CHALLENGING FOUNDATION
BUILT IN THE HEART OF NEW YORK CITY

By Douglas P. Gonzalez, P.E. and Joseph L. Yamin, P.E.

Rising along the East River in Manhattan's midtown is a brand new world-class hospital facility for one of New York's major academic medical centers. This state-of-the-art hospital building is fully integrated into the adjacent medical campus. Accomplishing this required locating the unique 21-story building on a congested urban site with numerous physical constraints that posed significant challenges. Designed by Ennead Architects in collaboration with NBBJ, the new hospital consists of a 7-level podium for operating rooms which also incorporates a fully enclosed and automated parking system, and a 14-story tower for single-bedded inpatient rooms.

The site originally had several hospital buildings and related construction that were demolished to make way for the new structure. South of the construction site is the remaining campus with major hospital, academic, and research buildings. The new structure is located directly adjacent to the existing operational hospital to allow for passageways between the two.

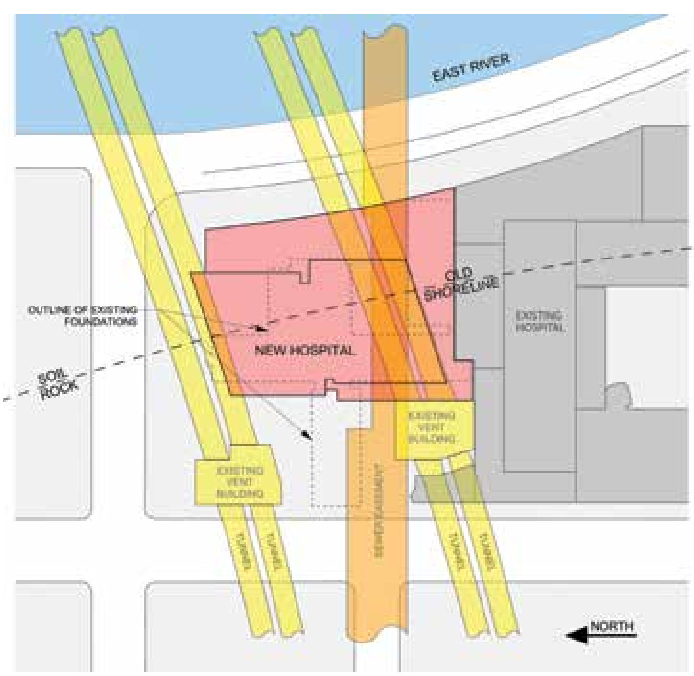
Constraints in the ground that created challenges for the project included a major sewer and its easement, four tunnel tubes of the Amtrak commuter train lines, two ventilation buildings for the tunnels, as well as existing building foundations and underground utilities. As is the case with much of Hospital Row along Manhattan's east side, the ground surface is located a few feet above the nearby river level resulting in increased flood risk. With the site being the only remaining property available to build on, all these foundation and ground level challenges had to be overcome while not compromising the programmatic needs of the hospital and campus.

The 21-story, 830,000-square-foot hospital is the crowning jewel of an extensive campus transformation. Courtesy of Ennead Architects.

Foundations

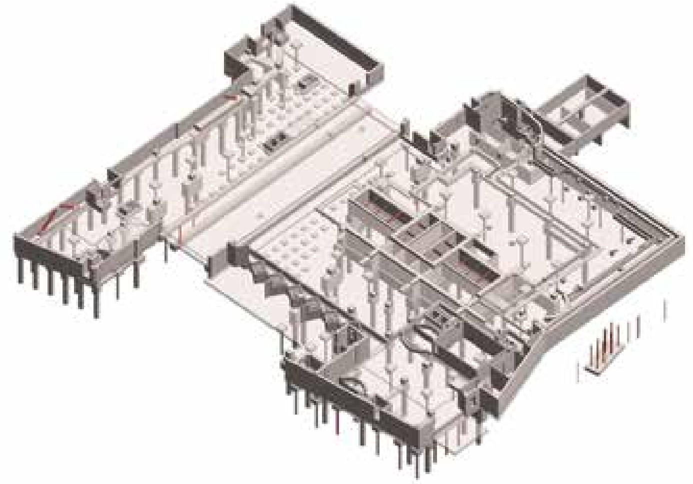
The project is located in midtown Manhattan's east side, on land that is outboard of the original historical shoreline which was reclaimed from the East River. This reclamation process occurred in various stages from the mid-19th century through the early 20th century as Manhattan developed. The result is that the site subgrade consists of a 35-foot upper layer of uncontrolled fill, i.e. rubble, brick, and timber, over various layers of silt, clay, and sand that are then underlain by bedrock. Much of the timber encountered is remnants of the historic shoreline bulkhead. The bedrock underlying the site consists of Manhattan schist and is located approximately 50 to 115 feet below grade, sloping down toward the river. Rock core results indicated bedrock of varying quality but, in general, below the weathered surface the rock is a minimum Class 1c Intermediate Rock. Given the poor soils and depth to bedrock, deep foundations were a natural choice for this site since they allow the load to be delivered directly to bedrock and their discrete nature minimized the impact to existing infrastructure.

The site contains four Amtrak Rail Tunnels as well as a combined sewer outfall (CSO) for New York City. The tunnels, which are approximately 65 feet below grade, are clustered in pairs with two tunnels toward the north end of the site and two at the south end of the site below the CSO. The agreed upon easement for deep foundations was 10 feet clear in plan from the tunnel spring line. An extensive study of the impact of caisson elements near the existing tunnels was performed by the Geotechnical Engineer. Given that these rail tunnels



The existing site conditions presented a challenge for the structure and its foundations.

Caisson installation, given the tight site constraints. Note, installation began before the demolition of adjacent structures.



Revit model of the foundation system showing the pressure slab and concrete flood walls. Note, openings between perimeter walls are infilled with barriers to create the "bathtub" system.

are critical infrastructure, it was necessary to confirm there was no detrimental impact to the tunnels. As a result of the study, caissons near the tunnels have isolated portions of their socket length above the tunnel spring line to avoid possible load shedding to the tunnels.

Given the tunnel diameters, spacing, and easement requirements, there is an 80-foot zone running northeast through the southern half of the site where no deep foundations could occur. As a result, long span transfers of the building structure, spanning 100 feet or more, were provided. Also, the building's services and structural core had to be shifted eccentric to the building massing to avoid this tunnel zone. A similar zone occurs at the north end where the new building only partially extends over the tunnel zone. This was accomplished with cantilever foundation plate girders, which in some cases were 6 feet deep, as well as cantilevered floor framing above.

The building transfers in the superstructure resulted in large column loads on many of the foundations, which led to the decision to use high capacity drilled caissons. A schedule of multiple caisson types was proposed that ranged in capacity from 3,000 kips to

8,000 kips. The caissons are 36 inches in diameter and consist of steel reinforced concrete within a permanent steel casing that is seated into bedrock. The casing was installed via vibratory hammer and the rock socket was accomplished with conventional rotary drilling methods using reverse circulation heads to clean out the spoils. Both operations were coordinated with the hospital to minimize disruption. Also, it was agreed with Amtrak that caissons located nearest the tunnels would be installed with tight tolerance controls on verticality and deviation.

In addition to tunnel proximity, caissons were carefully installed as close as 5 feet to the existing hospital, as well as through the abandoned basements of the demolished buildings and old shoreline bulkheads. A comprehensive monitoring program was implemented above grade and within the tunnels to measure the effects of foundation construction on the tunnels and existing buildings.

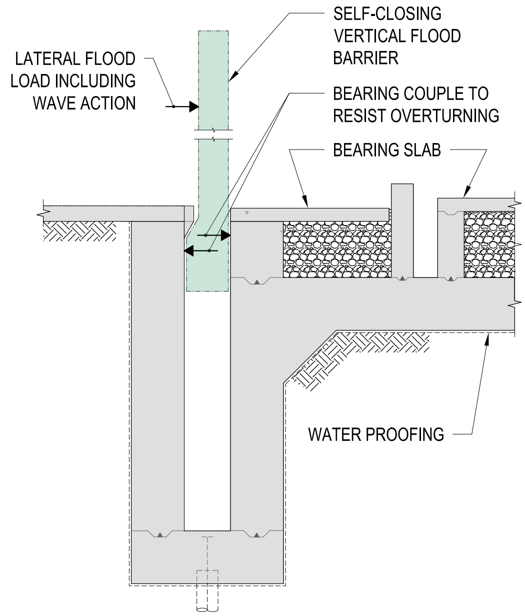
The caissons were originally designed with studded core steel consisting of heavy rolled shapes. However, because there were large lead times for the core steel and the final caisson tip elevations were determined based on actual rock quality encountered, there was concern that the contractor could not meet the foundation schedule. This resulted in the use of threadbar as the caisson steel reinforcement instead of the core steel. Benefits of this approach included shorter lead times and flexibility to accommodate varying rock socket lengths, especially since longer threadbar lengths could be achieved quickly with mechanical couplers instead of field welding extensions to the rolled core steel.

The threadbar reinforcement was specified as Grade 75 with sizes ranging from #18 to #28 bars, depending on the caisson capacity. Bars were spaced equally in a circumferential ring, typically one to two layers, with an opening in the center to allow for a tremie pipe. Before installation of the rebar cage and concrete operations, the rock socket was flushed out to remove any remaining spoils and then video inspected to confirm rock quality.

Ground Floor Construction

Given the proximity to the East River and the existing ground water elevation, the new hospital building's lowest level is at grade. With its main entrance and its loading docks on street level, the hospital needs to protect numerous open entrances from the risk of rising flood waters. While the original flood risk for this site, as defined by the Federal Emergency Management Agency (FEMA) flood maps, was mitigated by slightly elevating the majority of the ground level, the revision of the FEMA flood elevations post-Hurricane Sandy resulted in the need for a wholesale rethinking of the flood protection strategy.

The resulting increase in the Design Flood Elevation of approximately 7 feet, which also included an allowance for sea level rise, could only realistically be accommodated by providing a building-wide resilient "bathtub" or "boat" system to keep flood waters out of the building. This approach, coupled with the elevating of critical MEP services and hospital functions above the ground floor, provided a system-wide resilient building. The upgraded ground level includes a building-wide spanning pressure slab with additional mini-caissons to resist uplift from hydrostatic pressure, as well as flood walls to resist lateral hydrostatic and dynamic wave loads. The pressure slab is typically 12 inches thick with drop panels at supporting caissons. At the building perimeter, cantilevering concrete flood walls behind façade elements are supported by a thickened pressure slab. The concrete bathtub is protected by a continuous pre-applied waterproofing system. Also, the pressure slab supports a 3-foot interstitial MEP zone of crushed stone with a bearing slab above, allowing services to run throughout the Ground Floor within the bathtub system.



Perimeter foundation detail to support proprietary self-closing flood barrier at the storefront entrance.

The real challenge was protecting the large openings throughout the building for entrances and loading docks. To do this, the project uses every conceivable, deployable flood barrier type from multiple vendors. These include 1) flip-up barriers at the loading dock and parking entrances; 2) swing barriers at the loading dock ramp; 3) sliding barrier at the ambulatory entrance; 4) redundant submarine doors at points of egress; 5) redundant deployable stacking barriers at Ground Floor elevator entrances; and 6) a self-closing flood barrier at the 225 feet long entrance storefront. The majority of these barriers represent common flood protection technology. However, the self-closing barrier at the entrance storefront is less common. This barrier type employs a passive wall system constructed of fiberglass encased foam, which is less dense than water thereby allowing the barrier to deploy itself as flood waters rise. This system was chosen at the main entrance because the system is completely hidden below grade when closed except for a metal strip in the sidewalk pavement. The barrier withstands flood loads as a simple bearing force couple, resisted by prying on a 24-inch-thick foundation trench structure which houses the barrier.

Another challenge was extending the pressure slab over the existing sewer and providing flood uplift support on either side within the easement zone. Here, shallower soil-anchors were specified and installed in the top 30 feet of soil to maintain the minimum required vertical clearance above the crown of the tunnels. These tie-down anchors consist of small diameter casings, with a #10 threadbar grouted into soil that resists uplift by mobilizing the soil mass.

Summary

The existing site constraints, coupled with the challenge of providing a flood resistant structure, presented significant challenges to the foundation and ground level construction. However, with careful consideration and thoughtful design, the team was able to overcome these challenges and bring to reality a state-of-the-art, resilient hospital to serve the surrounding community well into the 21st century.▪

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