ACIPS - CASE STUDY
STATIC LOAD TESTS VS COMPUTER ESTIMATED SETTLEMENT

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What is an Auger Cast Pile

• Also Know as
  – Continuous Flight Pile (CFA) Auger Piles,
  – Augered Cast-in-Place (ACIP) Piles,
  – Drilled Displacement Piles,
  – Screw Piles

• Sequence of Construction
  – Drilling
  – Grouting Begins before withdrawal of the tools
  – Reinforcement Placing
Installation Process

Source: Bauer Maschinen
Auger Cast Pile Installation Equipment
### Auger Cast Piles vs Drilled Shafts

**DRILLED SHAFTS**
- Wide Range diameter, 24 to 96 inches not uncommon;
- Heavy Load;
- Applicable to any soil or most rock;
- Typically used widely spaced as to reduce capacity due to group action;
- Use Casing and Slurry for Temporary support;
- Concrete filled.

**AUGER CAST PILES**
- Diameter 12 to 36 inches;
- Most often used in pile groups;
- Faster installation than drilled shaft;
- Limited to soil or poor rock;
- Grout or Concrete;
- Harder to inspect and QC problems;
- Success is highly operator dependent;
Transportation CFA Uses

FHWA identifies Transportation Project Where CFA tend to have advantages.

- Time Sensitive Project;
- Vibration Sensitive Projects;
- Project where battered piles are required (ODOT does not currently agree with this);
- Project with a large number low capacity piles are needed:
  - Embankment Foundations,
  - Sound Walls.
- Retaining Structures

ODOT 2015 Workshop announced BDM updates for the Use of CFA Piles Guidelines Still Forth Coming

What We know:
- Not Acceptable for Bridge Support;
- Will Be used for:
  - Noise Barrier Wall Foundations;
  - Temporary Support of Excavation;
  - Solider Pile and lagging Walls; and
  - Sign Post foundations.

What I think ODOT might consider them for:
- Embankment Support;
- Stone Aggregate Column uses;
- Slope Stabilization;
- Non Critical Structures.
Tied-Back Auger Cast Pile Installation
Underground View of Auger Cast Pile Installation
Base of Installed Auger Cast Piles
Watertight Excavation Support via Secant Auger Cast Pile Walls
Transportation CFA Uses

Traditional Concerns from FHWA about CFA piles

- No nationally accepted design protocol for CFA (static design capacity);
- No national guideline specification for method and materials;
- No standards for quality control and assurance;
- No universally accepted standards for pile acceptance (static load test results).

Geotechnical Engineering Circular #8 Design and Construction of Continuous Flight Auger Piles 2007

- Recommends Reese and O’Neil for Static Design and Settlement
- Provides Specifications for methods and materials; and
- Discusses Quality Control Measure.
RECOMMENDED METHODS FOR ESTIMATING STATIC AXIAL CAPACITY OF CFA PILES (Reese and O’Neil 1988)

Granular Soil

(c) Normalized Load Transfer in Side-Shear

(d) Normalized End-Bearing
RECOMMENDED METHODS FOR ESTIMATING STATIC AXIAL CAPACITY OF CFA PILES (Reese and O’Neil 1988)

Fine Grained Soil

(a) Normalized Load Transfer in Side-Shear vs. Settlement in Cohesive Soils

(b) Normalized End-Bearing Capacity vs. Settlement in Cohesive Soils
RECOMMENDED METHODS FOR ESTIMATING STATIC AXIAL CAPACITY OF CFA PILES

### Cohesive Soil

\[
f_s = \alpha \cdot S_u
\]

\[
\alpha = 0.55 \quad \text{for} \quad S_u / P_a \leq 1.5
\]

\[
q_P = N_c^* \cdot S_u
\]

\[
N_c^* = 9
\]

\[
N_c^* = \frac{4}{3} \left[ \ln I_x + 1 \right]
\]

\[
I_x = \frac{E_S}{3S_u}
\]

### Granular

\[
f_s = K \cdot \sigma_v' \cdot \tan \phi \leq 200 \text{ kPa (2.0 tsf)} \quad \text{(Equation 5.17)}
\]

\[
\beta = K \cdot \tan \phi \quad \text{(Equation 5.18)}
\]

\[
\beta = 1.5 - 0.135 \cdot Z^{0.5} \quad \text{for} \quad N \geq 15 \text{ bpf} \quad \text{(Equation 5.19a)}
\]

\[
\beta = \frac{N}{15} (1.5 - 0.135 Z^{0.5}) \quad \text{for} \quad N < 15 \text{ bpf} \quad \text{(Equation 5.19b)}
\]

\[
q_p \text{ (tsf)} = 0.6N_60 \quad \text{for} \quad 0 \leq N_60 \leq 75 \quad \text{(Equation 5.20a)}
\]

\[
q_p = 4.3 \text{ MPa [45 tsf]} \quad \text{for} \quad N_60 > 75 \quad \text{(Equation 5.20b)}
\]
Standards for Pile Appétence  
Static Load Test

The static load test is the industry standard for pile testing. Advantages of this system:

• Fast, inexpensive installation of reaction;
• Installing Contractor can perform test; and
• Relative light loading of CFA pile make testing practical.

Integrity Testing

• Pile Head Impact Testing (Sonic Echo Test, Sonic Mobility)
• Down the hole tests (Sonic Cross hole logging and Thermal Testing)

4.4 GEC 8

It is imperative that the demonstrated installation procedure be followed for all production pile installations.
In general, there are three limit state conditions that must be satisfied for design of CFA:

1. **Geotechnical Ultimate Limit State (GULS).** The pile should have a load resistance that is greater than the expected loads (service loads) by an adequate margin to provide a required level of safety (safety factor). For axial compressive loads, the GULS is defined as the load resistance at a displacement equal to 5% of the pile diameter in an axial static load test;

2. **Service Limit State (SLS).** The pile should undergo deformations at service load levels that are within the tolerable limits appropriate for the structure. The actual definition of the service limits should be determined by a rational assessment of the sensitivity of the structure to deformations.

3. **Structural Ultimate Limit State (SULS).** The pile must have sufficient structural capacity when the pile is subjected to combined axial and flexural loads such that structural yielding of the pile is avoided. The SULS provides a second definition of foundation strength.
The Davisson criterion, commonly used for driven piles, and shown for reference in Figure 6.1, will sometimes underestimate the ultimate resistance and is not appropriate for CFA piles.

**Formula**

$$0.150 \text{ in.} + \frac{D}{120} + \frac{PL}{AE}$$

- **D** = Pile Diameter (inches)
- **L** = Length of Pile (inches)
- **A** = Area of Pile (inches$^2$)
- **E** = Modulus of Elasticity (psi) $1820\sqrt{f'_c}$

Adopted as the most conservative estimation of axial capacity based on International Building Codes accepted methodologies.
Limit States For Design
Load Test

Figure 6.1: GULS and Short-Term SLS for Axial Load on a Single CFA Pile

![Diagram showing limit states for design load test](image)

- **SLS (short-term loading only)**
- **GULS**
- **Displacement Limit at Service Load**
- **Load (P)**
- **PL/AE + d/120 in. + 0.15 in.** (Davisson Criterion)
- **0.05d**
- **Measured Curve**

**Equation:**

\[ PL/AE + \frac{d}{120 \text{ in.}} + 0.15 \text{ in.} \]

**Variables:**

- \( P \) = Pile Length
- \( A \) = Pile Area
- \( E \) = Pile Modulus
- \( d \) = Pile Diameter (in.)

The “ultimate” resistance in the Davisson criterion is defined as the point at which Davisson line intersects measured load vs. deflection curve.
The Davisson Criterion

Shortcomings of the Davisson Offset Limit Applied to Axial Compressive Load Tests on Cast-In-Place Piles

W. Morgan NeSmith, Member, Geo-Institute
Timothy C. Siegel, P.E., Member, Geo-Institute

1) The assumption that the cast-in-place pile behaves as a “fixed-base, freestanding column.”

2) The assumption that an elastic line is a dependable reference line for interpretation of load tests on cast-in-place piles. Kulhawy and Chen (2005) concluded that the DOL assumptions tended to overestimate the stiffness of short piles and underestimate the stiffness for longer piles.

3) In contrast, cast-in-place piles and other types of drilled piles do not compress the soil beneath the pile toe during installation. Thus, a greater downward movement of the pile toe would be required to mobilize the end resistance for cast-in-place piles if all other conditions were equal.
“Static Testing of Deep Foundations” (Kyfor et al., 1992) - FHWA-SA-91-042;

“Design and Construction of Driven Pile Foundations,” Volumes 1 and 2 (Hannigan et al., 2006) - NHI Course FHWA-NHI-132021;

“Micropile Design and Construction” (Sabatini et al., 2005) - FHWA NHI-05-039; and

“Drilled Shafts” (O’Neill and Reese, 1999) - FHWA-IF-99-025
Typical Test pile Layout (Plan)
Typical
Test Pile Layout (Profile)
Typical Load Test Configuration
Circleville, Ohio
32' Long Load Test

TP104-32  16-in. diameter, 32 foot long, augercast pile

SOFIDEL
Circleville, Ohio
GCI 16-F-19536
August 11, 2015

Design Load = 73 tons
2x Design Load = 146 tons
4x Design Load = 292 tons

Geotechnical Ultimate Limit State (GULS) = 0.05d
Circleville 32’ Long Shaft
Calculated Load Capacity SHAFT Load Capacity

Design Load (73 ton)
Depth = 21.8 ft
Circleville 32’ Long Shaft
Calculated SHAFT Settlement

Load Test Deflection = 0.08 in
Predicted Deflection = 0.08 in
Circleville, Ohio
42’ Long Load Test

TP104-42  16-in. diameter, 42 foot long, augercast pile

Design Load = 73 tons
2x Design Load = 146 tons
4x Design Load = 292 tons

SOFIDEL
Circleville, Ohio
GCI 16-F-19536
August 15, 2015

Settlement, in.

Load, tons

- load test  — elastic shortening  — Davisson failure criterion  — reload
Circleville 42’ Long Shaft
Calculated Load Capacity SHAFT Load Capacity
Circleville 42’ Long Shaft Calculated SHAFT Settlement

Load Test X1 Deflection = 0.06 in
Predicted X1 Deflection = 0.06 in

Load Test X2 Deflection = 0.17 in
Predicted X2 Deflection = 1.07 in
Goodale
Shaft Settlement Calculation

Design Load
85 tons
0.12 Inches
0.12 Inches from load test
0.52 Inches from Davisson

Design Load x2
170 tons
0.22 inches
0.32 inches from load test
0.78 Davisson at load

Axial Load (tons)
1. Reese and O’Neil is acceptable for design of size and depth for a design load. Load Tests verify that settlement and load capacity are accurately predicted at design loads.

2. A SF of 2.0 will generally result in the design capacity (Actual GULS) is typically higher although settlement is actually often higher than SHAFT will predict at twice Design load.

3. SULS will often be achieved well before GULS ($SULS = 0.4 - 0.25 f'c$) Ohio building code 0.3 $f'c$

4. CFA piles tend to plunge (settle at tip) greater than drilled shafts possibly due to smaller diameter than drilled shafts. This means when using CFA piles SLS should closely looked at.

5. Davisson Criteria should not be the universal acceptance criteria for load tests as it is too conservative for short piles and perhaps not conservative enough for very long piles.
Thank You!

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