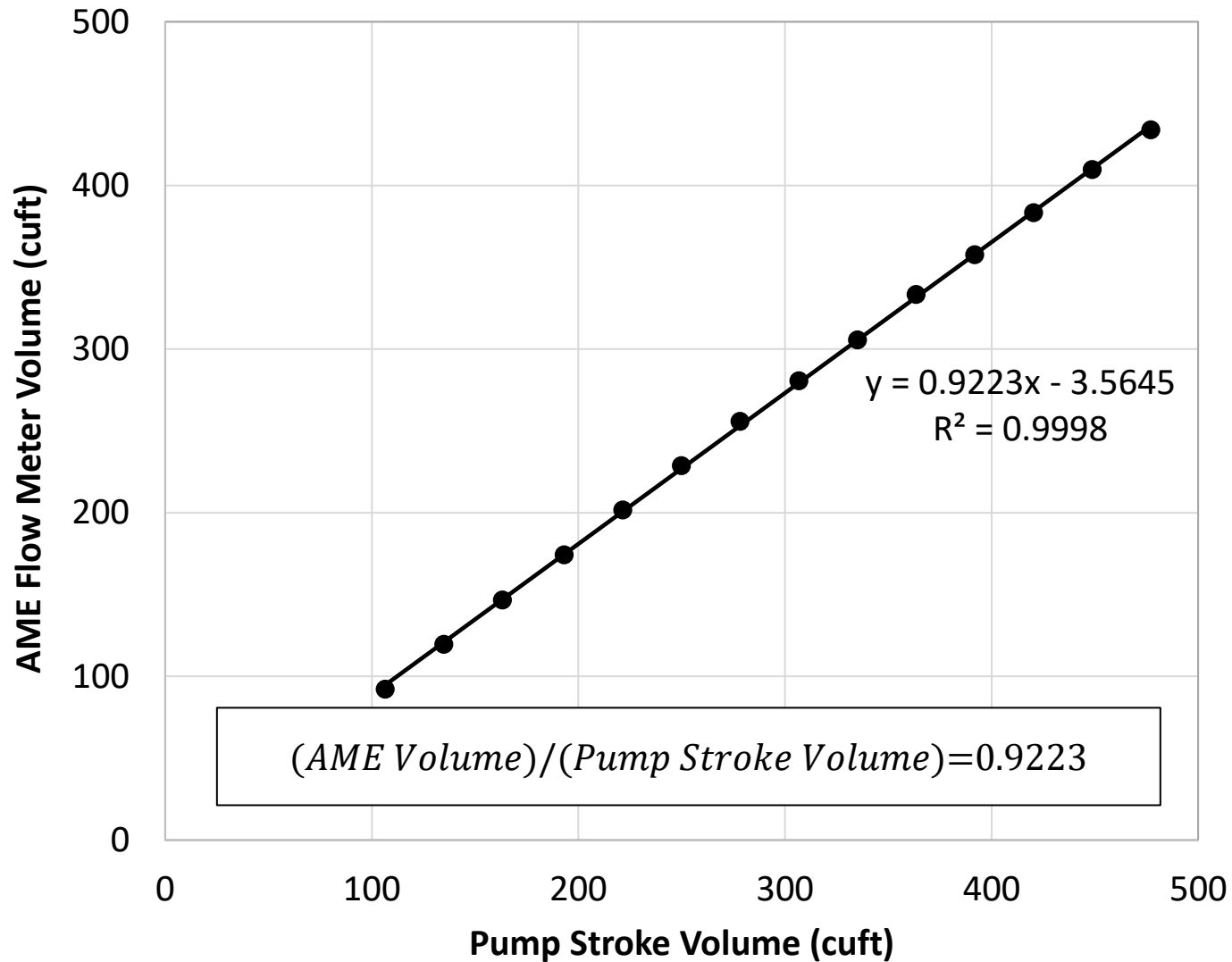
Analysis performed for 651 auger cast piles show 64% fall outside 3% agreement criteria (dashed red lines).
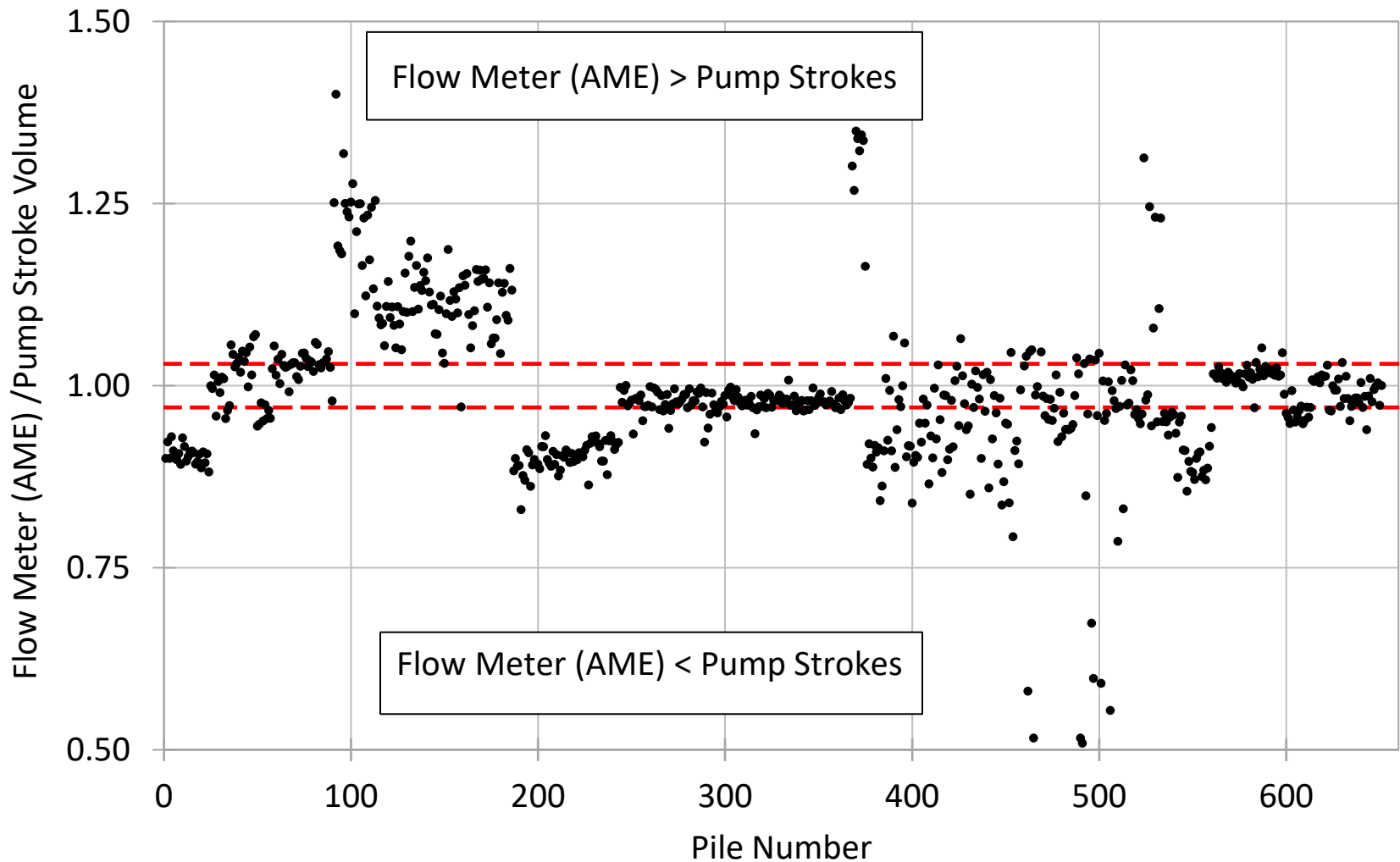
# Predicted vs. Measured Pile Diameter
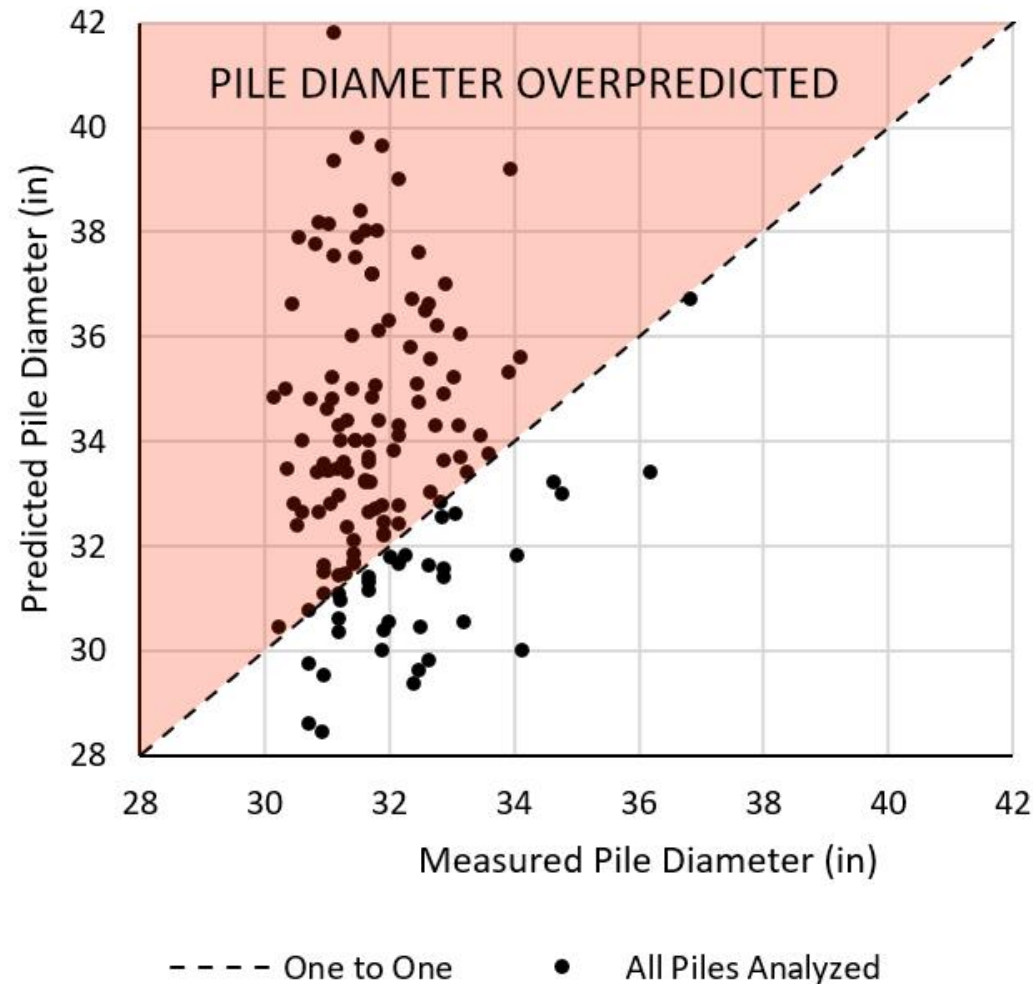
Analysis of as-built dimensions (taken at cutoff elev.) from 139 piles, resulted in 71% of piles being overpredicted.

AFF contributes to accurate pile volume and subsequently Thermal Integrity analysis through the T-R constant where average pile radius is required. To estimate AFF, two soil adhesion methods are mostly observed:
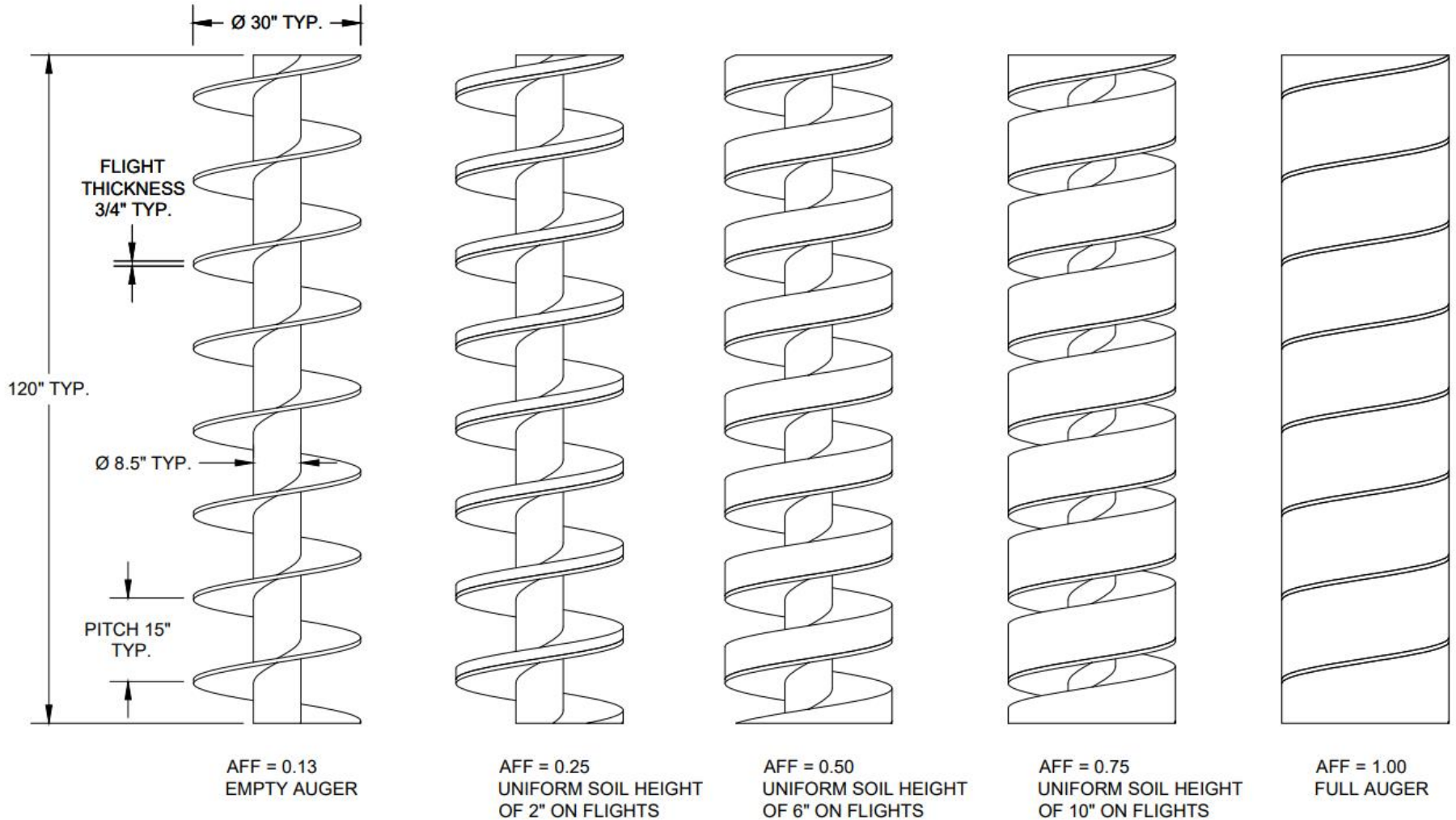

(left) soil clings to center stem **(right)** soil sits on auger flights

Effect of AFF on pile size calculated from thermal tests
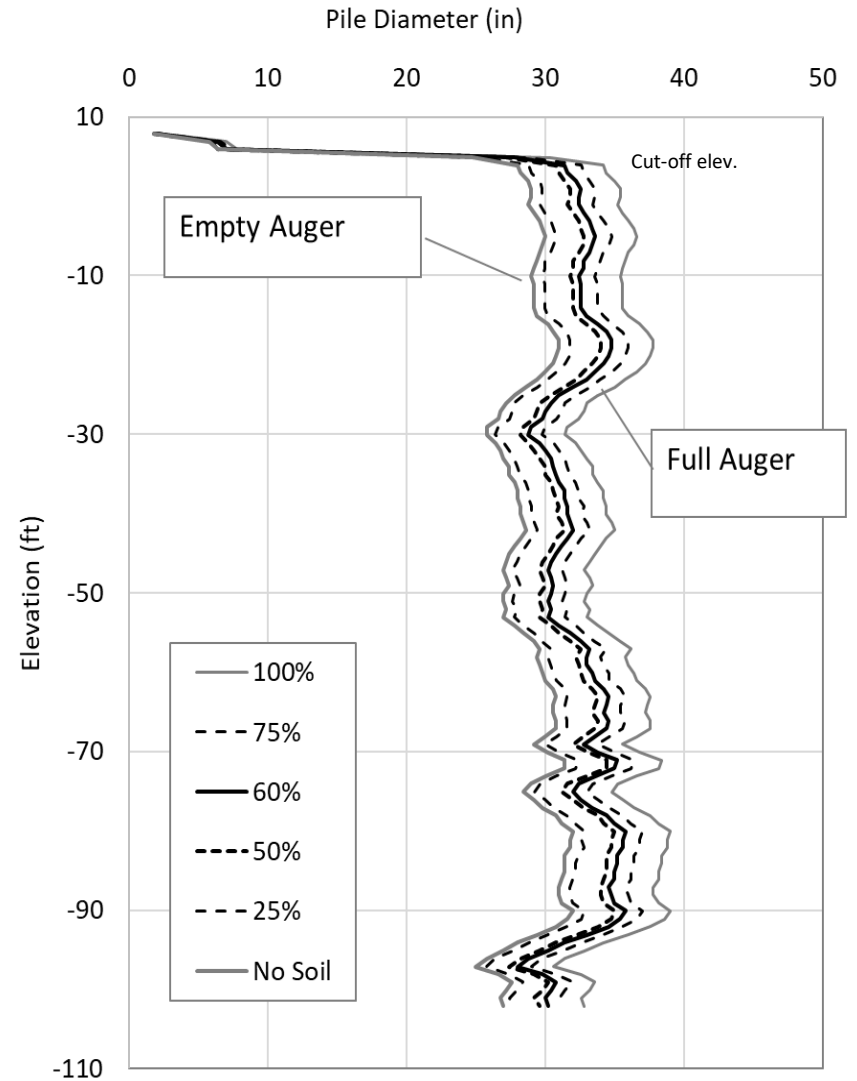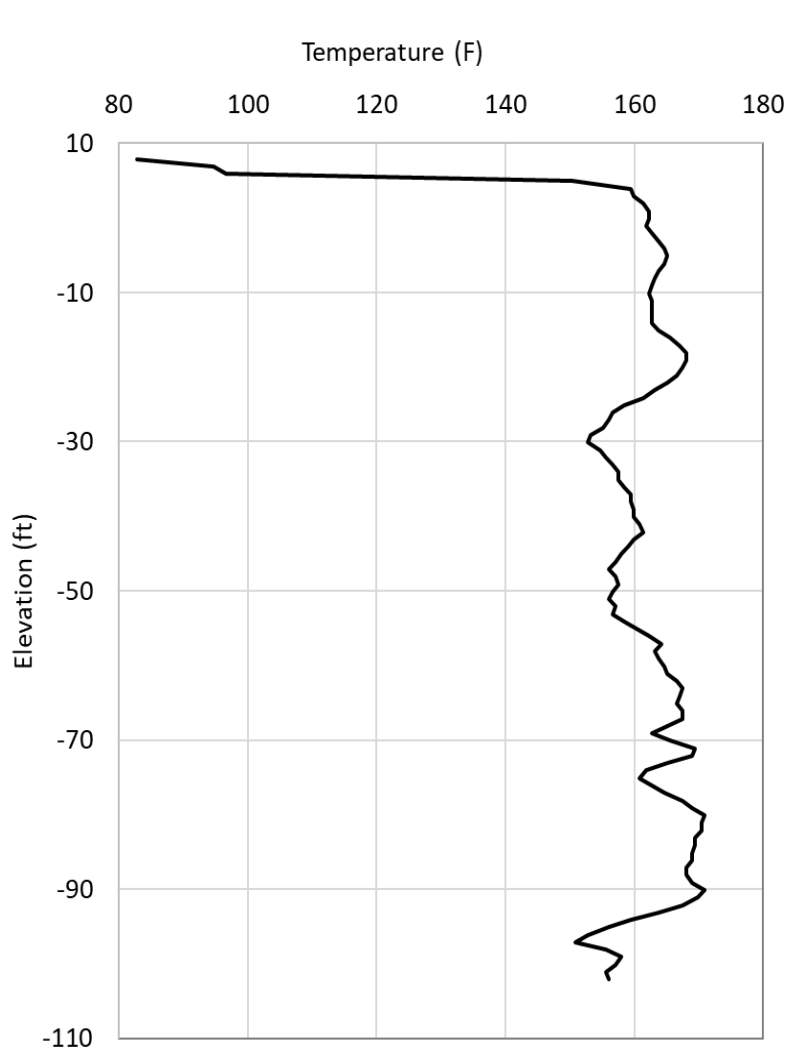
(left) original temperature profile, AFF = 0.6 **(right)** effect of AFF

Field estimation guides are envisioned to assist inspectors. Estimation guide for soil stacking:

Ø 30" TYP.

FLIGHT THICKNESS 3/4" TYP.

120" TYP.

Ø 8.5" TYP.

PITCH 15" TYP.

AFF = 0.13
EMPTY AUGER

AFF = 0.25
UNIFORM SOIL HEIGHT
OF 2" ON FLIGHTS

AFF = 0.50
UNIFORM SOIL HEIGHT
OF 6" ON FLIGHTS

AFF = 0.75
UNIFORM SOIL HEIGHT
OF 10" ON FLIGHTS

AFF = 1.00
FULL AUGER

NOTE: 10' CENTER SECTION OF
CONTINUOUS FLIGHT AUGER SHOWN

Field estimation guide for soil adhering to center stem:

Ø 30" TYP.

FLIGHT THICKNESS 3/4" TYP.

120" TYP.

Ø 8.5" TYP.

PITCH 15" TYP.

AFF = 0.13
EMPTY AUGER

AFF = 0.25
2.5" THICK WALL OF
SOIL WRAPPED
AROUND STEM

AFF = 0.50
6" THICK WALL OF
SOIL WRAPPED
AROUND STEM

AFF = 0.75
8.5" THICK WALL OF
SOIL WRAPPED
AROUND STEM

AFF = 1.00
FULL AUGER
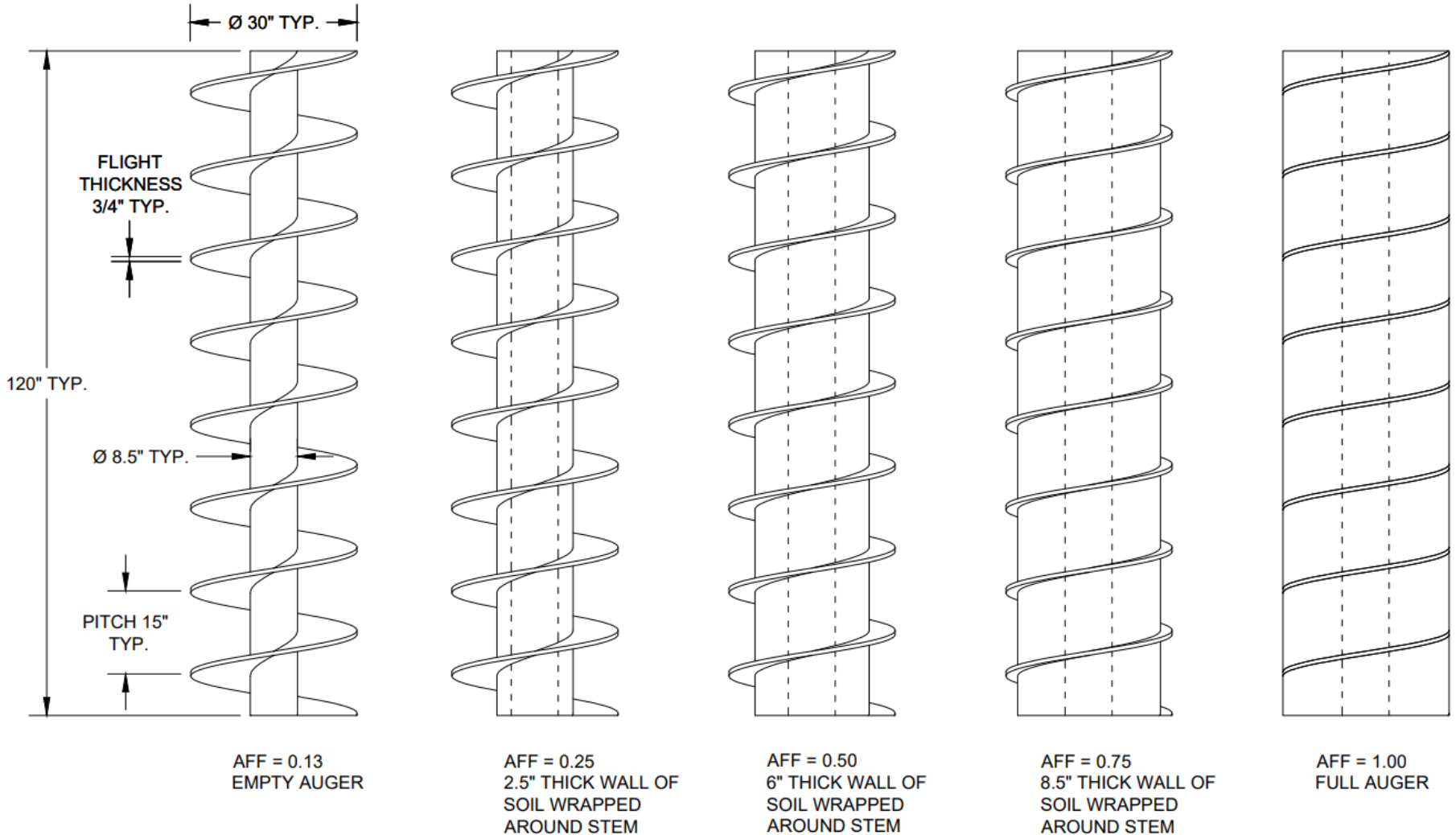
NOTE: 10' CENTER SECTION OF
CONTINUOUS FLIGHT AUGER SHOWN

Update on Work Performed

- Analyzed installation data of 386 auger cast piles for re-stroking events where the excavation was left partially or completely unsupported.

- Evaluated agreement between two grout volume monitoring methods (counting pump strokes and use of magnetic flow meter) for 651 auger cast piles.

- Continued cataloging additional installation and thermal testing data for further processing.

Questions?