Large Diameter Cast-in-Place Concrete Piles
Whitestone Expressway Project

This project in New York City involves the replacement of the northbound Whitestone Expressway over the Flushing River at the Van Wyck Expressway interchange. Three fixed span structures over the river will replace a bascule bridge that was built in 1939. The three structures over the river include the northbound Van Wyck Expressway ramp, Astoria Boulevard approach along the mainline northbound Whitestone Expressway and a ramp to Linden Place. Reconstruction of the ramp to southbound Van Wyck Expressway is also included in this work. This New York State Department of Transportation (NYSDOT) project was awarded in 2003 at a cost of $177 M. Located in the Flushing Meadows section of Queens, the project is near LaGuardia Airport, Shea Stadium, the U.S. Tennis Center, and the site of the 1939 and 1964 World's Fairs.

Aerial Photo of Project

During the design phase of the project, the challenge was to provide cost-efficient foundations that could resist high lateral loads in poor soil conditions. The project is located in a filled tidal wetland with Organic Silt deposits as thick as 50 feet. Below the Organic Silt are intermittent layers of Silty Clay underlain by Silty Sand with sporadic boulders. A requirement for the deep foundation design is the resistance of lateral loads from a seismic event including the transient loads induced by the soil. The foundation was also required to resist drag loads from consolidation of the Miscellaneous Fill and Organic Silt.

The objective was to find a deep foundation that provided efficient lateral stiffness, avoided soil clean-out, eliminated underwater concreting and was straightforward to inspect. It was also important to choose an installation method that could draw on local contractor experience in order to optimize competitive bidding. After weighing these considerations, large diameter cast-in-place (CIP) concrete piles became the foundation of choice. A new payment item for 18 inch and 24 inch CIP piles was created for this project since this was a first time use of these sizes on a NYSDOT project. CIP piles with a diameter of 14 inches were also used on this project.

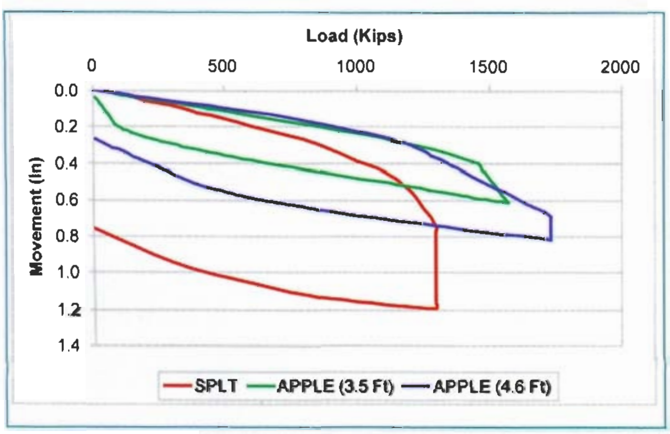
The NYSDOT CIP pile is a steel pipe driven with a conical or flat plate shoe. The pipe is filled with concrete after it is driven and is connected to the footing with a partial length reinforcement cage. The 24 inch pile was designed to carry a maximum allowable load of 500 kips and the 18 inch pile 270 kips. An allowable lateral load was initially calculated for each pile size based on assumed pile layouts. The analyses

Apple Test

were later repeated using the final pile group configuration to verify that the movement and stresses were within acceptable tolerances.

Static Pile Load Test

The piles were driven with a Delmag D46-32 single acting diesel hammer which has a rated energy of 122 kip-ft at the maximum stroke. Pile Driving Analyzer (PDA) monitoring was used to evaluate hammer operation, measure driving stresses and establish pile driving criteria through capacity verification. A static pile load test (SPLT) was conducted on the first 24 inch diameter pile installed on the project. PDA monitoring was also conducted on this pile during initial drive and restrike. The steel pipe did not have sufficient section to resist the expected failure load from the SPLT test therefore it was filled with concrete before the test. Consequently the diesel hammer was unable to sufficiently move the pile during the PDA restrike test that was performed after the SPLT. In order to determine the correlation between the SPLT and PDA results a restrike was done using the GRL Engineers' Apple system with a 40 kip drop weight.



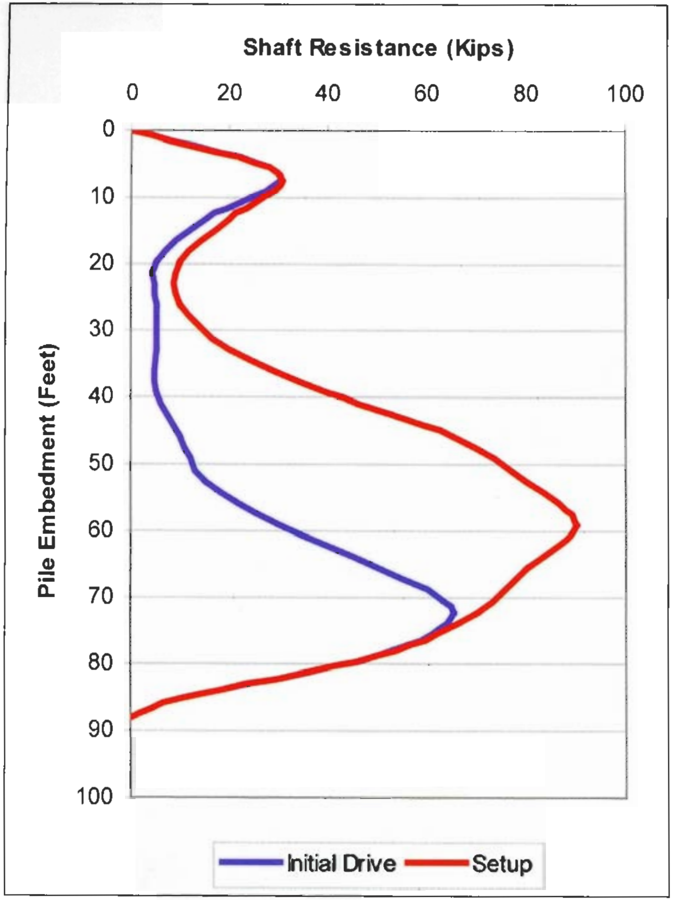
SPLT and Apple Load-Movement Plots


Static Pile Load Test

Apple Test

Early in the foundation work, it became a challenge to find a location that was accessible to the pile driving equipment and with sufficient space to construct the SPLT frame. Locations with the deep Organic Silt deposits combined with a thin veneer of Fill were not desirable to set up wood cribbing or drive reaction piles. Therefore the 24 inch diameter SPLT pile was installed at a footing location for 18 inch piles where the Organic Silt layer is thin and the Fill layer substantial. Since the pile was utilized in the foundation, it was located in the center of the footing where it could have the least effect on the lateral stiffness of the pile group. The load reaction was provided by eight tapered Monotube piles and steel billets supported on wood cribbing. The SPLT was conducted one month after the pile was driven. The toe of the 74 foot deep pile was in Silty Clay and it achieved a plunging failure load of 1300 kips at a top movement of 0.75 inches.

Seven months after the SPLT an Apple test was run using a 40 kip weight dropped at heights of 2.0, 3.5 and 4.6 feet with standard PDA equipment used for the strain and acceleration measurements. A virtually frictionless free fall of the weight is obtained by cutting the steel support cable with a remote hydraulic device. All of the footing piles were driven one month prior to the Apple test. A simulated static load-set plot obtained from the CAPWAP analyses showed the pile achieved a plunging failure at a higher load but at the same movement as the SPLT. The higher measured load from the Apple test was likely due to the longer setup period and consolidation of the soil caused by driving the surrounding footing piles.



Completed Piers

Shaft Resistance for 18 inch Pile

Since the two independent test methods were in agreement, confidence was gained in the determination of capacity from the PDA measurements. The piles achieved capacity close to the estimated length for the entire project and the hammer proved to be compatible with the pile-soil system. Templates were required in the river cofferdams to maintain proper pile plan location. At one pier location, pile damage was caused by obstructions and at other locations from hard driving caused by soil consolidation in combination with unrelieved buoyant forces. The damaged piles filled with sediment and could not be removed therefore replacement piles were driven at adjacent locations.

Depth Below Grade (Feet)	Soil Resistance (Kips) Initial Drive	Setup	Increase	Percent Increase	Soil Profile	SPT Spoon Blows (BPF)	Moisture Content
7	30	30	0	0%	Silty Sand Gravelly (Fill)	24	20
13	15	20	5	33%	Organic Silt	WOH	106
20	5	10	5	100%	Organic Silt	WOH	77
26	5	10	5	100%	Organic Silt	WOH	133
39	5	40	35	700%	Silty Sand Clayey Gravelly	7	59
46	10	65	55	550%	Silty Sand Gravelly	22	20
52	15	80	65	433%	Silty Sand Gravelly	29	18
59	30	90	60	200%	Silty Sand Clayey Gravelly	27	17
66	50	80	30	60%	Silty Sand Clayey Gravelly	23	18
72	65	70	5	8%	Silty Sand Gravelly	37	29
79	50	50	0	0%	Silty Sand Gravelly	66	14
85	10	10	0	0%	Clayey Silt Sandy Gravelly	57	15
TOE	125	240	115	92%	Clayey Silt Sandy Gravelly	46 20	
SUM	**420**	**815**	**395**	**94%**	**Percent of SUM**		

The data presented in the following table (page 50) and shown in the graph to the left is from PDA initial drive and restrike tests performed on an 18 inch diameter pile. The increase in soil shaft resistance after setup was most dramatic in the Silty Sand Clayey Gravelly layer with the setup increase for the entire pile almost 100 percent.

Large diameter cast-in-place concrete piles are a cost-efficient solution for foundations with high lateral and axial load demand especially where footing space is limited. Due to the lower redundancy of the group, it becomes more critical to maintain the specified pile alignment and to avoid damage. Careful attention should be paid to controlling driving stresses and where obstructions are likely pre-drilling should be considered. PDA monitoring played a valuable role in maintaining quality control on the pile driving throughout the project. ▼