Constructibility of Augered Cast-In-Place Piles

By Tracy Brettmann, P.E.

Augered Cast-in-Place (ACIP) 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. However, engineers' concerns with installation issues and quality control (QC) in the past have limited their use.

ACIP piles were first introduced in the 1940's, and are also known as auger cast, auger pressure grouted, augerpile, and continuous flight auger piles. In the 1990's the Deep Foundations Institute coined the generic term Augered Cast-In-Place piles to describe this type of deep foundation system.

New technologies have been developed recently that add to the QC options available for ACIP piles. These new technologies can effectively supplement existing QC procedures and are becoming more popular, especially in new markets where ACIP piles have not been used much.

Pile Jobsite, Houston, TX.

INSTALLATION PROCESS

ACIP piles 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 grout volume is then 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 The auger is then withdrawn in a controlled manner, slowly rotating clockwise as the pumping continues to both maintain the head of grout and avoid intrusion of water or soil into the grout column.

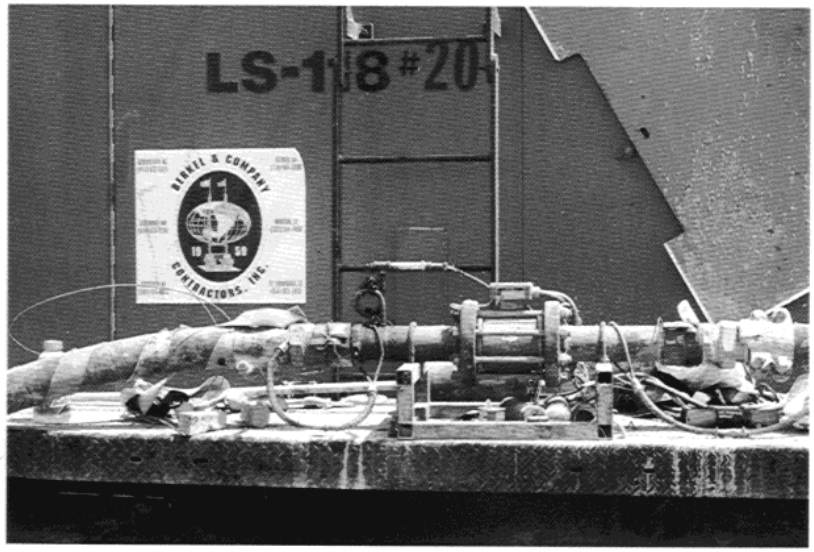
The upper portion of the pile is screened of debris that may fall in while the spoils are removed from the pile location. Reinforcing steel is then placed through the fluid grout column, and the pile top elevation is established by either dipping out or adding fluid grout to the pile.

The grout used consists of Portland cement, flyash, sand, water, and a grouting aid admixture to increase the flowability and eliminate shrinkage during curing. The typical range of compressive strengths for the grout is 3,000 to 5,000 psi.

QC DURING INSTALLATION

In the past, QC has been performed manually by an "inspector." The "inspector" is typically an engineer or technician working for the project's geotechnical engineer or testing laboratory. These manual QC procedures were developed over many years and were published as industry standards by the DFI in the 1990's. They include:

- Grout testing: checking grout fluidity (flow rate) and temperature, and making samples for strength testing.
- Pump calibration: measuring the volume of grout pumped per stroke by counting the number of strokes required to fill a known volume, and dividing the volume by the number of strokes.
- Pile installation: observing the drill depth and grout volume pumped for each pile. Observation of the grout volume pumped is considered to be the most important aspect of the QC process.
- Observing the grout volume involves recording the number of pump strokes used to create the initial grout head, and the number of pump strokes for each five-foot increment along the pile. Typically, a minimum grout head of five feet and a minimum volume of 115 percent of the theoretical volume are required for each increment. The total volume pumped into a pile generally ranges from 120 to 150 percent of the theoretical volume. These volumes are estimated by multiplying the number of strokes by the pump calibration. While this technique is approximate, it has shown good quality results over the years.
- Equipment has been developed in recent years that automatically monitors and records key aspects of the pile installation process. Typical systems measure: (1) time, depth and hydraulic pressure during drilling, and (2) time, depth, grout volume, and grout pressure during grouting. The systems provide a real-time graph for the operator to watch during installation, a print-out of the data, and a digital record that can be stored electronically.
- Grout volume is measured with an in-line magnetic flowmeter that is accurate to within 2 percent. Since the flowmeter measures volume directly, it does not require a pump calibration. Time is measured to the nearest second and depth is measured to the nearest 0.1 ft. These tools result in a remarkably precise and accurate record of pile installation compared to the manual techniques. This equipment does not replace the inspector. It simply provides an accurate and automatic record of key aspects of the pile installation process.



Flowmeter: In-Line Magnetic Flowmeter.

QUALITY ASSURANCE AFTER INSTALLATION

Even though piles installed in accordance with the specifications are considered acceptable, there are times when additional testing is beneficial. This is especially true in new markets where use of ACIP piles has been limited. Designers may require some additional quality assurance that the methods in the specifications result in a good quality, continuous pile that does not contain defects such as necking, soil inclusions or poor quality grout.

Nondestructive testing (NDT) of the structural integrity of the pile can be performed using sonic methods. These tests are performed after the grout has sufficiently cured. The NDT methods used in practice for ACIP piles can be grouped into two categories: (1) surface reflection, and (2) direct transmission.

Surface reflection methods (or pulse echo) involve striking the top of the pile with a hammer to generate a stress wave that is partially or completely reflected by changes along the pile. Wave reflections are monitored with an accelerometer at the top of the pile and, with a few assumptions, the depth to a reflection can be estimated. Unfortunately this NDT method has limited applicability for ACIP piles because the length to diameter (L/D) ratio typically exceeds 30. The reliability of this

Main Control Unit for PIR-A Monitoring Equipment.

method for ACIP piles is further reduced because the process of pumping grout under pressure through various soil layers produces piles with multiple changes in cross-section (bulges in softer layers).

Sonic integrity logging is a direct transmission technique that was developed to overcome both the L/D and multiple changes in cross section limitations. Singlehole sonic logging (SSL) is typically used for ACIP pile applications. With this method, a pair of ultrasonic source and receiver probes is lowered down a single access pipe in the center of the pile. The travel time and signal strength of an ultrasonic pulse traveling between the probes (though the pile) is measured along the full length of the pile. Changes in travel time or signal strength identify the depth where a soil inclusion or poor quality grout is present. Typically only 10 to 20 percent of the piles on a project are selected for SSL. The testing is usually performed at the very beginning of the project to verify that pile installation procedures are resulting in good quality piles. NDT should only be used to supplement detailed installation records and soils information, not as a stand alone, pass/fail type of test.

COMMON MISPERCEPTIONS

There continues to be several common misperceptions of ACIP piles, especially with consultants and designers who do not have much experience with them.

1. Piles are difficult to inspect so little can be done to control quality. While this may have been true a long time ago, industry standards for installation and quality control were published over a decade ago. Recent development of automated monitoring equipment has further improved the ability to monitor and control key aspects of the installation.

2. Piles cannot be adequately

reinforced for high lateral or seismic loading. Advancements in grout mixes and equipment over the past 20 years have led to piles with diameters up to 36 inches with full-length rebar cages. Steel pipe and wide flange sections can also be used for reinforcement, if necessary.

3. A full length cage is required so ACIP piles can't be used. In practice, there are actually only a few cases where a full-length cage is required due to the structural loading conditions. In most cases a partial-length cage in the upper portion of the pile and/or a full length center bar would meet the loading requirements. The most cost effective designs match the actual loading conditions (compression, tension, lateral) with the minimum allowable amount of reinforcement along the pile section to meet those requirements.

4. Piles can't be socketed into rock. Advancements in the size of the equipment, types of rigs used, and drill bits over the last several years have resulted in large increases in both the amount and strength of rock that can be penetrated.

5. Pile quality is highly dependent on the contractor. Use of the latest QC technologies would likely eliminate the word "highly" from this misperception. However, it is true that pile quality depends on the skill of the contractor. Most specifications contain minimum experience requirements for a contractor (typically five years), both in terms of overall experience and similar job specific experience. While the QC new technologies may be a significant improvement, qualified and experienced contractors will always be a fundamental requirement. ❍

Surface Reflection Integrity Testing.

Sonic Integrity Logging.

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The Deep Foundations Institute has just published the 2nd edition of their Augered Cast-In-Place Pile Manual. The committee overseeing the guideline"addresses current trends in ACIP pile construction and quality control." Updates include discussions of higher capacity ACIP piles, and commentaries on automated monitoring equipment and non-destructive testing. (ed.)