NEW DEVELOPMENTS IN AUGER PRESSURE GROUTED (APG) PILES

Presented by:

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Berkel & Company Contractors, Inc.
Advantages of APG Piles

- Speed of Installation
- High Capacity
- Economic
- Adaptable to Limited Access Areas
- Minimal Vibrations from Installation
- Installation Independent from Soil Conditions
What are APG and APGD piles?
APG Piling Rig

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APG Piling Rig

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Crane Pile Installation
APGD Piling Rig

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Berkel Displacement Pile Tool

- Stem, smaller than flighting
- Displacing element. Same diameter as the flighting below
- +- 3 feet, regular flighting, 12” to 18” diameter

Stem becomes progressively larger, terminating in the displacing element

Reverse flighting
APGD PILE INSTALLATION
APGD Piling Rig
PILE LOAD TESTING
Pile Load Test in Static Compression

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High Strain Dynamic Test

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TP-11 (16”-dia. APGD x 45’)

Load vs. Deflection Plot

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Automated Monitoring Equipment (AME)
Overview of Drilling Platform and Sensors

- Stem Rotation Proximity Sensor
- Grout Pressure Transducer
- Main Wrench Proximity Sensor (Depth)
- Inclinometer
- Hydraulic Fluid (turntable) Pressure Sensor
Automated Monitoring Equipment

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Inspector’s Remote Monitor

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### Graphs for PileNo.: SUPER PILE

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>-49.97 ft</td>
</tr>
<tr>
<td>Tip Elev.</td>
<td>32.57 ft</td>
</tr>
<tr>
<td>Pile CO</td>
<td>15.68 ft</td>
</tr>
<tr>
<td>Ground SF</td>
<td>17.40 ft</td>
</tr>
<tr>
<td>P_KDK</td>
<td>121 bar</td>
</tr>
<tr>
<td>Rotation</td>
<td>27 RPM</td>
</tr>
<tr>
<td>P_GROUT</td>
<td>0.0 psi</td>
</tr>
<tr>
<td>Flow</td>
<td>0.0 gal/min</td>
</tr>
</tbody>
</table>

**Total Volume:** 0 ft³

**GRD:** 0.0 ft

**Recording On**

![Torque Graph](image)

**Volume / INC (100%)**
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pile No.</td>
<td>SUPER PILE</td>
</tr>
<tr>
<td>Berkel&amp;Co.</td>
<td>0</td>
</tr>
<tr>
<td>Depth</td>
<td>-61.21 ft</td>
</tr>
<tr>
<td>Tip elev.</td>
<td>-43.81 ft</td>
</tr>
<tr>
<td>Rec Time</td>
<td>03:07</td>
</tr>
<tr>
<td>Max Depth</td>
<td>-62.19 ft</td>
</tr>
<tr>
<td>Penetration</td>
<td>8 ft/min</td>
</tr>
<tr>
<td>Rotation</td>
<td>25 RPM</td>
</tr>
<tr>
<td>P-Grout</td>
<td>22.4 psi</td>
</tr>
<tr>
<td>P-KDK</td>
<td>0 bar</td>
</tr>
<tr>
<td>Flow</td>
<td>106 gal/min</td>
</tr>
<tr>
<td>GRD</td>
<td>0.0 ft</td>
</tr>
<tr>
<td>Last Inc</td>
<td>0</td>
</tr>
<tr>
<td>Step</td>
<td>31 from 31</td>
</tr>
<tr>
<td>RD</td>
<td>0.02 ft</td>
</tr>
<tr>
<td>Need</td>
<td>1.8 ft³</td>
</tr>
<tr>
<td>Act</td>
<td>2.1 ft³</td>
</tr>
<tr>
<td>Perc</td>
<td>119%</td>
</tr>
<tr>
<td>Volume</td>
<td>2 ft³</td>
</tr>
<tr>
<td>Perc</td>
<td>2%</td>
</tr>
<tr>
<td>Remdepth</td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td></td>
</tr>
<tr>
<td>No Errors</td>
<td>Mode: Flowmeter</td>
</tr>
<tr>
<td>Sensors</td>
<td>are ok</td>
</tr>
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</table>
Auger Torque vs. Depth

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Incremental Grout Factors

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### Pile Data for Pile No: SUPERPILE '09

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>6/3/2009</td>
</tr>
<tr>
<td>Start Time</td>
<td>11:15:02 AM</td>
</tr>
<tr>
<td>End Time</td>
<td>11:25:41 AM</td>
</tr>
<tr>
<td>Total Time</td>
<td>00:10:39</td>
</tr>
<tr>
<td>Max Drill Depth</td>
<td>62.19 ft</td>
</tr>
<tr>
<td>Finished Pile Length</td>
<td>60.47 ft</td>
</tr>
<tr>
<td>Pile Tip Elevation</td>
<td>-44.79 ft</td>
</tr>
<tr>
<td>Ground Surface Elevation</td>
<td>17.40 ft</td>
</tr>
<tr>
<td>Pile Cut Off Elevation</td>
<td>15.68 ft</td>
</tr>
<tr>
<td>Elapsed Drilling Time</td>
<td>00:02:26</td>
</tr>
<tr>
<td>Elapsed Grouting Time</td>
<td>00:07:43</td>
</tr>
<tr>
<td>Total Pause Time</td>
<td>00:00:00</td>
</tr>
<tr>
<td>Theoretical Pile Volume</td>
<td>106.90 ft³</td>
</tr>
<tr>
<td>Total Grout Volume</td>
<td>113.06 ft³</td>
</tr>
<tr>
<td>Total Grout Factor</td>
<td>1.06</td>
</tr>
</tbody>
</table>

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**Summary Data**

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PIR-A Components

Control Unit

Magnetic Flowmeter
Nondestructive Testing (NDT)
NDT Controversy

- Many methods and versions available
- Experiences with NDT have ranged from very good to complete failure
- Reliability of methods have been questioned
- NDT practitioners are unwilling (or unable) to make quantitative judgements
- NDT creates more questions than answers
APG Piles Unique Properties

- Large length to diameter ratio (>30)
- High component of capacity in skin friction
- Pumping grout under pressure through layered soils produces multiple changes in cross-sectional area (bulges)
- These properties limit the applicability of certain types of NDT methods
Integrity Testing Methods

- Impulse echo methods - testing from the pile top with a hammer impact
- Limited to an L/D ratio <30
- Cannot detect small (< 1 ft long) defects
- Difficult to distinguish bulges and necking
- Use should be limited to providing additional information - not as a sole pass/fail indicator
Impulse Echo (PIT or PET)
Impulse Echo (PIT)

Figure courtesy of Pile Dynamics Inc
Records Can Be Difficult to Distinguish

A

B

C
Simulated Response - Bulge
Simulated Response - Bulge
Simulated Response - Neck
Sonic Logging

• Crosshole for large piles and singlehole for small (<24 inch) piles
• Developed to overcome sonic echo limitations
• Access tubes must be installed in piles
• Potential for debonding between PVC and grout is a problem
• Typical testing rate is 1 to 10%
SSL Set-Up and Sonic Log

![Diagram of SSL Set-Up and Sonic Log with labels for TO LOGGER, SOURCE, WAVE DIRECTION, RECEIVER, ACCESS HOLE OR TUBE, SIDE VIEW, and TOP VIEW. A graph showing LENGTH (m) against Time (µsec) is also present.]

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Sonic Logging
NDT Summary

• Evaluation of NDT records must include three initial steps
  1. Review the soil conditions
  2. Review the detailed pile installation records
  3. Review the NDT records

• Use this information to determine if the anomaly is indeed a defect in the pile

• A bulge in the pile would not be considered a defect
Limited Headroom Application
Limited Head Room (LHR) Installation

- Used where overhead clearances are at least 8.5 ft
- Track-mounted or forklift mounted drilling equipment
- Piles are drilled with auger sections typically 3 ft to 10 ft in length
- Installation time much longer than with crane-mounted equipment
Typical Limited Head Room Rig
Track Mounted LHR Rig
Earth Retention
Earth Retention - Temporary
Earth Retention - Permanent
Ground Modification
Ground Modification Systems

- Installation of displacement piles results in an increase in soil density
- Liquefaction mitigation
- Piled rafts using APGD piles to increase modulus of soil
- Cast-in-place ground improvement elements (CGE)
- Mechanically compacted ground improvement elements (MGE)
Cast-in-Place Ground Improvement Elements CGE’s

Same equipment and processes as auger pressure grouted displacement piles

May be cast with normal grout mixes or low strength fillers, depending upon application
Alternative: MGE
Feed granular material via reverse rotation to form a Mechanically compacted Ground improvement Element

1. Tooling rotated in downward transport direction to the target improvement level. Can be rotated in the upward transport direction where necessary to penetrate hard zones.

2. Feed granular material via reverse rotation. Use increase in torque or crowd to determine when to move up to next increment.

3. Continue until ground heave is noted at the surface.
Auger Pressure Grouted Energy (APGE) Piles®
Geothermal Technology

• Geothermal heat pumps, or ground source heat pumps, replaces/supplements traditional air conditioning and furnace systems
• The heat pumps simply “move” the heat from one place to another absorbing heat from the ground during heating and extracting heat from the building during cooling
• Geothermal systems deliver up to 4 times more energy than they consume resulting in both cost savings and carbon reduction (up to 50%)
Benefits of using APGE Piles®

- Low extra over cost for geothermal installation
- Minimal impact on piling program
- Uses building piles as thermal mass
- Heat recovery between seasons
- Makes excellent Value Engineering sense
- Provides a Stable & Sustainable energy source
Thermal Conductivity Testing
Thermal Conductivity

• Conductivity is one of the key components used in both the design and operation of geothermal systems

• The ability to measure the thermal conductivity of an energy pile is key to proving the pile is acceptable, similar to running a pile load test to prove capacity
Thermal Conductivity Values
(SI Units - W/m*K)

- Air: 0.024
- HDPE: 0.45 (PVC: 0.23)
- Water: 0.6
- Glass: 1.0
- Thermally Enhanced Borehole Grout: 1.35
- Normal Concrete/Structural Grout: 1.35
- Ice: 2.0
- Saturated Clay: 2.0-2.5
- Saturated Sand: 3.0-4.0
- Limestone: 1.5-3.0
- Shale: 1.5-3.5
- Granite: 3.0-4.0
- Copper: 390
- Diamond: 545
Test Procedures

• ASHRAE published recommended procedures for formation thermal conductivity tests (2007)
• Test duration is 36 hours minimum but 48 hours is preferable
• Data should be analyzed using the line source method
• Power variation should be less than 10%
• Heat rate should be between 15 W to 25 W per foot of depth
Thermal Conductivity Test Unit
APGE Pile® and Pipe Loops
Group Test Results

\[ y = 4.1374 \ln(x) + 82.26 \]
Conclusions

• APG piles have many advantages that will result in continued use and market growth
• New APGD (displacement) piles can now be better utilized in soft soil conditions and for ground improvement
• Pile load testing, automated monitoring, integrity testing can be used for better quality control
• Piles can be used for low headroom, earth retention and ground improvement applications
• Energy piles can be used for cost effective and energy efficient heating and cooling applications
Berkel & Company Contractors

- Over 50 years of experience
- Nation’s largest pile contractor
- Regional offices nationwide
- www.berkelandcompany.com