Estimating the As-Placed Grout Volume of Auger Cast Piles

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GRIP 2022

Gray Mullins, Ph.D., P.E. and Tristen Mee
Project Manager: Juan Castellanos, P.E.

USF UNIVERSITY OF SOUTH FLORIDA

Auger Cast Piles

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

This Not this

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

Image source: (**left**) FDOT

Installation Process

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

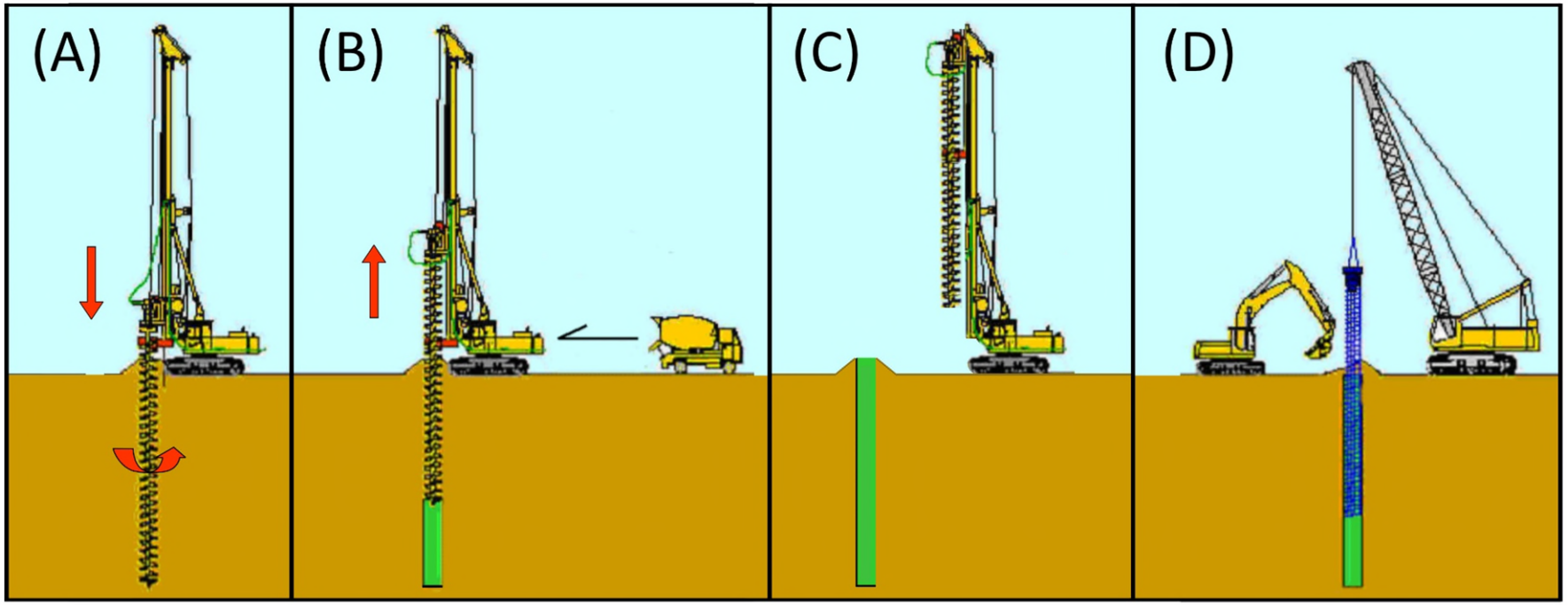


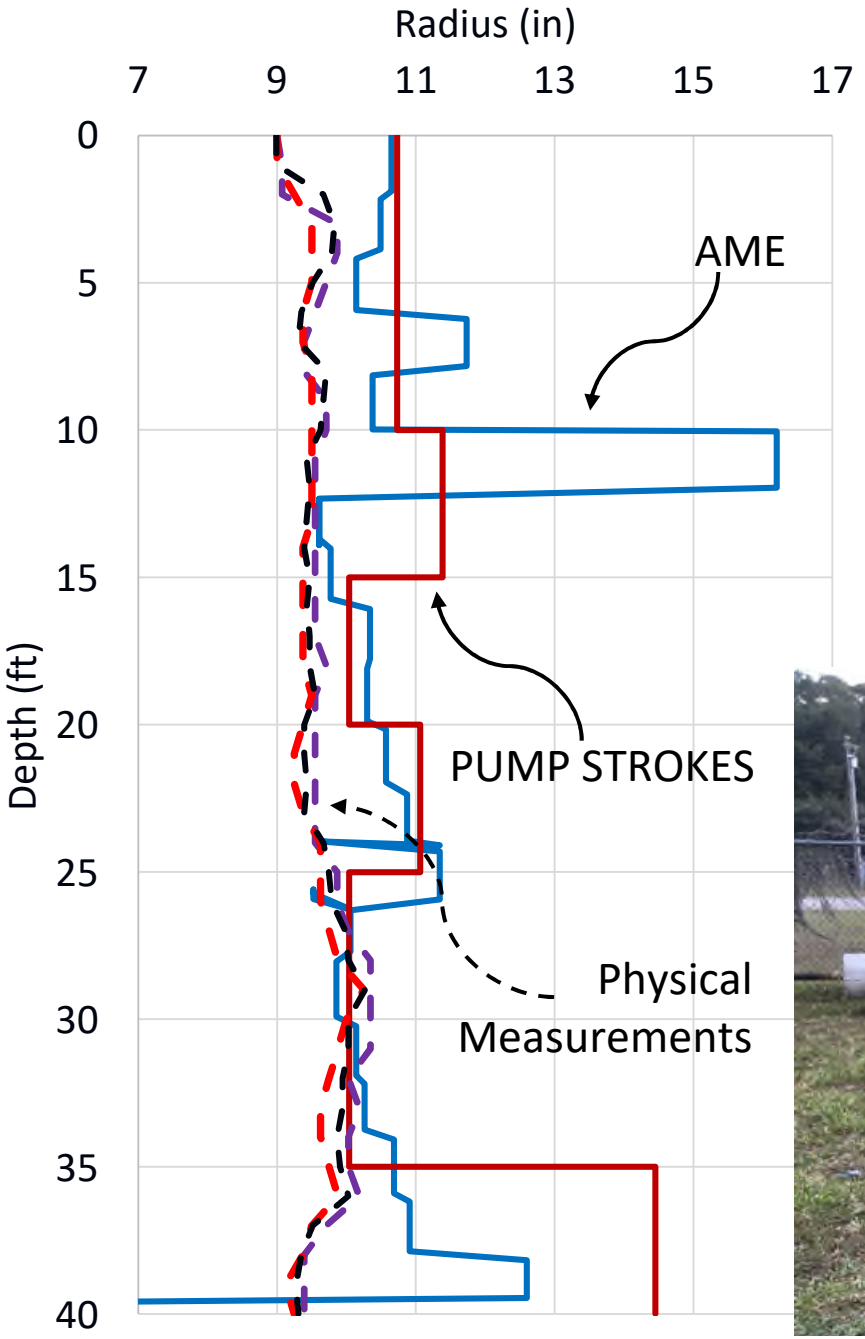
Image source: Adapted from Geotechnical Engineering Circular (GEC) No. 8 (2007)

Grout Volume Monitoring

Grout volume is monitored by (1) a magnetic flow meter and (2) counting pump strokes and using accurate pump calibrations (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 ACIP 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

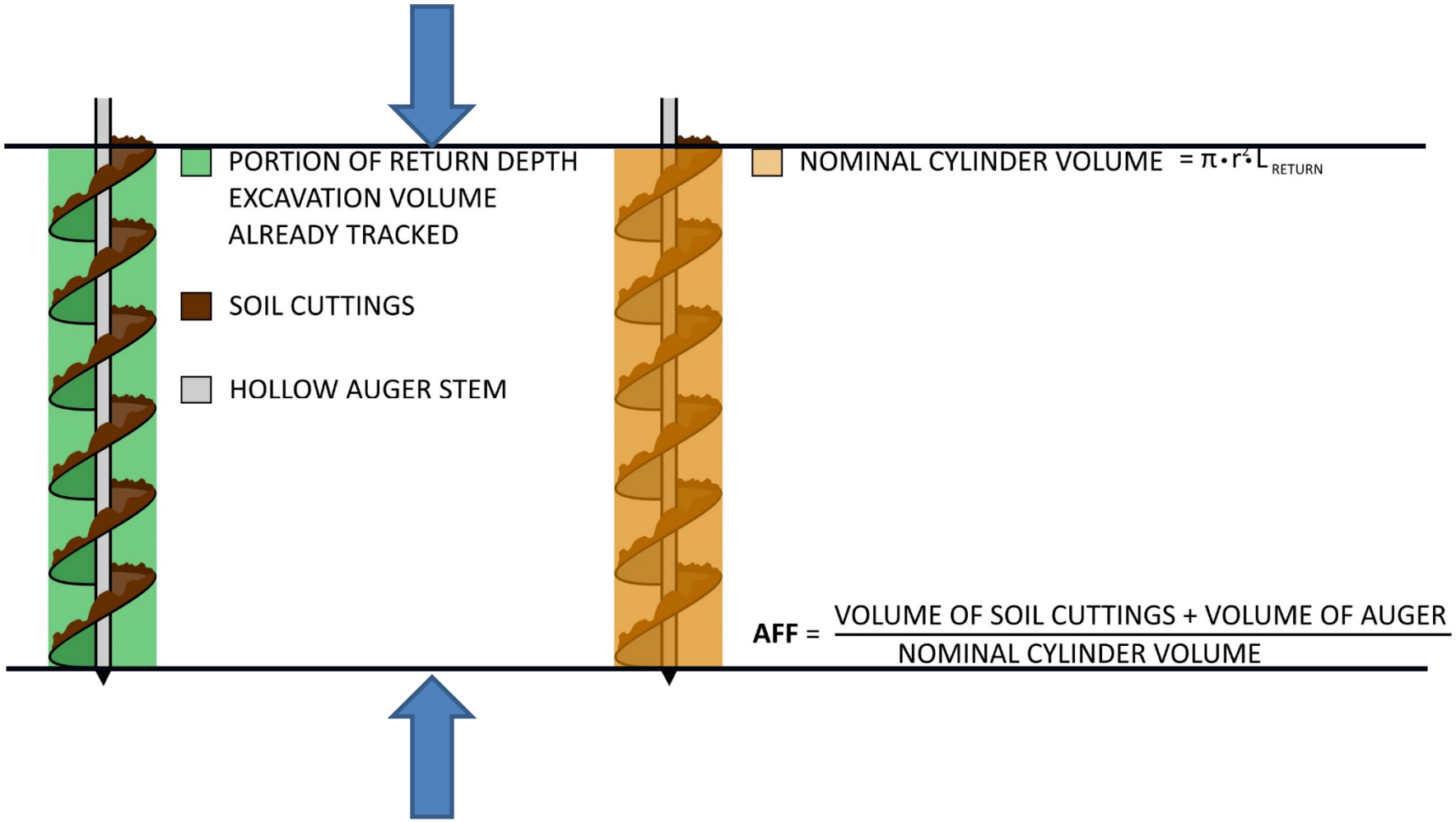
SOIL CUTTINGS

HOLLOW AUGER STEM

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

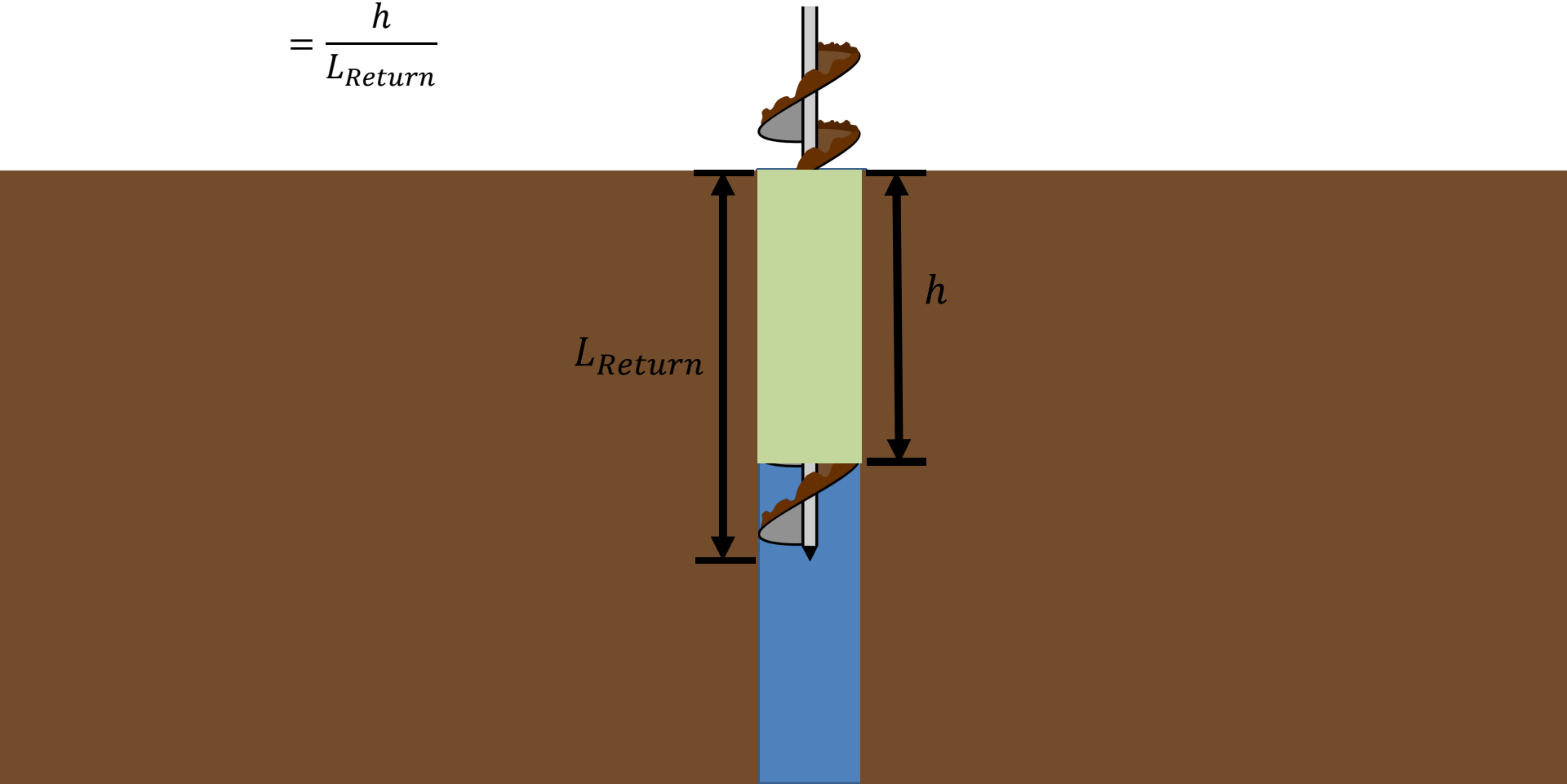
$$\textbf{AFF} = \frac{\text{VOLUME OF SOIL CUTTINGS + VOLUME OF AUGER}}{\text{NOMINAL CYLINDER VOLUME}}$$

Auger Fill Factor (AFF)

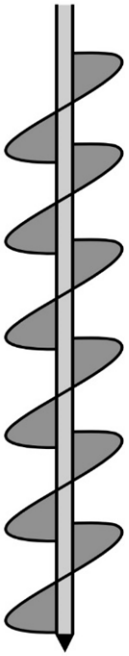


$$AFF = \frac{Volume_{Auger+soil}}{\pi r^2 L_{Return}} = \frac{\pi r^2 h}{\pi r^2 L_{Return}}$$

$$= \frac{h}{L_{Return}}$$

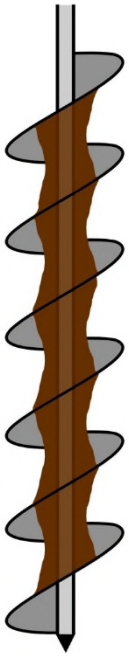


Qualitative Modes of Soil Cutting Adhesion



EMPTY AUGER

SOIL CUTTINGS SIT ON AUGER FLIGHTS



SOIL CUTTINGS CLING TO AUGER STEM

Soil Cutting Adhesion Examples

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.

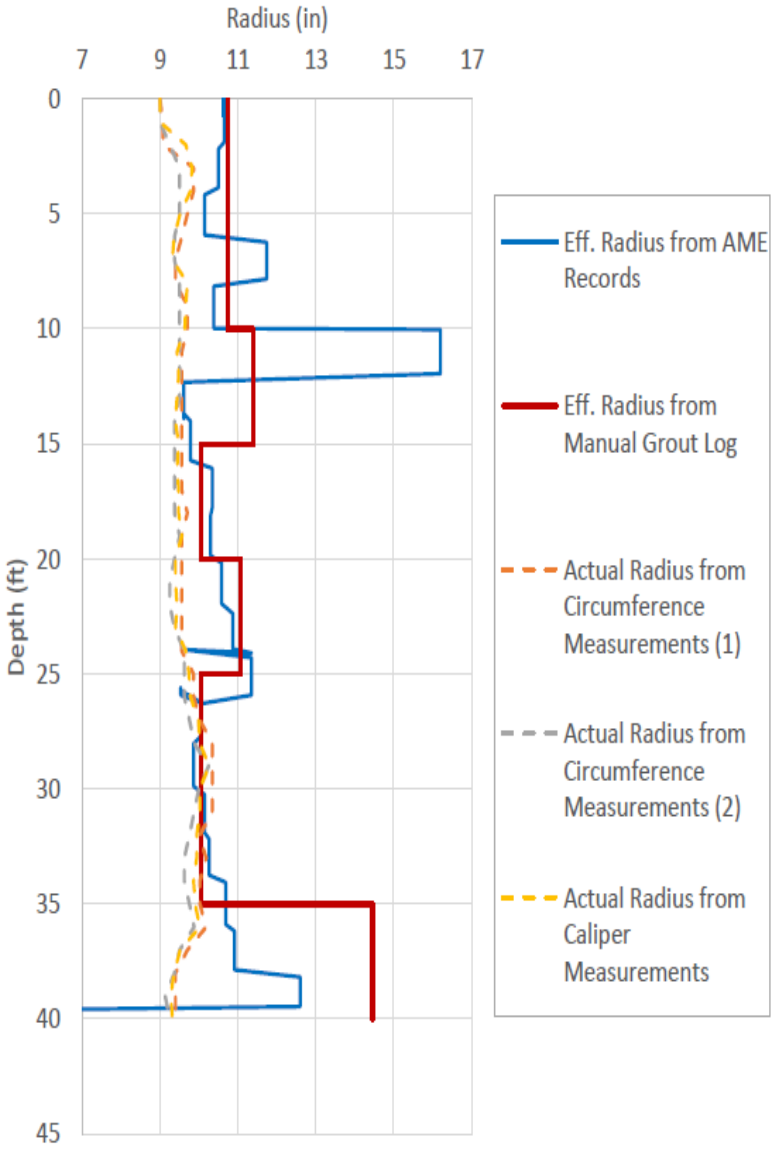
Objectives

- 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

Data Sources – FDOT/DFI Pilot Study



Data Sources - DFI Pilot Study

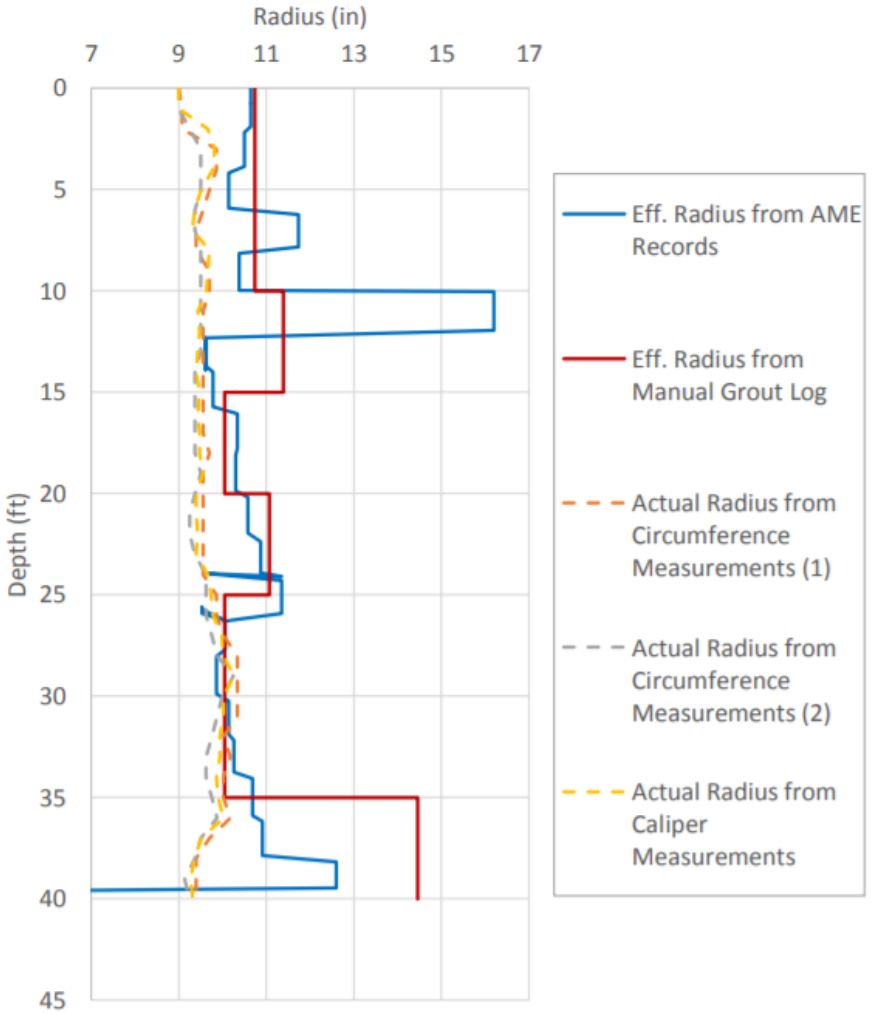


Image source: **(left)** ACIP Pile Installation Monitoring, Full-scale Load Testing, and Extraction program – DFI (2017)

Data Sources – I-395/SR 836/I-95

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

Auger Cast Data Types

Six data types were identified during auger cast installation:

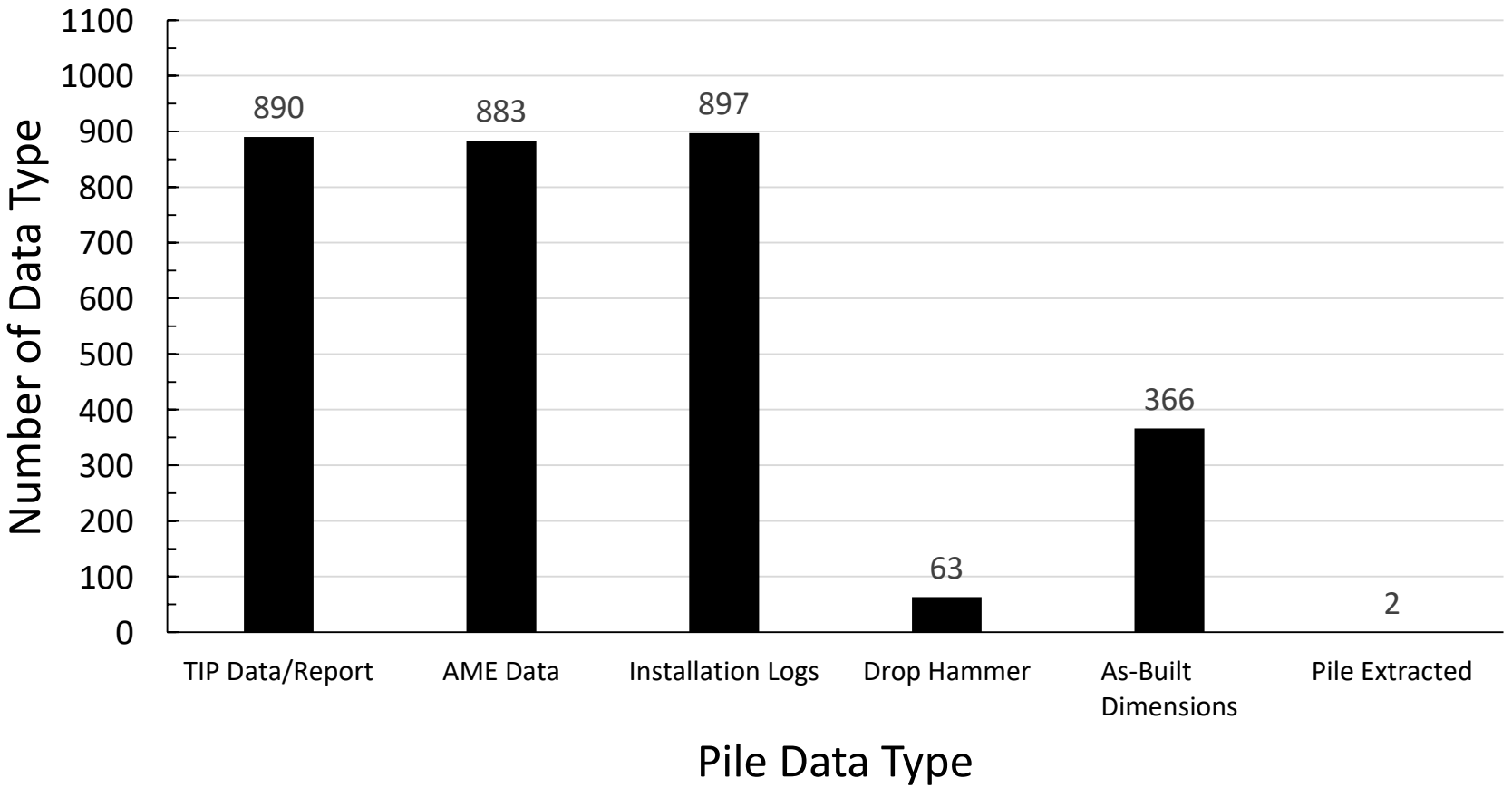
1. Thermal Integrity Profiling (TIP) data and associated report
2. Automated Measuring Equipment (AME) Data
3. Installation logs
4. Drop Hammer Test Results
5. As-built pile dimensions recorded at cut-off elevation
6. Pile extraction and associated pile measurements

Data Collected to Date (August 2022)

To date, installation data has been collected from:

- 9 bridges
- 80 piers
- 1050 piles

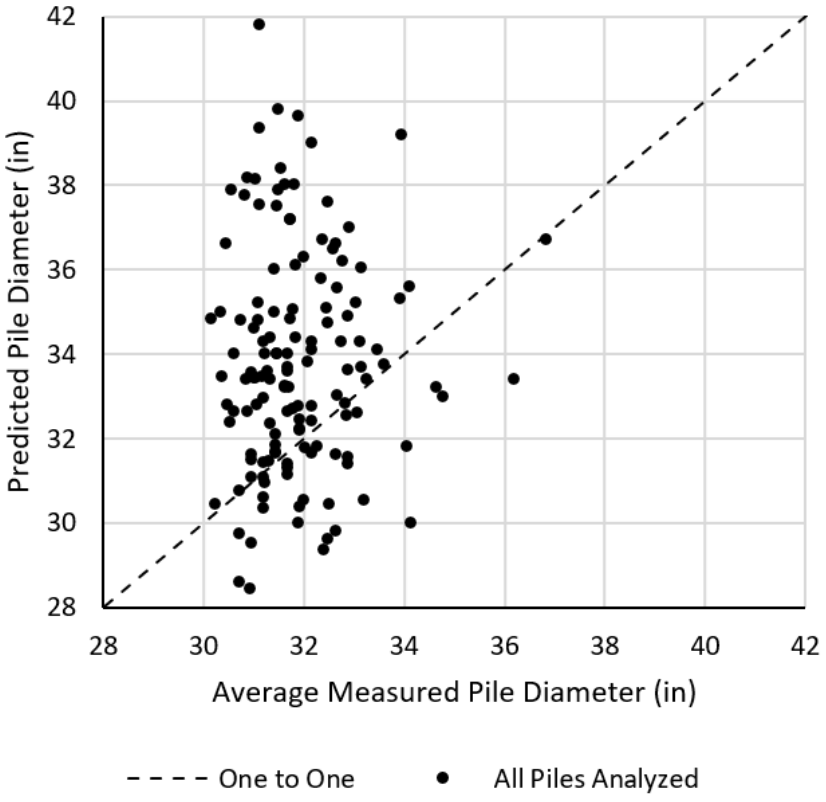
Data Type Schedule

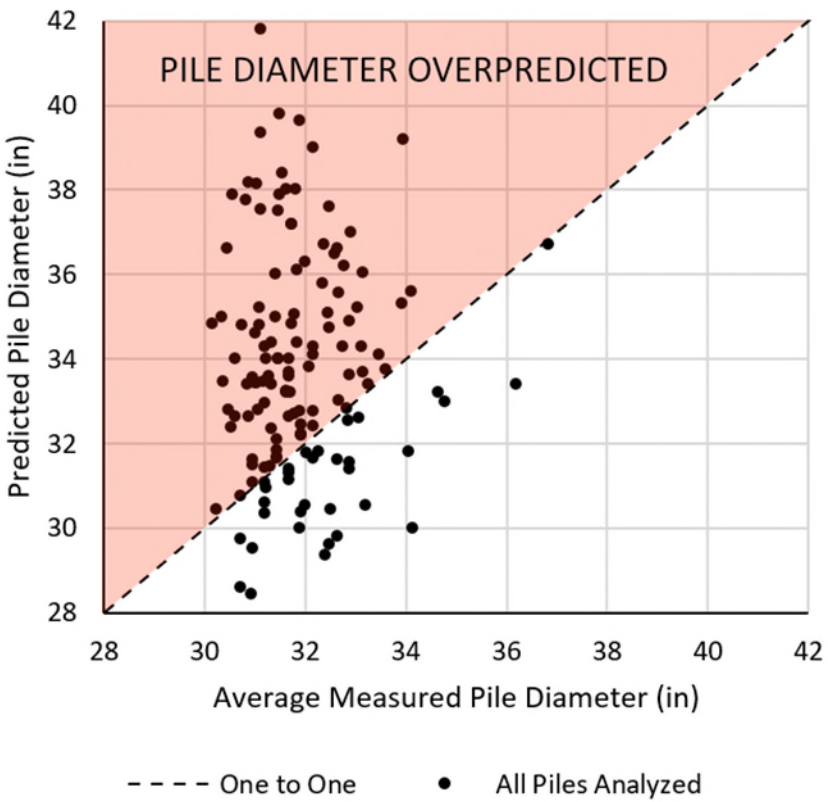


Types of Analysis Performed

- Analysis of partial and complete auger re-stroking
- Grout volume comparison between pump strokes and flow meter volume (AME)
- AFF back-calculation using measured pile dimensions at cut-off

Predicted vs. Measured Pile Diameter





Analysis for 139 piles using an AFF of 0.6 to 0.8, resulting in 71% of pile diameters being over predicted. 139 piles represent piers 4-4R, 4-4L, 7-9L, 7-11R, 101-3, 101-6, 101-9, 101-17, 101-19

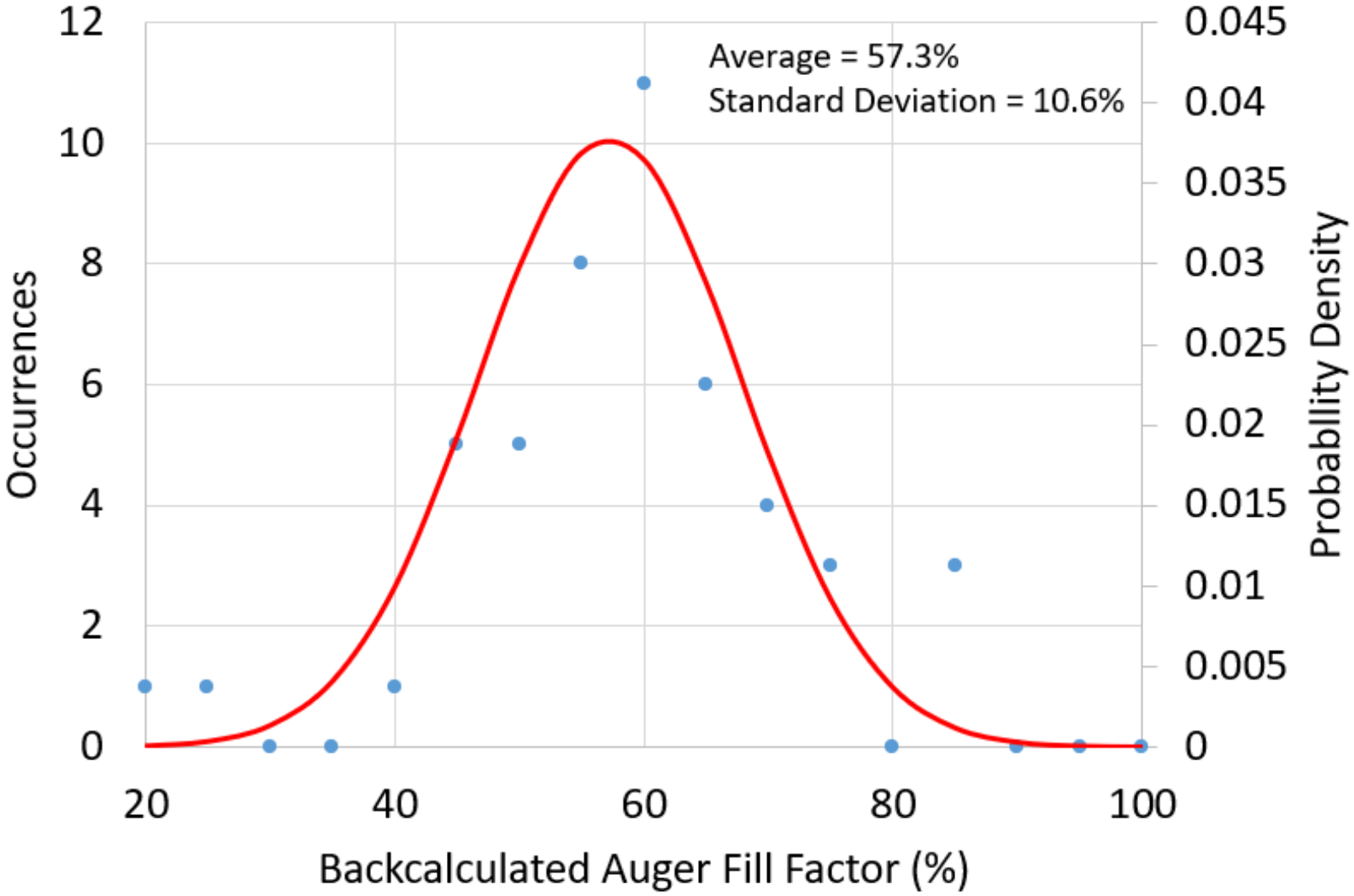
Two Data Sets

Two distinct data sets have been identified as follows:

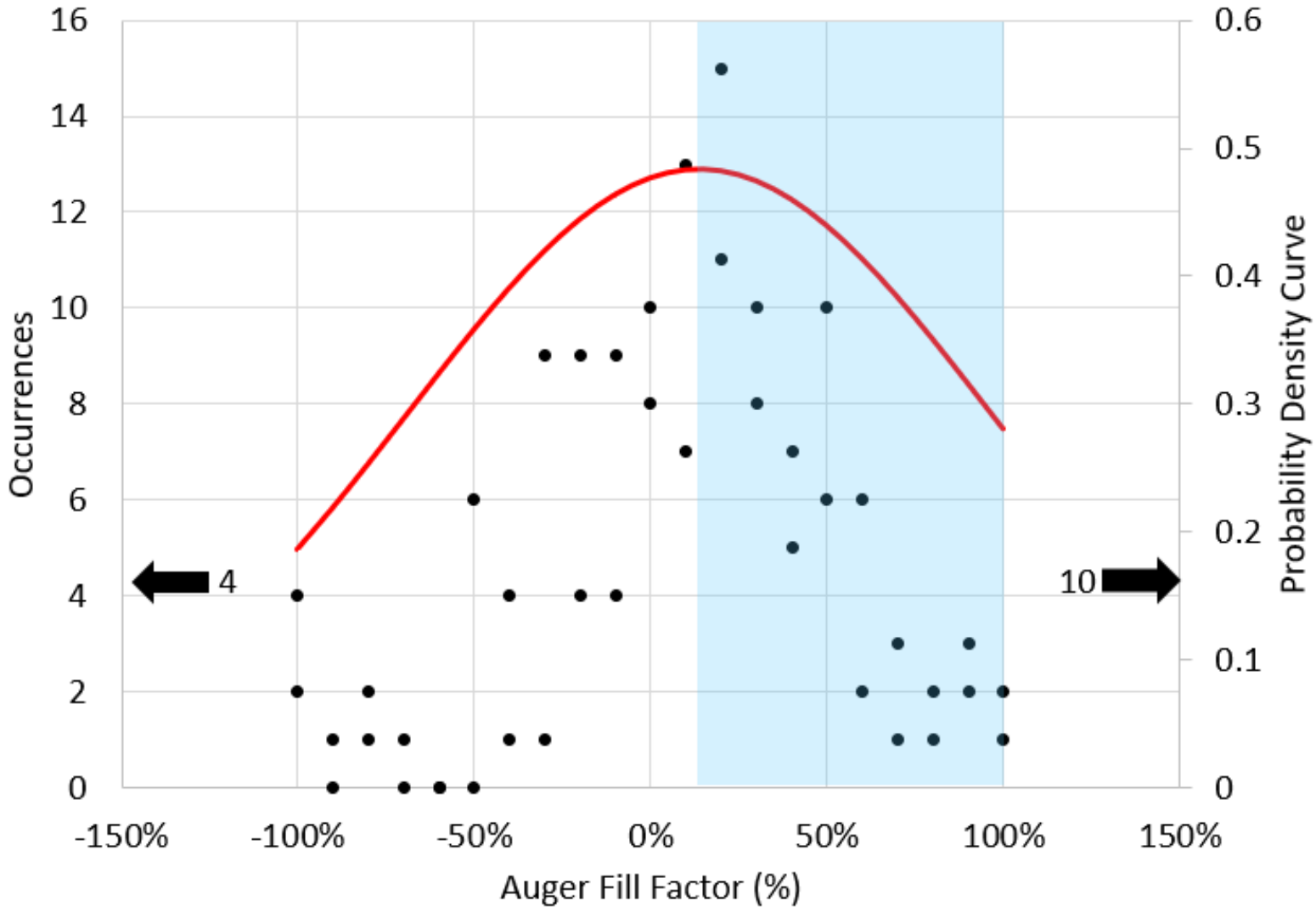
Data Set #1: Piers 4-15, 4-16, 5-15L, 5-15R, 5-16L, and 5-16R

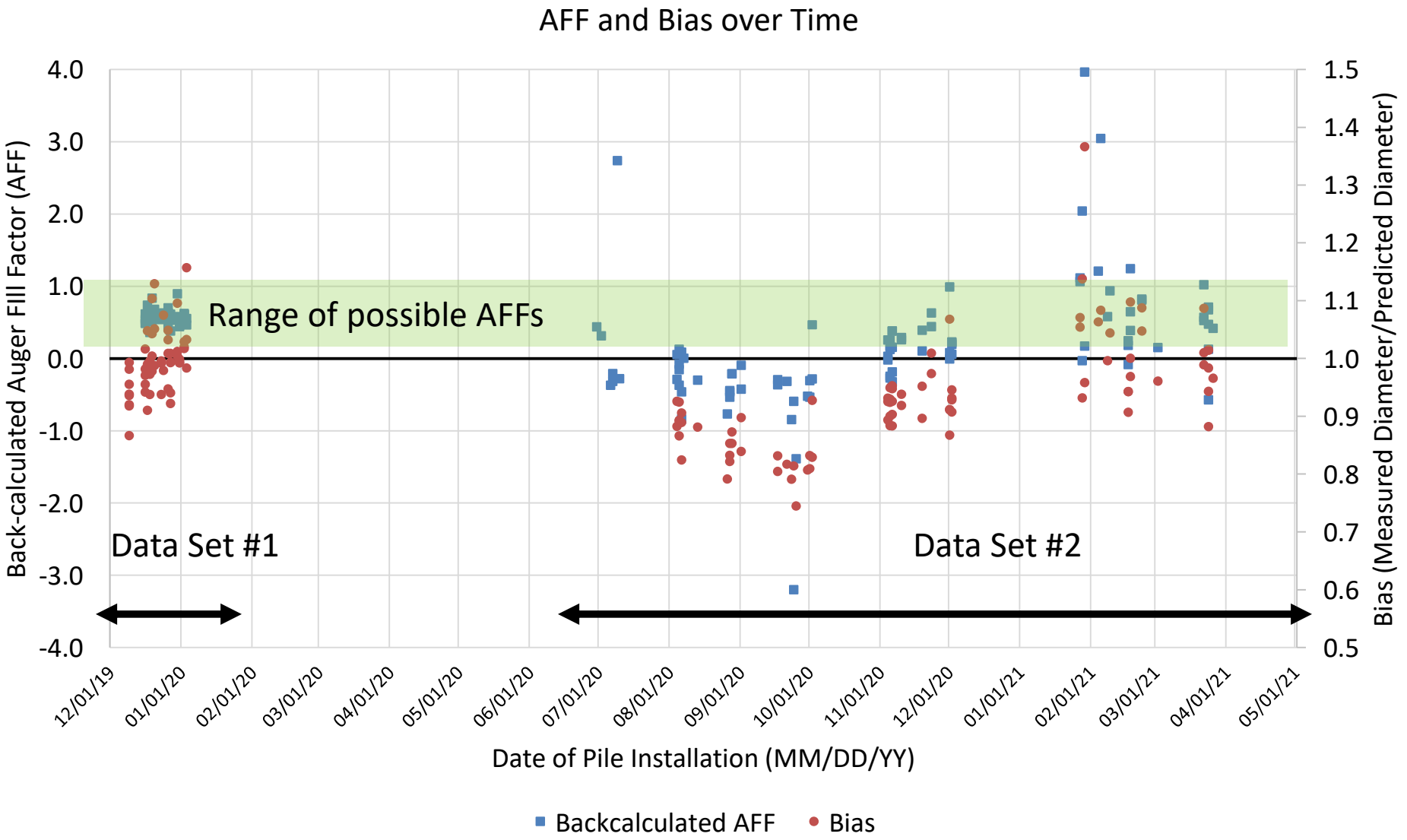
Data Set #2: Piers 4-4R, 4-4L, 5-11L, 7-1, 7-8L, 7-8R, 7-9L, 7-11R, 101-3, 101-6, 101-9, 101-17, and 101-19

Data Set #1 AFF Back-calculation



Data Set #2 AFF Back-calculation




AFF and Bias over Time
Back-calculated Auger Fill Factor (AFF)
Bias (Measured Diameter/Predicted Diameter)
Range of possible AFFs
Data Set #1
Data Set #2
Date of Pile Installation (MM/DD/YY)
Backcalculated AFF
Bias

Moving Forward

- Continue the collection and categorizing of pile installation data. 1050 piles have been collected as of August 2022.
- Continue grout volume analysis on new incoming data.
- Continue investigation into grout volume discrepancies during auger cast installation and new analysis methods.


Questions?