Energy Pile Research Heating Up in Texas

Energy piles are a relatively new technology that can reduce heating and cooling costs of buildings up to 80%. Increased use of this technology on a more widespread basis will help reduce growing energy demand, depletion of natural resources and adverse effects of carbon dioxide emissions from fossil fuel consumption. Energy piles have seen steadily increasing usage in Europe over the past decade, but have received little attention in the U.S.

The National Science Foundation (NSF) is currently funding a research program conducted by Virginia Tech on energy piles in the U.S. to develop a detailed understanding of their behavioral mechanisms. The research project will answer key questions about long-term thermo-mechanical issues and energy pile performance, and produce new industry guidelines for field testing procedures. This research will further promote the use of energy pile technology in the U.S., which will help reduce our dependence on fossil fuels and the adverse effects of greenhouse gas emissions.

Berkel Test Site – Texas

The Berkel test site is at the company's regional office in Richmond, Texas. The test piles were installed by Berkel & Company using Auger Pressure Grouted (APG) pile installation techniques. Auger Pressure Grouted (APG) and Auger Pressure Grouted Displacement (APGD) piles continue to see significant growth in the market due to their unique combination of speed of installation and high capacity that results in one of the most cost effective deep foundation systems available. APG piles were first introduced in the 1940s, and are also known by a variety of names including auger cast and continuous flight auger piles. In the 1990s the Deep Foundations Institute established the generic term Augered Cast-In-Place (ACIP) piles to describe this type of deep foundation system.

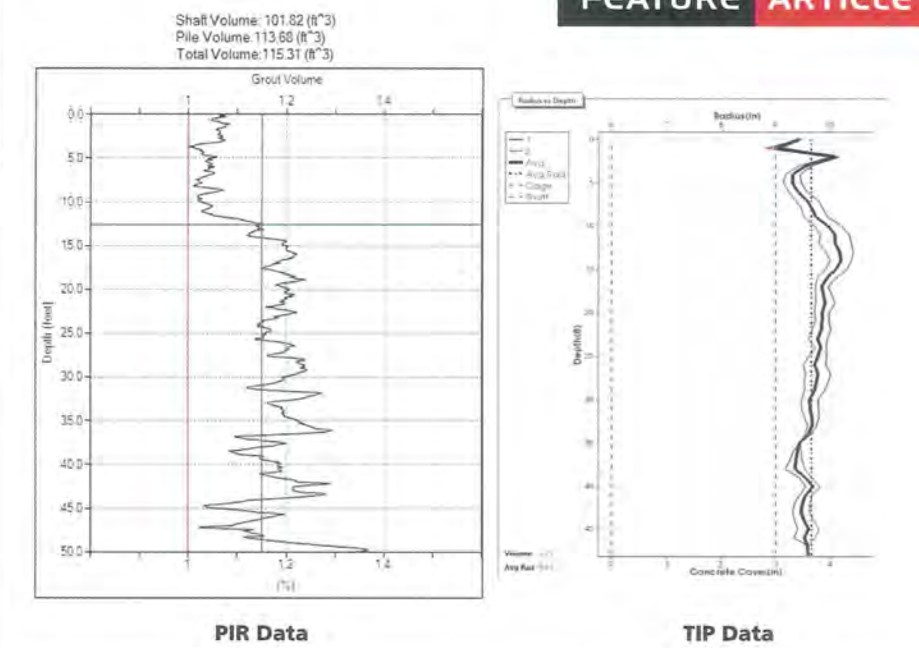

Figure 1. Test Pile 1 - PIR installation data and TIP test results

APG piles installed with geothermal pipe loops are called Auger Pressure Grouted Energy (APGE) Piles®. They are constructed by rotating a hollow stem, continuous flight auger into the ground to the desired tip elevation. When the required depth is reached, a high strength fluid grout is pumped under pressure through the hollow stem of the auger exiting through the tip (or bit). A pre-established amount of grout is pumped prior to lifting the auger to build up a "grout head" around the outside of the auger. The auger is then withdrawn in a controlled manner slowly rotating clockwise as the pumping continues to both maintain the head of grout and avoid any intrusion of water or soil into the grout column. The reinforcing steel and geothermal pipe loops are then installed through the fluid column of grout to complete the pile installation process.

Three 18 in (0.7 m) diameter APGE Piles® were installed as part of this research program. Two piles were installed to 50 ft (15 m) and one pile was installed to 30 ft (9 m). The piles were installed with full length rebar cages, a full length center and a single PEX geothermal loop attached to the center bar. The soil conditions consist of roughly 30 ft (9 m) of stiff clay overlying 30 ft (9 m) dense sand. The groundwater table is about 12 ft (3.6 m) deep. We used a Pile Installation Recorder (PIR) on the drill rig to monitor and record key aspects of the pile installation process.

Test Pile Instrumentation

The test piles were installed with a significant amount of different types of instrumentation, making them quite possibly the most highly instrumented test piles ever installed. In addition to vibrating wire strain gauges and thermistors, the piles were also instrumented with some relatively new technology consisting of full length fiber optic lines and thermal integrity profile wires. The fiber optic lines provide a near continuous measurement of both strain and temperature during testing. The fiber optic technology can resolve strain and temperature measurements on a 4 in (10 cm) spacing along the length pile. The fiber optic temperature line was attached to the center bar. The remainder of the instrumentation was attached to the rebar cage. The thermal wires for the thermal integrity profiler (TIP) testing consist of temperature sensors spaced 1 ft

AUTHORS Tracy Brettmann, P.E., D.GE, Berkel & Company Contractors and C. Guney Olgun, Ph.D., Virginia Tech

(30 cm) apart. The TIP results provide an evaluation of pile integrity consisting of shape, grout quality and location of rebar cage by monitoring the heat of hydration during curing of the grout. Vibrating wire piezometers and thermistors were also installed in soil adjacent to each test pile.

Pile Installation Information

The engineers collected a significant amount of detailed pile installation and pile integrity information as part of this research. In addition to the PIR and TIP data, impulse echo testing was also performed on each pile using Pile Integrity Tester (PIT) Model PIT-X. The engineers also performed profile analyses using the results of the PIT data to compare to the PIR and TIP data. (The results of the installation and integrity test data from Test Pile 1 are shown in Figure 1).

Thermo-Mechanical Test Set-Up

The thermo-mechanical testing on each of the piles occurs over several weeks ranging from 3 weeks to 7 weeks per test. These long test schedules are required to allow for several cycles of heating and cooling of the piles. The preliminary test results will be summarized in a future Part 2 of this article. Two types of load tests will be performed. For one type of test, the pile will first be tested to failure using ASTM D1143 standards (Procedure A) and then will be cycled daily under heating cooling cycles with no axial load for 7 weeks. After the thermal cycles are completed the pile will be reloaded to failure again. For the other type of test the pile will first be loaded to design load (factor of safety of 2.0) and then different levels of temperature increments would be applied for 3 weeks, with the constant design load acting on the pile during the entire test.

Thermo-mechanical test facility

Load testing

The test set-up utilizes two heat pumps so that two tests can be performed at the same time. The test piles and heat pumps are also connected to a heat sink system consisting of a separate energy pile group that was installed for previous thermal conductivity research at this site. The configuration of heat pumps, piping and test piles is shown in the pictures below. Berkel's mechanical engineer, Jim Shaver, and Virginia Tech graduate student, Melis Sutman, designed and fabricated this complex testing apparatus.

This project couldn't have been possible without the generous support of many people and suppliers.

Project Credits:

- Thermo-mechanical test set-up: Jim Shaver and Melis Sutman
- Heat Pump Supplier: Florida Heat Pumps/Mechanical Equipment Sales
- Pile Instrumentation Supplier: Geo-Instruments
- PEX Geothermal Loop Supplier: REHAU Construction
- Fiber Optic Instrumentation/Analysis: Cambridge University
- Thermal Integrity Profiler Equipment/Analysis: GRL Engineers
- Pile Contractor: Berkel and Company Contractors

(This is part one of two part article on the energy pile research being conducted at the Berkel test site in Texas. This part describes the test pile installation and energy pile tests. Part two will discuss the preliminary results of the tests).