ACIP piles being installed at the Revel Casino in Atlantic City, NJ

The Evolution of Augered Cast-in-Place Piles

In 2013, Augered Cast-in-Place (ACIP) piles are a mature foundation technology throughout the United States. General guidelines for the design and construction of ACIP piles are available along with numerous references for design in specific North American geologies. In fact, the current generation of contractors and geotechnical practitioners might view ACIP piles as just another deep foundation option to be considered, along with driven piles, drilled shafts and others. This acceptance has developed, however, over a 60-plus year period.

The term, Augered Pressure-Grouted (APG) pile is often used when referring to ACIP piles because the piles emerged out of construction processes at the Intrusion-Prepakt firm in the late 1940s. The company's specialty was pressure grouting and pre-placed aggregate concrete. The grouting was typically accomplished by driving a pipe to a target level and then injecting grout under pressure. In some soil conditions, it was necessary to use an auger to reach the desired grouting depth. In these circumstances, the grout pipe was driven beside the auger and grout was pumped as the auger was withdrawn. The grout pipe was then withdrawn as well. This was the genesis of the APG, or ACIP pile, and many piles were installed using this technique.

Patent, Licenses

The patent application, "Method for Forming Piles" was filed by Raymond Patterson of Intrusion-Prepakt in 1951, and the patent was granted in 1956. The process was eventually modified when a suitable hollow-stem auger was developed. Licenses were granted to the Lee Turzillo Contracting Company and Berkel & Company Contractors, Inc. in the late 1950s. Each of the three companies coined their own terms for the piling process: "Pakt-In-Place" for Intrusion-Prepakt, "Auger Pressure-Grouted" for Berkel and "Augercast" for Turzillo. Over time, "Augercast" was frequently used as a generic term for the system. The installation of these piles was, and still is, a highly nuanced process; "contractor dependent" is a term often seen today. Intrusion-Prepakt, Berkel and Turzillo all had personnel who were part of the original group that developed the system and who appreciated the craftsmanship involved in forming sound piles.

Early installation platforms were wagon or truck-mounted, and augers were advanced by relatively low-torque power units of about 15,000 ft-lbs (20.3 kN-m). Leads were mounted on mechanical cranes that made it difficult to retract the auger smoothly, and grout was placed with pneumatic pumps. Masonry sand was used in the grout (to allow the grout to be pumped with the fairly low-power pneumatic powered piston pumps), and grout was batched on site from bagged cement, fly ash and a grouting agent. The use of the fine masonry sand limited the achievable compressive strength to typically about 3,000 psi (20.7 MPa). The construction of 400 to 500 linear ft (122 to 152.5 m) of piling in a single day was considered quite an accomplishment. The piles were generally 12 in to 16 in (0.3 m to 0.4 m) diameter with short lengths and of relatively low capacity. The contractors installing ACIP piles worked continuously to address these issues through the development of improved equipment and processes.

1970s and 1980s: Transitional Period

The level of ACIP pile activity increased steadily in the early 1970s, although they were still being used primarily where loads were fairly modest or where substantial uplift resistance was required.

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This time was also a transitional period for the ACIP pile industry. Equipment with increasingly higher torque was becoming available. Gear boxes with 30,000 ft-lbs (40.7 kN-m) of torque were now common). The installation process was also being refined. Ready mix companies were now routinely supplying grout, and mixes with concrete sand could be used thanks to more powerful and efficient pumping equipment.

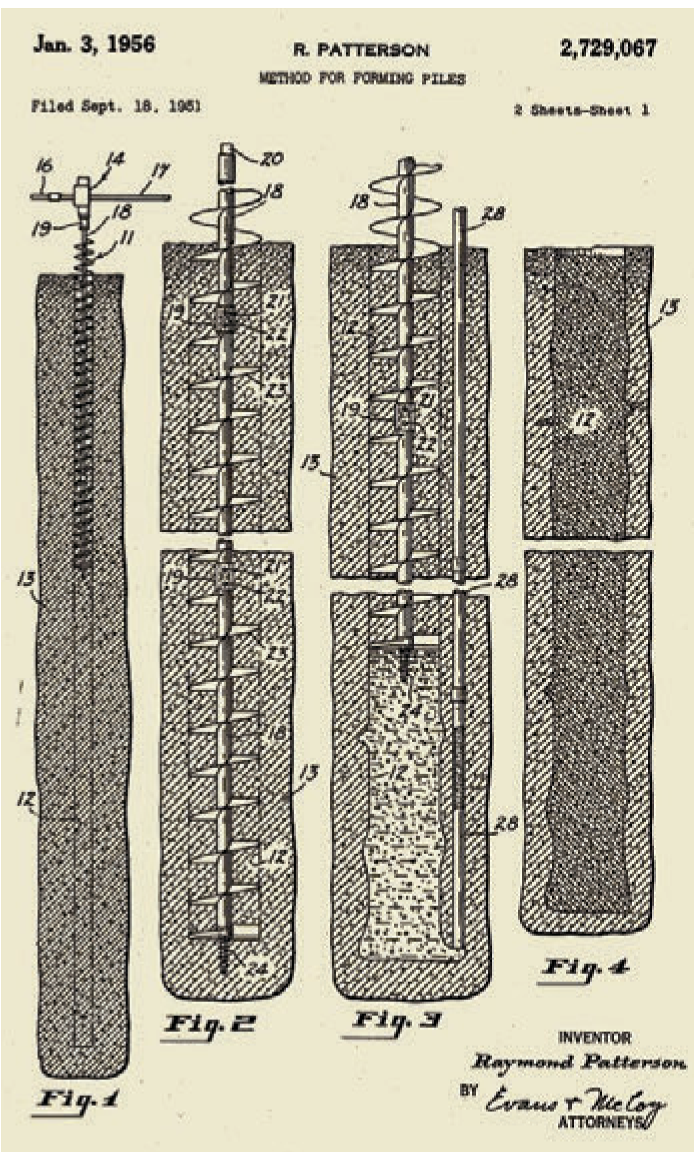
Additionally, the original patent for ACIP piles expired in the mid-1970s, and the number of companies offering the system grew. This led to a greater exposure of the system in the market. However, it also diluted the pool of those with a deep appreciation of the nuances of the process. The installation looks simple, and most of the major equipment needed can be rented; however, seemingly minor changes in materials or procedures typically have a large impact on the finished product.

As installers were making significant advances in equipment, materials and installation processes, market forces were also at work that would provide more opportunities for ACIP piles. In many markets where ACIP piles were beginning to gain some acceptance, driven piles and drilled shafts were more traditional and widespread. Raymond Step-Taper piles were a staple in many of these markets. Additionally, inexpensive oil-field pipe, suitable for piling, had become available and driven systems tended to dominate the market. Drilled shafts were also typically used where loading and subsurface conditions were appropriate.

In the 1980s, as the price of steel increased and the oil field pipe that had been so plentiful (and cheap) was beginning to dry up, ACIP piles moved into the void that was being created in the driven pile market. At the same time, the ACIP pile industry developed more powerful equipment capable of producing in excess of 40,000 ft-lbs (54.2 kN-m) of torque; tooling capable of penetrating more resistant materials; and more powerful, more reliable and higher capacity grout pumps. Projects that exemplify the advances in the system were the World Congress Center in Atlanta, where piles were extended into partially weathered rock and the Miami Rapid Transit System with piles penetrating into soft limestone. These projects solidified the position of ACIP piles in their respective areas (which were both experiencing rapid growth) and provided a template for the introduction of the system in other major metropolitan areas.

Growing Knowledge Base

Another significant factor in the growth of ACIP piles during this time was a substantial increase in the knowledge base in the geotechnical engineering community and an increasing level of confidence in ACIP pile quality control processes. References for static capacity analysis and quality control began to appear more frequently, and standard specifications became a part of the deep foundation literature. In 1990, the Deep Foundations Institute (DFI) published the *ACIP Pile Manual*. This was the first industry-based document that provided a detailed, comprehensive guide for installing ACIP piles (the manual was updated in 2003). DFI has also published a model specification and *Inspector's Guide to ACIP Piles*.



The patent application for "Method for Forming Piles" granted in 1956

From the earliest installation of cast-in-place piles, the question of, "How do you know what you have here?" has asked been asked. The issues of whether or not the piles being formed were sound, continuous and of the proper diameter were of high concern, as installation was very operator-sensitive. Early basic inspection guides included monitoring the drill depths and the grout volume and reinforcing steel placement. The drill leads were marked to indicate drill depths and the grout pumps were calibrated for their output. From this, a pumping procedure in terms of the number of strokes-per-foot could be established for given diameters in varying soil conditions.

Early installation of ACIP piles

This same basic process is used today, but the methods of gathering information have changed radically. There are numerous monitoring systems on the market to electronically measure tool depth, torque, grout placement and a variety of other parameters during ACIP pile construction. The first modern automated monitoring system in North America was the Pile Installation Recorder (PIR), developed by Pile Dynamics, Inc. working with Berkel & Company on its development and implementation in 1995. Since that time numerous other automated monitoring systems have become available.

An example of the market penetration of ACIP piles in the 1990s was the preparation for the 1996 Olympic Games in Atlanta, where the system was selected for the majority of construction where deep foundations were needed. The most visible symbol of the Olympics, the Olympic Stadium (later to be transformed into Turner Field, home of the Atlanta Braves), saw the installation of more than 123,000 ft (37,490 m) of piling that ranged from 35 ft to 85 ft (10.7 m to 25.9 m) in length.

The project included 16 in (0.4 m) diameter piles with a design compressive load of 150 tons (1,335 kN), requiring a grout compressive strength of 6,000 psi (41.4 MPa). This, in contrast with the struggle to produce 3,000 psi (20.7 MPa) grout 30 years earlier is an example of how one component of the ACIP system has advanced, and all aspects of the process have advanced similarly. Clearly, the major thrust in the use of ACIP piles has been in development of equipment, materials and processes to go "bigger and deeper," and the increase in design loads reflects that emphasis. Certainly, increases in capacity of conventional ACIP piles will occur with development of more powerful equipment; however, new processes seem to be the likely source of significant changes in the cast-in-place pile industry.

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Approximately 400 ACIP piles were placed for the Maui Hyatt Timeshare Tower in 2012

During the 1990s, European systems based on fixed mast installation platforms entered the U.S. market. In contrast to the historical emphasis on the casting process seen in conventional ACIP piles, the European drilled displacement (DD) and Continuous Flight Auger (CFA) piles evolved with an emphasis on control of the drilling process, and these systems brought with them a broad base of related data acquisition technology.

Technology Tour

In 2002, representatives of AASHTO and FHWA embarked on a technology scan tour of Europe. The purpose of the trip was to see if there were construction techniques in place in Europe that would be of value in accelerating FHWA projects. Several processes found to be of interest were documented in two papers by Ali Porbaha, Dan Brown, Alan Mcnab and Richard Short. Both papers were presented at the DFI Annual Conference on Deep Foundations in San Diego in October of 2002.

A major element of the tour was an interest in the European method of installing cast-in-place piles, and that interest developed into an initiative to produce FHWA Geotechnical Engineering Circular (GEC) No. 8, *Design and Construction of Continuous Flight Auger Piles,* which was published in April, 2007. The implementation of the European systems and the fusion of European and conventional U.S. systems continue today.

Over the past 60-plus years, the ACIP pile industry, and the application of the system have changed dramatically. Today, APG piles of over 42 in (1.1 m) diameter and 150 ft (45.7 m) in depth are not uncommon. Where ACIP piles were once used to support relatively modest loads, they are routinely installed in geologies today where the load limits are structural (from code limits relating the allowable load of the grout or concrete used) rather than geotechnical. For example, 24 in (0.6 m) diameter APG piles have been installed to support 400 ton (3,559 kN), or greater, single-pile compressive loads on multiple projects in the past few years.

At the Hindu Temple in Windsor, N.J., 750 ACIP piles are being installed for a new temple with 1,000-year design life

Conclusion

Contractors working in the ACIP pile arena have recognized the need to develop higher-capacity equipment, refine installation and quality control procedures, and to develop materials and equipment to provide ever increasing capacities in a broader range of subsurface conditions. Material suppliers have developed grout additives that make it possible to cast piles with increasingly reliable high capacities and to insert reinforcing steel to greater depths. Just as important, many in the geotechnical community have responded with a willingness to evolve technically, and the result has been the application of ACIP piles over a broad range of construction types in an increasing variety of geologic settings.

Visit the DFI ACIP pile committee web page at www.dfi.org to learn more about this technology.