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## New Kosciuszko Bridge – Transforming the New York City Skyline

The Kosciuszko Bridge, named in honor of Polish military engineer and Revolutionary War hero Tadeusz Kosciuszko, carries I-278 over Newtown Creek, the dividing line between the New York City boroughs of Brooklyn and Queens. At the time of the bridge's construction in 1939, Newtown Creek was an industrial hotbed lined with petroleum refineries, coal handling facilities, metal processors, and chemical and fertilizer manufacturers. The waterway became one of the largest shipping hubs in the Northeast, and to accommodate the maritime traffic, the existing Kosciuszko Bridge was constructed with a fixed span 125 ft (38.1 m) above the mean high water level. This resulted in a structure that now features nonstandard roadway grades on both approach spans, inadequate sight distances across the main span and entrance ramps with insufficient merge lengths. Serving more than 160,000 vehicles per day, the bridge has become

notorious locally for its state of structural disrepair and severe congestion.

In May 2013, the New York State Department of Transportation (NYSDOT) awarded a design-build contract to the joint venture of Skanska USA Civil Northeast, Kiewit Infrastructure Company and ECCO III Enterprises (SKE), in conjunction with design partner HNTB New York Engineering and Architecture. The project scope includes design and construction of a new eastbound bridge and improvements along a 1.1 mi (1.8 km) segment of the Brooklyn-Queens Expressway (BQE), as well as demolition of the existing bridge. With the exception of some minor replaceable items, the bridge has a required 100-year design service life. A new westbound (Brooklyn-bound) bridge, built within the footprint of the existing Kosciuszko Bridge, will be completed under a separate contract.

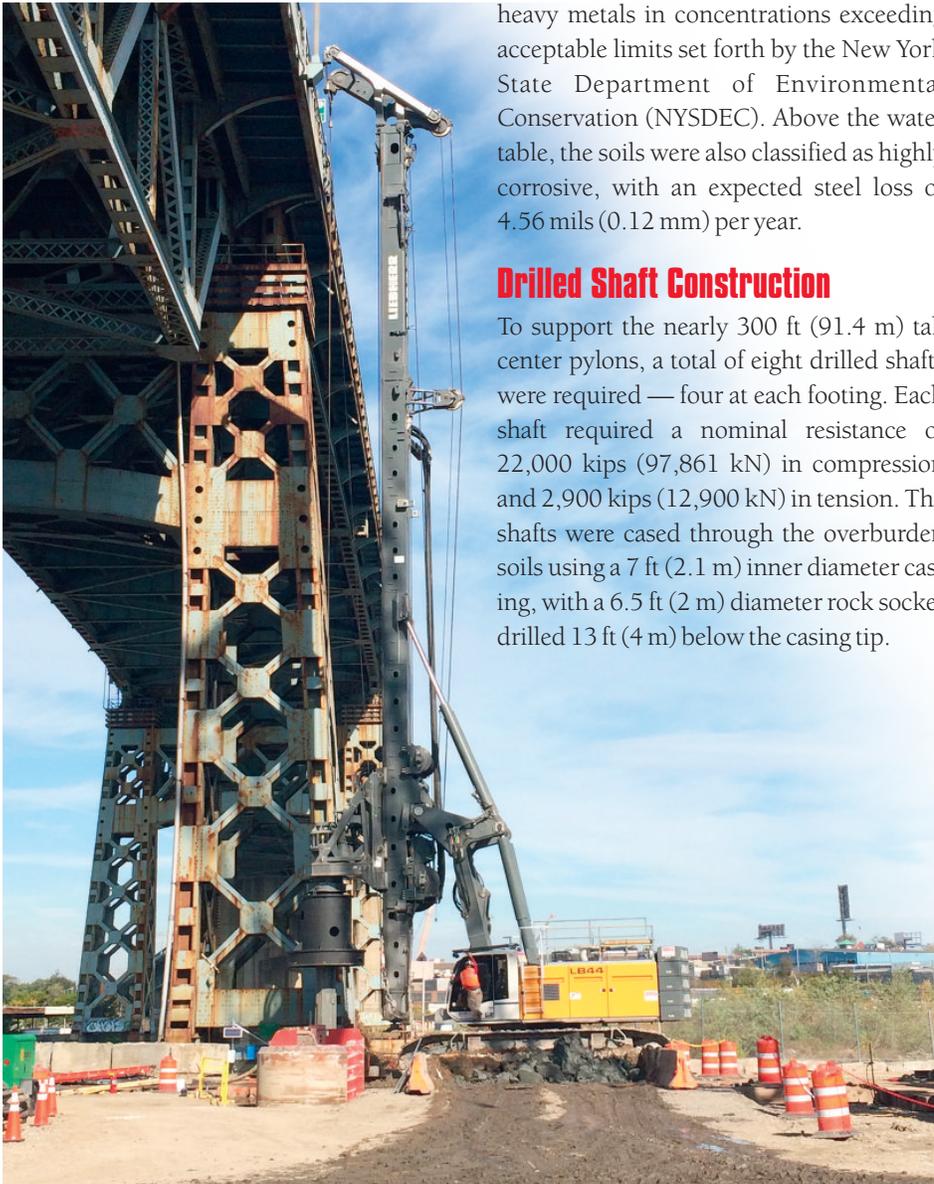
The new Kosciuszko Bridge is designed as a cable-stayed structure, the first of its kind in New York City. The approach span piers and connector abutments, not discussed in this article, are supported primarily by driven piles, along with a limited number of micropiles at several abutments constructed under low-headroom conditions. At the center pylon, rock-socketed drilled shafts of unprecedented size and capacity within the metropolitan area were the signature feature of the project's deep foundation work.

### Subsurface Profile

In the area of the center pylon, on the west bank of Newtown Creek, the general soil profile consists of approximately 20 ft (6m) of urban fill overlying a thin organic clay layer, then glacial deposits composed of silty sand with gravel and a lower clay layer known as the Raritan Formation. Beneath lies a layer of decomposed rock, consisting

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**Overburden drilling adjacent to the existing bridge**

heavy metals in concentrations exceeding acceptable limits set forth by the New York State Department of Environmental Conservation (NYSDEC). Above the water table, the soils were also classified as highly corrosive, with an expected steel loss of 4.56 mils (0.12 mm) per year.

### **Drilled Shaft Construction**

To support the nearly 300 ft (91.4 m) tall center pylons, a total of eight drilled shafts were required — four at each footing. Each shaft required a nominal resistance of 22,000 kips (97,861 kN) in compression and 2,900 kips (12,900 kN) in tension. The shafts were cased through the overburden soils using a 7 ft (2.1 m) inner diameter casing, with a 6.5 ft (2 m) diameter rock socket drilled 13 ft (4 m) below the casing tip.

of undisturbed natural bedrock that has been chemically weathered. The result is an extremely stiff green clayey soil with SPT values from 50 to over 100 blows per foot (0.3 m). The competent rock below consists of Fordham Gneiss with pegmatite inclusions. Testing of core samples indicated unconfined compressive strengths ranging from approximately 8,000 psi (55 MPa) at the rock surface up to 36,000 psi (248 MPa). The static water table was encountered 15 ft (4.6 m) below existing grade.

In addition, environmental soil and groundwater sampling revealed that decades of industrial activity in the area resulted in the presence of semi-volatile organic compounds (SVOC) as well as

Once the project was awarded, SKE began a soil boring program to provide a more comprehensive study of the subsurface conditions than the contract bid borings provided. Additional borings in the area of the drilled shaft footings confirmed that the drilled shaft casing would have to advance through about 30 ft (9.1 m) of decomposed rock, but also revealed a severely sloping bedrock condition that was not anticipated. With the surface of the gneiss inclined at nearly 30°, serious concerns arose within the project team about the feasibility of conventionally advancing casing up to 170 ft (51.8 m) deep, then seating it nearly 5 ft (1.5 m) into the sloped rock. Establishing a seal around the full circumference of the casing was

critical to the project schedule to allow the use of reverse circulation drilling (RCD) methods to excavate the socket length.

Installation methods were revised to incorporate an oversized 8 ft (2.4 m) diameter shaft supported by polymer slurry. A 162,000 gal (613 m<sup>3</sup>) slurry plant was mobilized to the site to batch and hold KB International's Enhanced SlurryPro CDP system. A Liebherr LB44 hydraulic rotary drill rig was used to install surface casing and excavate the overburden. The temporary 8.5 ft (2.6 m) casing was installed 40 ft (12.2 m) and seated into the upper clay layer to prevent any possibility of vertical migration of shallow contaminants into the lower aquifer.

During the drilling process, each shaft was profiled multiple times using a SoniCaliper<sup>®</sup> provided by Loadtest to confirm verticality of the open hole. Depths to rock varied from 147 ft (44.8 m) to 170 ft (51.8 m), but careful control of the drilling process yielded minimal vertical deviations ranging from 0.34% to 0.76%. Once rock was encountered, it was drilled and leveled with conventional tooling. This was a time consuming, but critical step in the construction process. Casing was then lowered into the open hole in sections ranging from 50 ft (15.2 m) to 80 ft (24.4 m) using a Liebherr LR1350 service crane. Two full-penetration welded splices were required per shaft, with the fully-deployed casing string weighing as much as 48.5 tons (44 tonnes). This casing was surveyed into place, then twisted and seated into the bedrock. The seal in rock was confirmed when a head differential in the slurry level of about 10 ft (3 m), created by pumping down the inside of the casing, could be maintained.

One caveat of this installation method was that once the casing was installed, an annular space was created that could not remain open. To adequately resist lateral loading, full engagement with the surrounding soils had to be re-established. SKE chose to fill the annulus using a fluid sand-cement grout. Three injection pipes were lowered into the annulus at 120° apart, and each shaft was tremie grouted from the casing tip to the surface in a two stage installation. This process mitigated the risk of differential pressures created by the liquid grout from deforming the casing.

Once the casings were sealed and grouted, RCD was used to excavate each 6.5 ft (2 m) rock socket. The pile top rotary table spun a 67.5 ton (61 tonne) drill string, including a full-faced roller cutting bit attached to the bottom. In the reverse circulation process, compressed air is injected into the bottom of the drill string, creating a pressure differential that airlifts cuttings back to the surface. Flowrates on the order of 2,000 gpm (7,570 Lpm) are typically generated by this type of system. However, strict environmental regulations prohibited any water to be supplied from or discharged into the nearby Newtown Creek without first being treated to bring heavy metals, pH and solids down to acceptable levels. Instead, all flushing water was supplied from nearby hydrants and recirculated in a continuous loop, settling out the rock cuttings in a lined detention pond. Further complicating the installation,

this phase of the work had to be performed as a two-shift operation during the dead of winter in order to maintain the project schedule. Temperatures typically rose above freezing for only a few hours each day, requiring a significant effort to keep pumps running and prevent supply and discharge piping from icing up.

Due to the depth of the shafts, reinforcing cages were constructed in three sections, using internal template rings attached to “hourglass” stiffening frames. The fully assembled cage contained 18 No. 18 75 ksi (517 MPa) vertical bars, with bundled bars in the upper 60 ft (18.3 m) and weighed nearly 50 tons (45.5 tonnes). Custom designed and built lifting rings were used to pick and suspend the cage sections during splicing and concrete placement.

Although the concrete supplier’s ready-mix plant was located only about 2 mi (3.2 km) from the site, local Brooklyn traffic would frequently push delivery times to 45 minutes or more. A 6,000 psi (41.3 MPa) self-consolidating concrete (SCC) mix, developed for previous Skanska projects, was chosen for its ease of workability and extended placement time.

### Quality Control

Since the shaft design relied on end bearing to provide nearly 80% of its capacity, ensuring cleanliness of the rock socket bottom prior to pouring concrete was paramount. A miniature shaft inspection device (Mini-SID) was

employed to determine the depth of sediment present at the tip of each completed shaft. Five individual bottom locations per shaft were probed, with the requirement that 50% of the base of each shaft have less than 0.5 in (13 mm) of sediment and no location exceeding 1.5 in (38 mm) at the time of concrete placement.

To meet these criteria, each shaft was airlifted, removing any fines leftover from the RCD and exchanging the entire fluid column with fresh water. Further, during construction of the first shaft, after a successful Mini-SID inspection was achieved, a 72-hour waiting period was imposed and the shaft inspection process repeated. This demonstration alleviated concerns that the shafts could fall out of specification if a weekend or unexpected downtime period occurred between the time of the Mini-SID inspection and concrete placement.

A “Chicago Method” Osterberg Cell (O-cell) load test, performed on the first completed production shaft, was then carried out to confirm the design end-bearing assumptions. This variation on the traditional O-cell test places the hydraulic jack at the shaft tip with a circular bottom plate of a reduced diameter compared to the rock socket. Unit end-bearing values are able to be verified by a single 6,000 kip (26,689 kN) capacity O-cell jack, which applies load onto the smaller diameter plate using the available side shear capacity and dead weight of the shaft above as a reaction.



Picking the bottom section of the O-cell cage



RCD settlement pond

In order for the Chicago Method test to provide meaningful results, the O-cell bottom plate must be wet set into competent concrete to ensure sufficient bearing is provided at the shaft tip. The entire reinforcing cage was lifted about 2 ft (0.6 m), while the tremie pipe extended down through a prefabricated notch on one side of the O-cell plate assembly. During concrete placement, the SCC mix performed as anticipated, flowing through a 6.625 in (168 mm) slickline tremie pipe and allowing the reinforcing cage to be plunged back to its plan elevation without incident.

The O-cell test was carried out one week later. A maximum load of 6,705 kip

(29,825 kN) was applied to the shaft, or 556 ksf (26.6 MPa) in end bearing. The shaft's performance was excellent, with only 0.144 in (3.7 mm) of vertical displacement generated at the tip, and negligible movement of the shaft above the O-Cell.

Traditional crosshole sonic logging (CSL) testing was performed on all eight shafts to confirm the integrity of the shaft concrete. Seven steel access tubes were installed within each reinforcing cage to minimize the potential debonding effects that frequently occur with PVC tubes. To augment the CSL testing, thermal integrity profiling (TIP) was also performed on the first three shafts that were poured. Although the TIP test method has been in

existence since 2007, this application was the first use of the technology on a NYSDOT project.

Seven thermal wires with discrete temperature sensors were tied to the reinforcing cages along their full length. The wires were cast into the shaft during concreting and connected to individual dataloggers once the pour was complete. The thermal profile is developed when the concrete reaches its peak temperature, which occurred an average of 55 hours following placement due to the high percentage of slag in the mix. The TIP reports not only provide an assessment of concrete quality, but also use temperature gradient data to evaluate the alignment of the reinforcing cage, shaft radius in the cased and socket lengths, and concrete cover provided. Both nondestructive test (NDT) methods detected only minor anomalies in the shafts with no serious structural defects.

Finally, a static lateral load test was carried out once the pier caps were excavated down to final cutoff elevation. Load was applied using a free head test frame to a maximum of 350 tons (318 tonnes). Shaft deflection was measured using traditional dial gauges at the ground surface and also profiled to a depth of 60 ft (18.3 m) using Measurand's Shape AccelArray, a micro-electrical mechanical system (MEMS) inclinometer string.

The test confirmed the effectiveness of the annulus grouting program in reinstating intimate contact with the surrounding soils over the length of the shaft. Head deflections were in line with predicted values, with approximately 0.5 in (13 mm) maximum displacement in both the test and reaction shafts.

## Conclusion

All eight shafts were accepted by NYSDOT with no required remedial action. Post-construction environmental sampling of nearby monitoring wells also verified that no vertical cross contamination between the aquifers occurred. Despite significant last-minute changes to the installation procedure, the drilled shafts were completed in early March 2015. Superstructure construction is currently underway, with traffic expected to be switched onto the new bridge by the close of 2016.



Reverse circulation drilling of the rock sockets



350 ton lateral load test setup