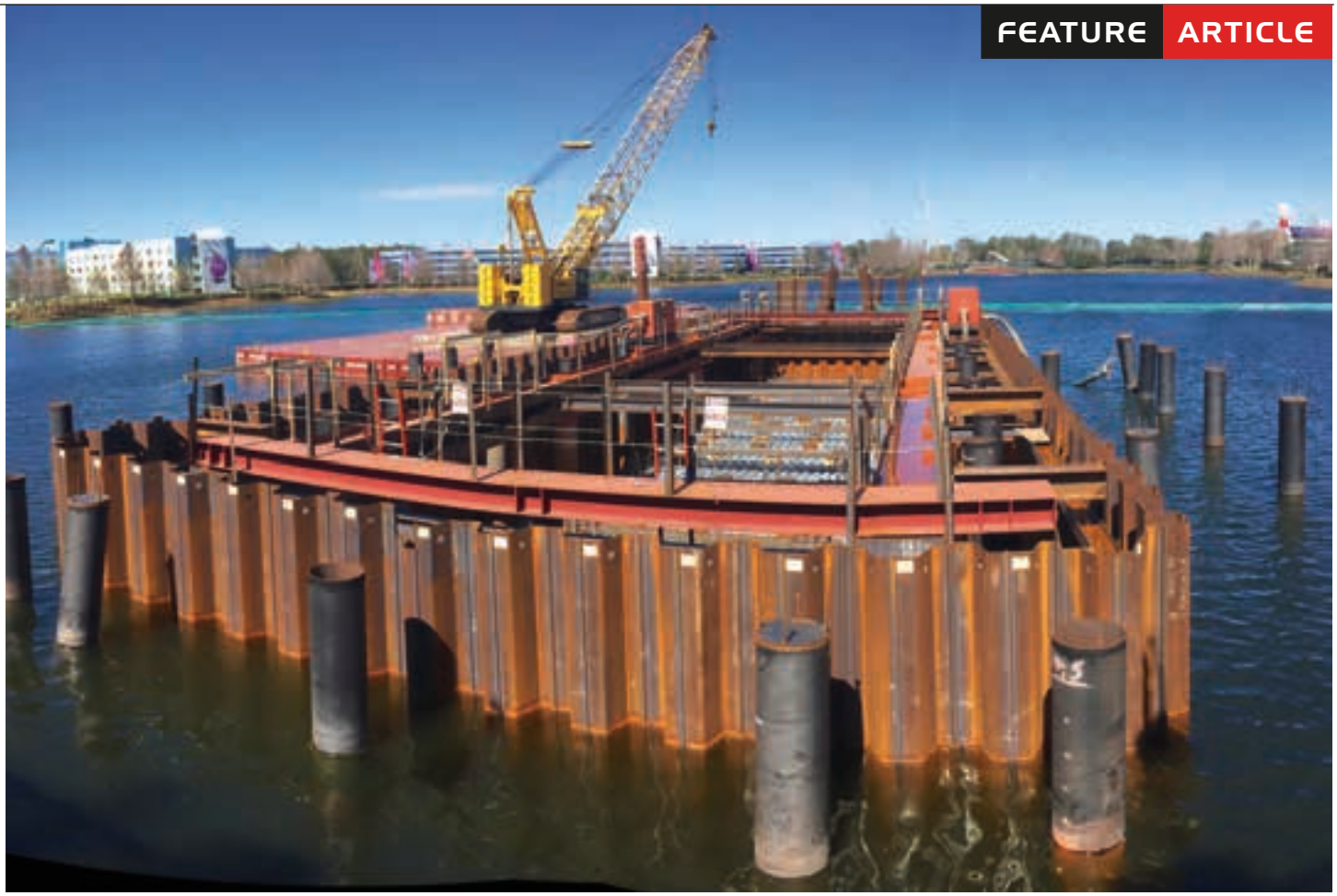

Multiple Pile Systems for New Disney World Skyliner System

Morris-Shea has completed construction of deep foundations for the new Skyliner Transportation System at Walt Disney World in Orlando, Fla. The foundation contractor worked closely with the project's general contractor, PCL Construction Services (PCL), to install more than 900 piles throughout the cable gondola system comprising six stations and numerous support towers. The new Walt Disney World ride will connect Disney's Riviera, Caribbean, Boardwalk and Animation resorts with the International Gateway at Epcot Center and Disney's Hollywood Studios Theme Park.

The foundation contractor recommended a design-build option in lieu of the originally specified pipe piles and augercast system that reduced construction expense, improved operational logistics, and provided scheduling and environmental benefits. The value engineered alternate resulted in the redesign of most of the foundations, ultimately incorporating six different pile types. The contractor also installed a temporary sheetpile cofferdam and falsework for the construction of the new Pop-Darr gondola station and constructed a sheetpile bulkhead for use as a work-barge dock.

Project Constraints and Logistics

Morris-Shea collaborated with PCL and Disney's structural and geotechnical engineers to provide design assistance to implement the most economical foundation solution for the variable access and subsurface conditions present at the various installation sites. There were many variables to consider, including drastic changes in soil conditions from one location to another, active utilities, tight access conditions, noise restrictions and guests who could not be disturbed. Some work and all equipment movement had to be performed at night to avoid impacting traffic and pedestrians during park hours. All material deliveries required close coordination and advance approval to minimize congestion and disturbance with park operations.

Much of the project included the installation of deep foundations for the ride's many towers. These support structures are generally spaced at 200 to 600 ft (61 to 183 m) on center, with each station's approach and departure towers placed at approximately 30 to 150 ft (9 to 46 m) on center. The towers' heights range from 20 to 90 ft (6 to 27 m) tall. Access to

AUTHOR *Gordon King, Morris-Shea*

Installation of a DDP

some tower locations required that the drill rigs fit through Disney property service road tunnels and between closely spaced buildings. Jobsites were also often located beside lakes, fire stations, medians, and near active parking lots and even a gas station.

The contractor's compact and powerful drill rigs (Fundex CD20D and TTD50) were able to access tight work areas and install a new type of DeWaal screw pile (SP) within the confined jobsites. Consequently, pile installation at the tower locations required minimal access preparation or post-pile installation site remediation. Standard DeWaal drilled displacement piles (DDPs) were installed where access and pile quantities justified the use of larger drill rigs (Fundex F3500), such as at the Hollywood, Caribbean and Trinidad gondola stations and nearby towers. Helical piles or SPs were installed on all other tower locations with the exception to Run B, where driven pipe piles were used.

The installation of DDPs and SPs was performed adjacent to and within Disney hotel complexes where strict noise limits and work hour restrictions were in effect. The use of DDPs minimized disturbance to guests by employing a quiet, vibrationless installation process that produced little or no spoils. The DDP foundations were primarily installed where vertical and horizontal clearances were sufficient for rig access. The SPs were installed where restricted access or height clearances were problematic and required compact rigs.

Subsurface Conditions

Construction of the gondola station and tower foundations encompassed a large area within Walt Disney World that included uplands and wetlands, developed and undeveloped property, and areas that have been altered by previous construction activities. Soils in the upland areas comprise a varying sequence of fine sands grading relatively clean to slightly silty, and occasionally clayey in composition from the existing ground surface to depths of approximately 35 to 75 ft (10.7 to 22.9 m) below grade. The upper sands are primarily in a medium dense-to-dense condition with localized zones that grade loose-to-very loose and/or very dense. The silty to clayey fine sands of the Hawthorn Formation were encountered below the upper sands and are underlain by the region's continuous limestone formation.

Portions of the proposed alignment are located in wetland areas to the east of Disney's Hollywood Studios and to the north of Buena Vista Drive. The borings in the smaller wetland near Buena Vista Drive disclosed a relatively thin layer of organic soils/peat from the ground surface to depths of 1 to 2 ft (0.3 to 0.6 m) below grade. Borings in the larger wetland east of Disney's Hollywood studios encountered organic soils and peat from the ground surface to depths ranging from 11 to 15 ft (3.4 to 4.6 m) below grade. Underlying the upper zone of organic soils, shallow borings encountered sandy soils typical of the upland areas followed by the Hawthorn Formation. In deeper borings, the Hawthorn materials persisted until encountering limestone at depths of 110 to 155 ft (33.5 to 47.2 m) below grade.

Pile Testing

Cone penetration testing (CPT) was performed with a 30-ton (27 tonne) rig at a test site near the Trinidad Station location. The foundation team also referenced its pile capacity software for load test data from previous piling projects to assist in predicting pile behavior. The foundation contractor optimized the foundation redesign assuring the DDP was a preferred value engineered alternate over conventional augercast piles. The Trinidad area had

Cone penetration testing at a test area

both of the predominate soil conditions represented across the total site — one test area had the dense upper sand layer and the other test area represented a looser soil.

Four piles each were installed and tested (two axial compression tests, one lateral test and one tension test) at each test area in both the dense soil and the looser soil profiles to evaluate the DDPs and SPs. Each static load test was performed on nonproduction piles. Based on the results of the load testing, the DDPs and SPs demonstrated the compressive, tension and lateral resistance required to facilitate development of the installation criteria for the production piles in the locations previously specified for conventional augercast piles.

Drilled Pile Installation

Helical PC-CIDH Piles

Helical, permanently-cased cast-in-drilled hole (PC-CIDH) piles, 14 in (356 mm) in diameter, were installed with a Fundex CD-20 drilling rig in the more restricted tower locations at the Caribbean resort. These piles were a value engineered alternate that replaced the originally specified 24 in (610 mm) diameter augercast piles. The use of the CD-20 and drilled helical piles minimized disturbance to the guests by reducing the need for demolition, site prep, tree removal and drill spoil disposal.

The helical PC-CIDH piles were installed adjacent to one another during the same workday, which would not be possible with the augercast piles due to quality control (QC) concerns. Consequently, the contractor was able to access and complete the tower foundations quickly. The installed helical piles were capped and could be buried over until PCL was ready to fill the pile with concrete and to construct the pile cap.

DeWaal DDPs

A Fundex F3500 drill rig was used to install the standard DDPs at the Trinidad, Hollywood Studios and Caribbean gondola stations. The high-capacity DDPs were rapidly installed with low noise at the stations and nearby tower foundations, as the DDPs were typically installed with cycle times as low as 10 to 15 minutes.

Installation of a DDP

Installation of these piles involved the advancement of the tool into the soil, which was fitted with a disposable end plate and advanced under significant axial crowd and torque. During drilling, the sidewalls of the borehole were supported by a temporary casing that also acted as a drill stem and large-diameter concrete tremie pipe. Upon reaching the specified depth, advancement of the tooling was halted, and a center reinforcing bar was inserted to the bottom of the temporary casing.

High slump, self-consolidating concrete with coarse aggregate was pumped through the temporary casing. The concrete flowed under pressure into the ground while the tool was withdrawn, leaving the sacrificial endplate behind. The reverse flight located on the topside of the displacement element assisted with the extraction by cutting and recompacting any loose soils. This added soil densification helped to minimize concrete overconsumption and optimize pile capacity. Increases in unit side friction over those typically observed for augercast piles range up to 30% in loose granular soils.

After the withdrawal of the tooling, a steel reinforcing cage was placed in the pile. The rebar cages were manufactured at one of three automated Morris-Shea in-house fabrication centers. Upon completion of each pile, the drill rig transmitted installation data to project managers and quality control professionals.

DeWaal SPs

The screw pile is a new and innovative variation of the standard DDP. Specialized SP tooling created screw shaped concrete threads on the perimeter of the pile, producing much greater shaft friction and overall pile capacity. The unique SP was developed by Morris-Shea and was first

Installation of pipe piles on Hourglass Lake

used in the restricted access conditions found at many of Walt Disney World's gondola foundation jobsites. The SP offered a vibrationless, cast-in-drilled-hole (CIDH) solution that minimized noise and eliminated spoils at Disney's Trinidad, Caribbean and Epcot International Gateway locations. Fundex CD20D and TTD50 compact drill rigs were ideally suited for installation of the SPs in these limited access sites.

The SP utilizes a steel casing with a sacrificial cutting head that advanced into the ground causing soil around the casing to displace laterally. This installation process transferred continuous torque and crowd forces to the tool until the desired depth was achieved. Drilling speeds were monitored to assure development of a well-formed SP profile that satisfied this foundation's high load capacities.

Minimal to no drilling spoils are produced or transported to the working surface, making this foundation application suitable for the environmentally-sensitive areas surrounding much of the Walt Disney World gondola system. After installation, each steel casing was filled with self-consolidating concrete and reinforcing steel, producing a high load bearing capacity. All aspects of the SP drilling process and concrete placement were observed and recorded by automated monitoring equipment (AME).

Driven Pile Installation

Pipe Piles

Pipe piles with a 20 in (508 mm) OD and a 0.5 in (13 mm) wall thickness were installed to depths up to 160 ft (49 m) to support the Pop-Darr station and five tower foundations located on Hourglass Lake. Similar sized pipe piles were driven on land for the Run B tower foundations where the depth to bearing strata was well over 100 ft (30 m) and often as deep as 160 ft (49 m). The pipe pile installation utilized lattice boom crawler cranes: a barge-mounted Kobelco CK1600 on Hourglass Lake and a Kobelco CK1000 on Run B. The piles were initially driven with a vibratory hammer and then seated with a Delmag D-25 direct drive diesel hammer. Load capacity for each pile was verified using PDA testing.

CD-29 rig used to install the H-piles

Preparation for construction of a pile cap

H-Piles

The foundation contractor installed driven H-piles at the International Gateway Station at Epcot. Access was very tight, so the contractor used a rough terrain crane with a vibratory hammer. The H-piles were driven in sections and spliced, as required, to reach the bearing strata more than 100 ft (30 m) below ground surface. Load capacity was confirmed by driving several H-piles with an IHC CPE-30 hydraulic hammer mounted on a Fundex CD-20 compact drill rig.

Cofferdam and Falsework

An internally braced cofferdam consisting of PZ-27 sheet piling, wide flange beam and a pipe bracing system was designed and installed at the Pop-Darr gondola station on Hourglass Lake. The foundation slab at the bottom of the new station is supported on driven pipe piles and is approximately 8 ft (2.4 m) below the lake's normal pool. The cofferdam provided a method to dewater the area, so concrete work could be performed by the general contractor. In addition, a temporary falsework support system was designed and installed at Pop-Darr for the concrete formwork. This installation included temporary pipe piles, bracing and support systems, which were all removed after the general contractor completed the concrete work. The foundation team also designed and installed a sheet pile bulkhead for loading and unloading cranes, materials and other equipment onto barges.

Preparation of concrete slab within cofferdam

Gordon King is engineer manager with Morris-Shea. King holds a B.S. degree from the University of Dundee, Scotland, an M.S. degree in geotechnical engineering from the University of Durham, England, and has more than 30 years of geotechnical consulting and specialist foundation contracting experience.