Augercast Piles in Hawaii

By James W. Niehoff, P.E.

A few days after initiating augercast pile installation for the 40-story Hokua Tower in Honolulu, the foundation contractor was approached by a neighbor who asked when pile driving would begin. Virtually all of the nearby high-rise structures were supported by precast piles driven to depths of 100 to 150 feet. The neighbor was relieved to hear that nearly ¼ of the foundations had already been installed, and that he would not be subjected to the noise or vibrations associated with pile driving.

Project Description

The Hokua Tower is a high rise condominium completed in 2005, located at the northeast corner of Ala Moana Boulevard and Queen Street west of the Waikiki area of Honolulu, Hawaii. The development includes a 40-story condominium tower and an adjacent 4-story parking structure that also houses retail and commercial space (*Figure 1*). The building incorporates a post-tensioned concrete structural system with a central core, housing elevators and stair wells, which is designed to resist wind and seismic shear loads.

Waikiki Area

The Waikiki area of Honolulu was not always the bustling tourist mecca that it is today. Until the early part of the 1900s, most of the area consisted of low-lying wetlands occupied by ponds and swamps. In the late 1920s, the Ala Wai Canal was constructed through the swamp, allowing it to drain and producing dry properties for the development of hotels and resorts. However, as might be expected in a former swamp, subsurface conditions are relatively poor, with peat deposits, loose sands, silts and clays extending from the surface to depths of about 20 to 30 feet. These near surface soils are underlain by a series of coral reef deposits, each about 20 to 40 feet in thickness. Basaltic bedrock, associated with the Koolau mountain range, typically lies several hundred feet below grade.

For the past 50 years, foundations for mid to high rise structures built in the Waikiki area were installed by predrilling through overburden soils and the upper coral formation, then driving precast piles to end bearing in coral limestone at depths of 100 feet or greater. Pile capacities were typically limited to 100 tons per pile. While these foundations were relatively easy to install, they were not particularly efficient or cost effective.

Hokua Foundation Design

Subsurface conditions at the site of the Hokua project were typical for the area, with about 25 feet of poor quality soil overburden, followed by an upper coral formation about 25 feet in thickness. This was underlain by about 30 feet of loose to medium dense gravel, then by another layer of coral. For this project, the geotechnical engineer judged that conditions were ideally suited for the use of augercast pile foundations.

Augercast piles are installed by drilling a borehole with a continuous flight, hollow-stem auger to a depth compatible with proper support, and then pumping high strength grout through the auger tip as the auger is withdrawn. A steel reinforcing cage is subsequently installed in the pile from the top, through the fluid grout, to resist lateral loads and to provide for connections to the pile cap (*Figure 2, page 24*). Support is derived by side shear resistance as well as end bearing. This pile type is particularly well suited to sites underlain by dense granular soils or weak bedrock materials, where high side friction can be developed between the fluid grout and the irregular sides of the borehole. Augercast piles typically range in diameter from 14 inches to 40 inches, and can support compressive loads ranging from 100 to over 1000 tons per pile.

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Figure 1: The Hokua Tower.

Project Team

Structural Engineer: Magnussen Klemencic Associates, Seattle, WA
Architect: Handel Architects LLP, San Francisco, CA
Construction Management: Brett Hill Management Group LLC, Honolulu, HI
General Contractor: Albert C. Kobayashi, Inc., Honolulu, HI
Augercast Pile Contractor: Morris-Shea Bridge Company, Birmingham, AL

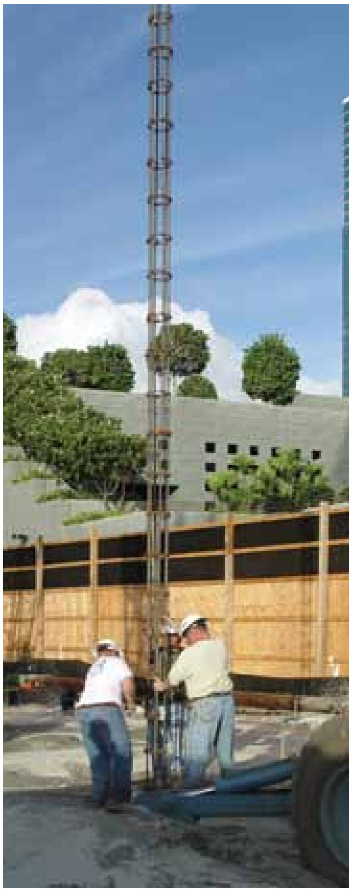

Figure 2: Pilot Hole Drilling.

Figure 3: Installation of Reinforcing Cage.

There was only one problem with the selection of augercast piles for this development. While this pile type had found wide use in the continental United States, it had never been utilized in Hawaii for foundation support. There were no local contractors with experience in installing these piles, nor a history of satisfactory performance. Local building officials were unfamiliar with the foundation and were uncertain as to whether it could be approved.

Ultimately, following several months of work with building officials, the design team, and the contractors, design and permitting issues were resolved and 18-inch diameter augercast piles were selected for support of the building. In the tower area, piles were designed to extend through the upper coral formation, the underlying gravel and into the second coral formation at a depth of 90 feet. These piles were designed to support compressive loads of 200 tons each. In the more lightly loaded 4-story parking deck section of the development, piles were designed to support a 150-ton capacity exclusively from the upper coral formation within 50 feet of the ground surface. This represented a 50 to 100 percent increase in capacity, at about ½ the depth of traditional driven piles.

Construction

Prior to pile construction, a series of boreholes were drilled with the crane mounted drill rig to confirm that the augers could penetrate the weak coral formations (*Figure 3*). Then, two load tests were performed on piles extending into both the shallow and deeper coral formations to confirm design capacity. Since the coral is irregularly shaped and contains numerous small voids and channels, grout formed an integral bond with the foundation materials. Side shear capacities of up to 6,000 pounds per square foot were developed in the coral strata. Both load tests demonstrated satisfactory support capacity and production pile installation was begun.

From a technical standpoint, pile installation proceeded smoothly. The only problem occurred at about the midpoint in the project when a concrete company labor strike cut the supply of grout to the project site for several weeks. Overall, the construction manager for the project estimated that the use of augercast piles resulted in a net savings of over $1 million when compared with traditional driven piles, considering the number and depth of piles and the size of pile caps. Further, neighboring property owners and the city were pleased with the reduction in noise and vibration during installation. As a result of this project, nearly all high rise construction in the Waikiki area has utilized either augercast piles or drilled pier foundations since 2005.

Figure 4: Pile with Settled Grout.

Construction Considerations

While the voids in the coral formations in the Waikiki area are beneficial to the development of side shear resistance for augercast pile foundations, they can cause problems as well. Grout volumes for piles installed in typical soil and rock profiles within mainland U.S. sites generally range from 110 to 140 percent of the theoretical volume of the pile. In porous coral formations, it is not unusual for grout volumes to range from 180 to 200 percent of the theoretical volume of the pile.

A short time after completion of the Hokua project, augercast piles were selected for use in the redevelopment of several city blocks in Waikiki. The local geotechnical engineer selected standard specifications for augercast pile installation that referenced a grout take factor of 145 percent. The pile installation contractor followed this specification and installed piles in a normal manner. Following installation of the reinforcing cages, the pile tops were covered with plywood sheeting to protect the fluid grout and to eliminate a hazard to workers. However, upon removing the sheeting several days later, the grout was observed to have dropped in some of the drilled boreholes to a level several feet below the groundwater table. The reinforcing cages had been pulled downward and distorted by the dropping grout (*Figure 4*). Ultimately, all of the installed piles required assessment by pile integrity testing and several required replacement at a cost of several hundred thousand dollars.

Conclusion

The introduction of augercast piles on the Hokua Tower project resulted not only in substantial cost savings for one project, but changed decades-old established foundation design practices in the most developed areas of Hawaii. As engineers, we must all look for opportunities to transfer technologies and construction practices to further the state of practice, and develop cost-effective and safe designs. We must also know the limitations of the technology and construction practices. Personal experience is critical in the application of structural and foundation systems to new areas, particularly in the preparation of specifications and the inspection of installation.▪

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