2012 OPA Winner: Top-Down Pedestrian Underpass at WTC Site
Route 9A Pedestrian Tunnel at the World Trade Center

The redevelopment of the World Trade Center (WTC) provided an opportunity for the Port Authority of NY and NJ to complete a long sought underground connection between all of Lower Manhattan’s transit lines, the World Trade Center and the World Financial Center (WFC) (Figure 1). Creating this connection was a challenge because the WFC lies west of the heavily trafficked Route 9A, also known as West Street. The previous connection was a bridge that required pedestrians to make significant level and directional changes to navigate the crossing. The positioning and elevation of the Route 9A pedestrian tunnel was established to provide pedestrians with a clear, single level, climate controlled corridor from the new WTC Transit HUB to escalators leading into the WFC Winter Garden.

As the most direct link to the WFC, tens of thousands of people a day will use the pedestrian corridor. To accommodate this large number of pedestrians and provide an obstruction free passage, the tunnel has a clear width of 50 ft (15.2 m). Although only 250 ft (76.2 m) long, that short length presented many technical challenges.

Here I describe how the challenges were overcome during the construction. However, some of the truly problematic issues arose from coordinating the phasing of this project with adjacent construction activities at the WTC, the reconstruction of Route 9A, and the WFC’s redevelopment program. The limited access to the...
excavation areas and confined site logistics were further complicated by having to maintain six lanes of traffic on Route 9A all times. The efforts were so intertwined that, well into the underpass construction, the Port Authority Construction Department decided to merge a portion of that work into the WFC redevelopment.

**Historical Context**

The west side of Lower Manhattan, in the vicinity of the WTC, is predominantly land reclaimed from the Hudson River. For two centuries, successive generations of bulkheads and piers were constructed into the river with the areas behind them filled with random fill and other debris. The most recent, and probably last generation of this filling, is the area now known as Battery Park City (BPC). The WFC is a high-end cluster of office towers that makes up the central business core of BPC and is immediately west of the WTC site.

Beneath Route 9A, workers encountered two old bulkheads. One was a rock-filled, timber crib and the other, a historic, granite faced, concrete seawall. The timber crib did not present any significant technical difficulties. The granite seawall was more problematic. Removing 50 ft (15.2 m) of seawall required approval from the NY State Historic Preservation Office. This approval was granted, with the condition that the seawall be disassembled rather than demolished, and this work be performed in the presence of an archeological team to document any significant findings.

In addition to old bulkheads, there are two, 100- year-old, cast-iron subway tunnels (PATH) traversing Route 9A. One of these tunnels is situated immediately north of the pedestrian underpass. The proximity of the tunnel is complicated by the manner in which the original WTC slurry walls were constructed around it. In order to ensure a proper seal around the tunnels, special slurry wall projections were built to intersect the tunnels at the point where the mid-height of the tunnel rose above bedrock surface. This allowed the excavation buckets to remove the materials above the tunnel and socket into the adjoining bedrock. The projection structure immediately north of the underpass presented an opportunity and a challenge in the underpass construction.

**Subsurface Conditions**

The surficial soils are miscellaneous fills and extend to a depth of from 30 to 35 ft (9.1 to 10.7 m). Underlying the fill is a deposit of river sediments. These consist of slightly organic, clayey silts. These soils, traditionally quite soft, have been significantly consolidated due to the fill loading, and also because there has been a general lowering of the groundwater due to decades of leakage into the adjacent WTC basement. Underlying the river sediments are glacial outwash deposits. The deposits are from 10 to 15 ft (3 to 4.6 m) thick and consist of dense sands, with occasional cobbles and boulders. Beneath the glacial deposits is a relatively thin layer, typically less than 5 ft (1.5 m), of decomposed bedrock. Bedrock is predominantly mica schist (Figure 2).

Groundwater level varies from east to west. At the seawall, it mimics the tidal variation of the river. While adjacent to the WTC slurry wall, groundwater levels are depressed as much as 15 ft (4.6 m) below sea level.

**Construction**

The original plan for the underpass construction envisioned all the work progressing in five separate stages across Route 9A using bottom-up technology (Figure 3). The excavation support was primarily secant piles, with jet grout closures beneath large utilities and at juncture points with existing structures. In addition, the project was able to make use of approximately 150 ft (46 m) of the existing WTC slurry wall for excavation support. All stages of the excavation were carefully choreographed with lane shifts and temporary bridging of Route 9A.

The multitudes of utilities that cross the tunnel alignment further complicated construction and presented challenges. There are at least 15 utilities traversing the excavation, the largest being a 78 in (2 m) sanitary sewer. This sewer was treated with great deference. In addition, there are two, very large, ~ 10 ft (3 m) communication duct banks crossing the excavation. These duct banks were also treated with great care.
Bottom-up Construction

The original, and more traditional, bottom-up method design was developed jointly by the Downtown Design Partnership (AECOM, STV and Calatrava partnership) and the Port Authority Engineering Department. The construction was performed by the Phoenix Constructors multi-venture using secant piles as the primary means of ground support. The Port Authority selected secant piles because they could be threaded between the multitude of utilities and other underground obstructions within the tunnel alignment.

The secant piles were 39 in (1 m) in diameter. The primary piles were cast using 2,000 psi (13.8 MPa) concrete and the secondary piles were cast with 4,000 psi (27.6 MPa) concrete. The pile overlap was 9 in (23 cm). The secondary piles were drilled 3 ft (0.9 m) into bedrock and reinforced with heavy steel cores (W24x279). The primary piles were drilled only 1 ft (0.3 m) into bedrock.

In addition to the secant walls, jet grout masses were used beneath smaller utilities and mini-pile tangent walls were used beneath larger utility clusters.

The work started on the eastern side of the underpass, adjacent to the WTC basement. In this zone, the slurry walls of the existing PATH tunnel projection provided a large portion of the ground support. This required the strategic placement of interior struts to ensure the transferred load coincided with the projection’s interior floor slabs.

The 78 in (2 m) sanitary sewer is located in this eastern portion of the excavation. To support the sewer, it had to be first exposed, cradled and then supported on a braced mini-pile system. The width of the sewer was such that the gap between the two secant piles straddling the sewer was too large for the jet grout treatment. To provide the necessary ground support, the area was locally dewatered and a system of timber lagging installed to support the exposed soil. Fortunately, the decades of depressed groundwater conditions had transformed the usually soft river sediments into a stiff consistency. The clay held up well during this staged excavation.

From an overall site risk perspective, the prospect of having a direct hydraulic connection from the Hudson River to the WTC basement through this tunnel construction zones was unacceptable to the Port Authority. To eliminate the possibility of catastrophic flooding of the basement, a temporary demising wall was included in the design. It was installed across the underpass at mid-length and was designed to resist a full head of water. This demising wall remained in place until the majority of the tunnel structure was in-place and the risk of river flooding was eliminated.

In the vein of “best laid plans…”, no sooner had the demising wall been removed, then Hurricane Irene came barreling up the East Coast heading straight for New York City. The associated storm surge was projected to overtop the Hudson River bulkhead and flood much of Lower Manhattan. The underpass tunnel, without its roof slab, rendered the entire WTC site vulnerable. With a days notice, the Port Authority directed the contractors to build soil berms around the excavation and sealed up any open penetrations in the seawall with timber blocking. Fortunately, the actual storm surge was less than predicted and the storm blew over the WTC site without major incident. Unfortunately, our neighbors to the north, especially upstate New York and Vermont, did not fare as well.

The westernmost section of the underpass presented another challenge. This section extended into a large, buried outfall flume that had direct hydraulic connection to the Hudson River. This open water condition was dealt with by first installing steel sheet piling around the perimeter of the area, thus isolating it from the open water. The volume inside was then filled with a flowable cement fill, using tremie methods. Once set the flowable fill provided a medium through which secant piles were installed and socketed into bedrock.
The granite faced seawall, which at first appeared to be a nearly insurmountable obstacle, was penetrated without much difficulty. Recent technological advances in the field of concrete cutting and removal made quick work of the seawall. The secant wall alignment was pre-cored, using oversized and overlapping core holes. The overlapping core holes provided a slot for the installation of 30 in (0.76 m) secant piles. As excavation progressed, the wall was disassembled while an archeologist documented the construction details and took representative samples for archival storage.

**Top-down Construction**

Approximately halfway through the construction, the WFC approached the Port Authority with its design for a new entrance into the WFC Winter Garden. It became apparent to both parties that there would be a significant schedule advantage if the western portion of the underpass construction were combined with the new entrance construction. After detailed negotiations, the completion of the westernmost stages of the underpass construction was contracted to the WFC property manager, Brookfield Properties. Their prime contractor was Turner Construction. Their excavation subcontractor was Urban Construction and their engineer was Mueser Rutledge Consulting Engineers. Utilizing secant piles installed by the initial contractor, the WFC construction team developed an innovative approach to the construction that shortened the schedule even more.

The excavation subcontractor, Urban Construction, re-evaluated the construction and determined that there would be a schedule advantage if they used a top-down approach. With this approach, the roof of the pedestrian tunnel was used as an interior brace, thus eliminating the need for one level of temporary interior bracing. In order to support the top-down walls, a system of mini-piles was installed along the wall alignments. These were used to support the permanent wall sections until the base slab was in place. The wall sections were cast in stages as the excavation progressed. Unlike the bottom-up approach, which required three levels of interior bracing, this approach utilized the tunnel roof slab for wall support and reduced the required number of brace levels to two. The top-down approach reduced the construction schedule by approximately a year and saved the project approximately $1 million.

The width of some of the bigger duct banks was too large to rely only on jet grout filler to provide the necessary soil and water support. In these areas, tangent piles were installed from beneath the utilities using low-head equipment. The tangent piles were 13-3/8 in (0.33 m) diameter mini-piles and were socketed 6 ft (1.8 m) into bedrock. To ensure a soil tight seal, workers injected grout behind the pile intersections to fill any gaps. Excavation progressed in stages with concrete “lagging” cast against the mini-piles to create a reliable retention system.

**Support of utilities and Route 9A over tunnel excavation**

**Summary**

Presently, the underpass is being fitted-out with escalators and architectural treatments and the WFC entrance structure is under construction. The pedestrian tunnel will be operational in time for the new WTC PATH Transportation HUB. The final product will be an appropriate compliment to the WTC redevelopment and will provide a spectacular entrance to the WFC.

It took a concerted effort by a large contingent of professionals to design and construct this relatively short tunnel. However, the effort was well worth it. The underpass is one of the last links in Lower Manhattan’s massive, post-9/11 infrastructure upgrade. Once open, the resulting transportation continuity will attract new businesses and further the already vibrant revitalization of the WTC area.

The Port Authority congratulates all those involved and thanks them for all their efforts.
Port Authority of New York and New Jersey's Underpass wins OPA Competition