CASE HISTORY: ROCKEFELLER UNIVERSITY RIVER CAMPUS BUILDING MINI-CAISSONS

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ABSTRACT

In 2015, Rockefeller University, a historic, cloistered medical research campus on the Upper East Side of Manhattan along the East River, embarked on the construction of a new building. The building would be squeezed into a tight slot between adjacent buildings and over the top of the busy six-lane FDR Drive. The foundations on either side of the FDR Drive presented different challenges to the design and construction of mini-caisson piles.

On the upland side west of the FDR Drive, drilling contractor Posillico offered the owner a value-engineered alternate to replace a proposed deep pier/wall on rock and rock anchors with a pile cap supported by 16 battered mini-caissons. An unconventional pile design featuring a steel pipe installed within the drill casing allowed the piles to develop the required lateral stiffness and isolate load transfer below the adjacent existing building foundation. The alternate solution eliminated the rock anchors and reduced the costly rock excavation by almost 2,700 tonnes (3000 tons) from the original plan. The owner also requested that the contractor accelerate the schedule in order to allow for steel erection to begin 2 months earlier than planned. On the riverside east of the FDR Drive, Posillico redesigned the 340-mm (13-3/8-inch) diameter 5,425-kN (600-ton) mini-caissons to 457-mm (18-inch) diameter for 10,850-kN (1200-tons). This led to a reduction in pile quantity and accelerated an important schedule milestone. The lateral requirements for both foundations required drilling the casing through the bedrock and partially extracting it to achieve the load transfer through friction in the rock socket.

This paper reviews the unconventional pile design details. It also explains how a proprietary under-reaming drilling system allowed the contractor to meet the compressive and lateral design requirements while also allowing for the use of smaller rigs than would otherwise be needed. Additionally, the paper reviews some of the difficult urban construction conditions within limited access environments including overhead and underground utilities, heavily planned material and equipment logistics and tight coordination of protection of traffic on the extremely busy FDR Drive.

BACKGROUND

Manhattan's Upper East Side is densely developed with primarily residential high rise buildings and street level retail shops. It is situated between Central Park and the East River. The FDR Drive – a six lane limited access highway – runs north-south along the river. Between the FDR Drive and the river is the John Finley Walk – a popular esplanade used by joggers, dog walkers, and anyone else from the neighborhood seeking a brief respite from the urban experience. The Upper East Side is also home to Rockefeller University – a world renowned medical research facility founded in 1901. The existing tree-lined campus sits atop a 40-foot high, hundred-year-old schist rock retaining wall. It features cloistered gardens amongst notably neoclassical architecture. Figure 1 shows a Google Earth view of the Rockefeller University Campus.

Figure 1. Google Earth view of Rockefeller University's tree-lined campus, the FDR Drive, and the John Finley Walk esplanade along the East River on Manhattan's densely populated Upper East Side (looking west).

New York City is currently undergoing a development boom for medical research institutions. In an effort to maintain its prestigious position and continue to attract talented researchers, Rockefeller University engaged Turner Construction Co. as construction manager in a campus expansion program known as the Stavros Niarchos River Campus. The program is built around construction of a 2-story building designed to span 24 meters (80 feet), east-west, over the top of the FDR Drive for 290 meters (950 feet), north-south, along the river. The new facility will feature state-of-the-art laboratories, administrative space, and a cafeteria. Atop the building, the cherished outdoor spaces and gardens of the existing campus will extend eastward to overlook the East River. Figure 2 shows a rendering of the project after completion.

Figure 2. Artist's rendering of the Rockefeller University campus following completion of the Stavros Niarchos River Campus construction (looking west).

The overarching structural design concept was based on installing piles in a narrow gap between the FDR Drive and the esplanade on the east side as the bedrock drops off below the deep East River. The western foundations consisted of piles along the southbound shoulder of the FDR Drive. Together, these pile foundations would support the new building which would be prefabricated in 19 modules and set during highway closures at night. Additionally, mechanical and electrical rooms (MERs) would be built between existing campus buildings on shallow foundations with rock anchors on higher elevation bedrock.

This paper focuses on issues related to the deep foundations required to support the new River Campus building. In particular, it focuses on two alternate pile designs proposed by the contractor – one pre-bid and the other post-award. The pre-bid alternate involved adding mini-caissons in lieu of piers and footings on rock within the existing campus for the MERs. The post-award alternate involved increasing the capacity of the individual caissons in the original design, east of the FDR Drive, to reduce the number of piles and, thus, accelerate the schedule.

PRE-BID VALUE ENGINEERED ALTERNATE: MINI-CAISSONS IN LEIU OF ROCK EXCAVATION

The base bid design for the MER shear wall foundations did not call for piles. Instead, rock excavation would be required in order to construct the new foundations beyond the influence depth of the adjacent buildings. The bedrock formation was known ahead of time to be hard and would require a great deal of line and channel drilling in order to make excavation possible without negatively impacting the adjacent structures. Additionally, due to the limited access to the area, loading out excavated rock was difficult and expensive. The original design also called for rock anchor tie downs due to tension loads on the shear wall foundations.

During the bid process, in an effort to reduce the duration and cost of construction, the contractor, Posillico, proposed installing mini-caissons that would provide the required compressive, tensile, and lateral capacities and would be designed so as to isolate the loads below the depth of the adjacent buildings. The cost for these mini-caissons was more than offset by saving almost 2700 tonnes (3000 tons) of rock excavation (and associated line and channel drilling as well as loading out, trucking and disposal) along with elimination of the shear wall on column line A1 (figure 4B) and associated rock anchors. Figure 3 shows the type of space and logistical constraints that drove up the excavation costs. Figures 4A and 4B contain the original designs as well as key components of the proposed alternate. Figure 5 is a geologic section through MER A showing the dramatic difference in bedrock elevations.

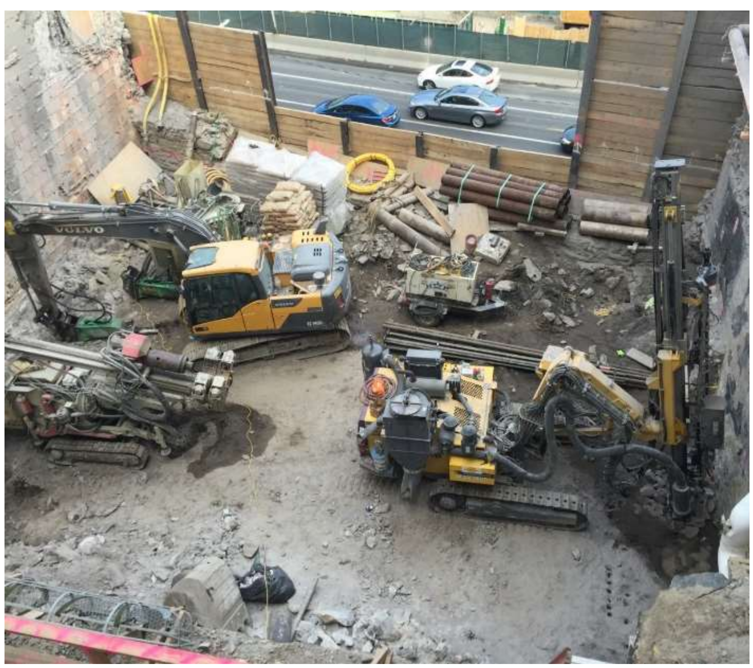

Figure 3. Construction of MER B foundation was performed with small rigs within tight constraints. At right is a small drill rig line drilling for rock excavation. The idle drill rig at left was used to install the alternate mini-caissons. Also shown is a small excavator used to break, excavate, and load out the rock, during night shifts, onto the FDR Drive, in the background.

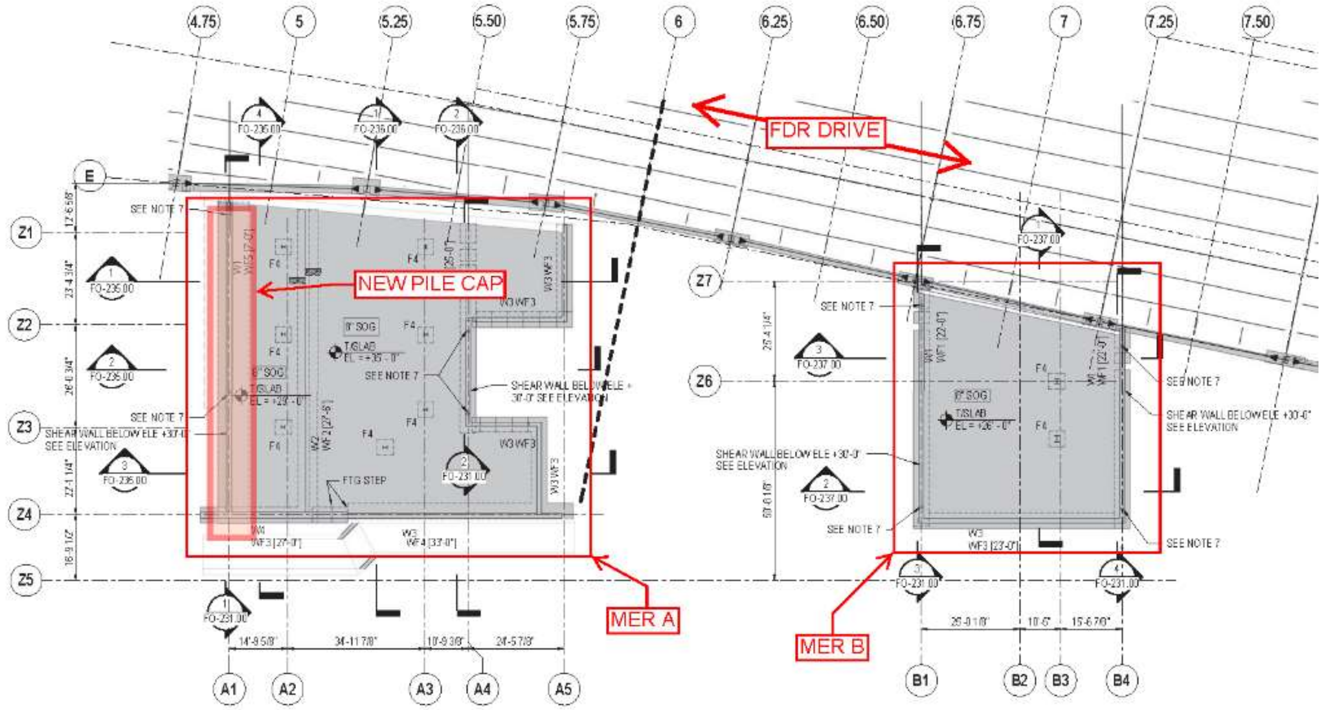

Figure 4A. Original foundation plan of MER A and B and the outline of the proposed pile cap.

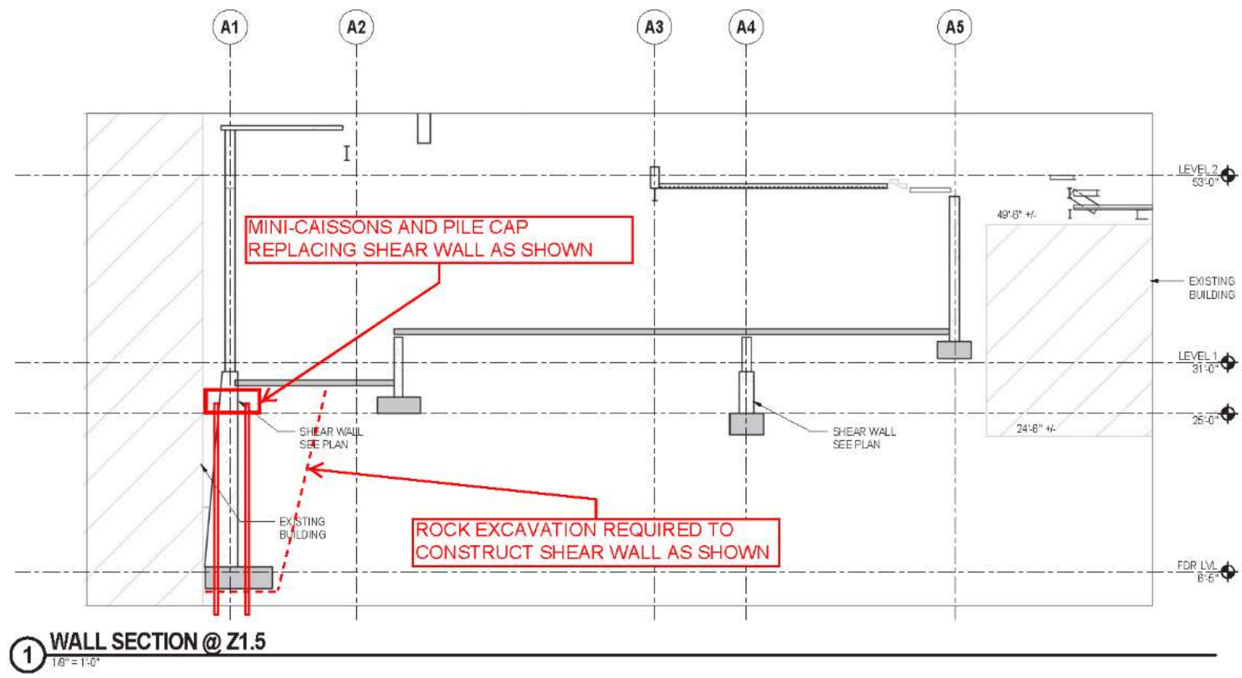

Figure 4B. Section through the MER A foundation per base bid (Section 1 from figure 4A).

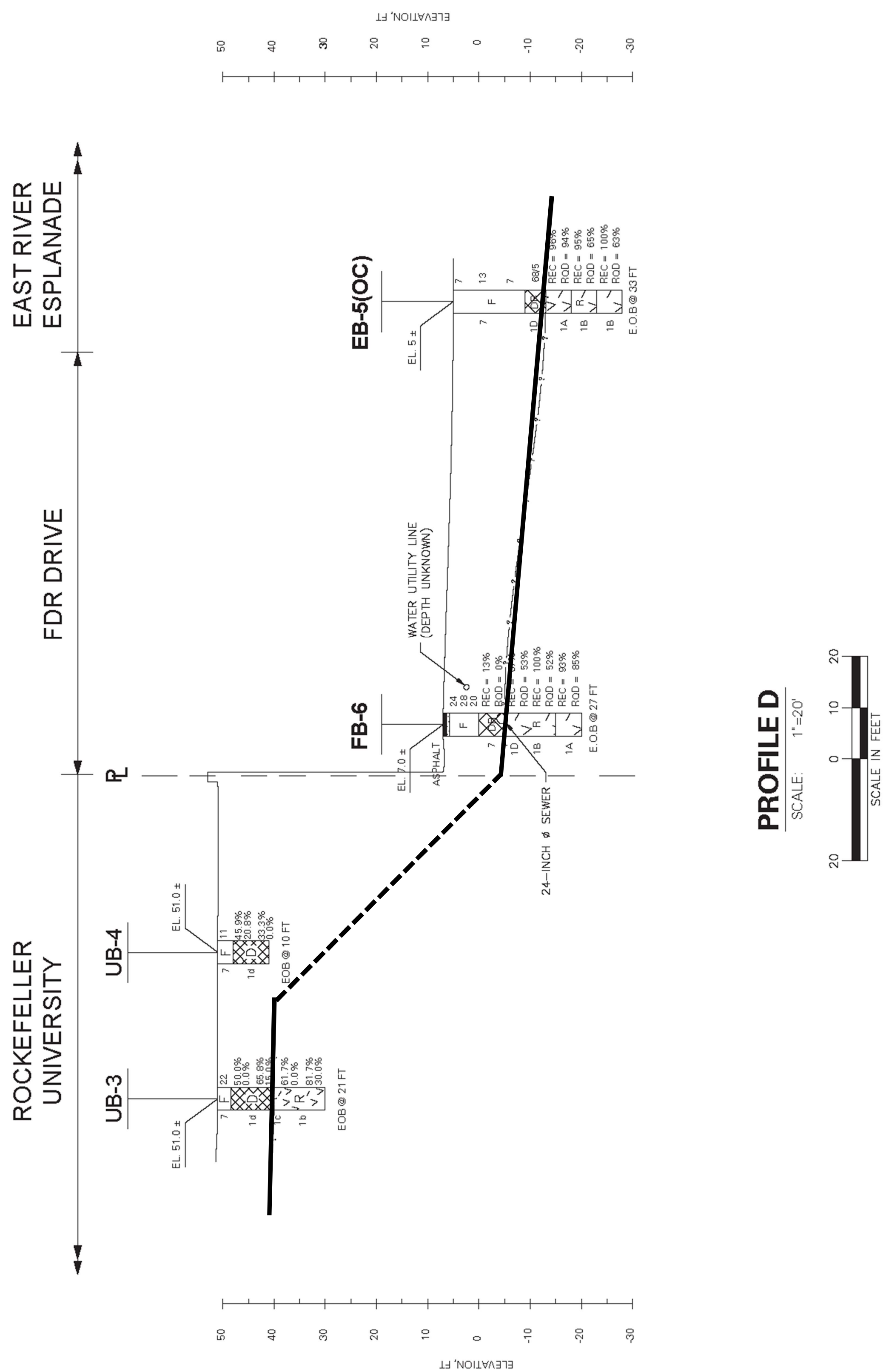

Figure 5. Geologic Section taken through MER A (labeled “ROCKEFELLER UNIVERSITY”), the FDR Drive, and the East River Esplanade (John Finley Walk).

In order to meet the allowable load and isolation requirements, the contractor proposed installing a 340-mm (13-3/8-inch) diameter casing down through the bedrock. Once the full drill depth was achieved, the casing was extracted to create a rock socket for transferring compressive and tensile loads via grout-to-ground bond. In order to isolate the load down past the adjacent foundations, an inner 273-mm (10-3/4-inch) diameter casing was inserted inside the 340-mm (13-3/8-inch) casing. The inner casing was wrapped in polyethylene sheeting as a bond breaker. Lateral load requirements were met by battering the piles as shown in figure 5.

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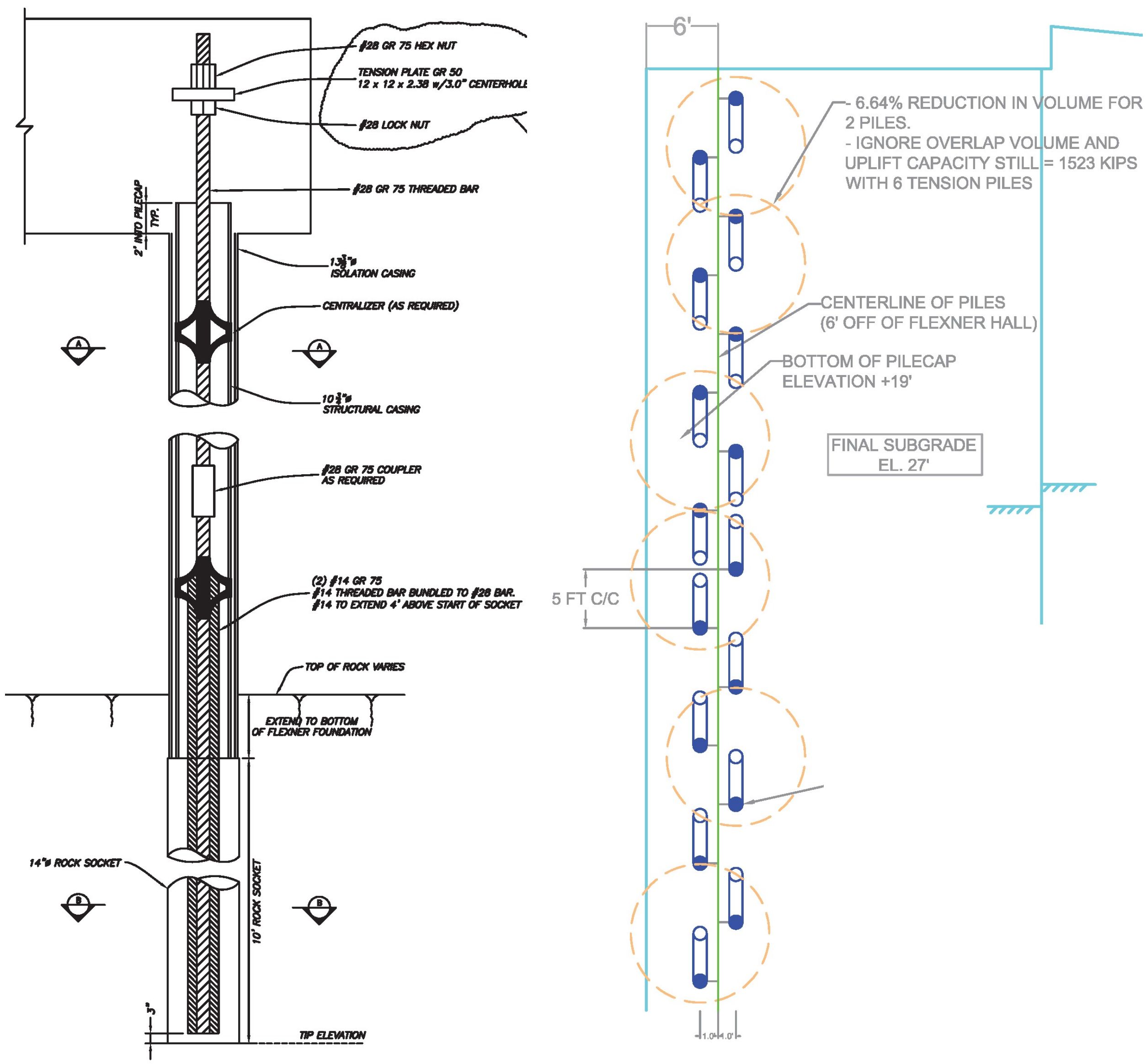

Figure 6. Pile layout and details for proposed alternate mini-caissons in lieu of the MER A shear wall shown in figure 4B.

Alternate mini-caisson allowable axial loads were 3620 kN (400 tons) in compression and 1810 kN (200 tons) in tension. Tension design was based on rock cone failure analysis shown by dashed circles and associated call outs in figure 5. The pile details in figure 5 show 273-mm (10-3/4-inch) inner load bearing casing and the 340-mm (13-3/8-inch) outer isolation casing. What is not made clear in figure 5 is the actual vertical dimension between the top of bedrock and the top of the rock socket. This ranged from 6 ot 8 meters (20 to 25 feet). The casing was typically drilled 9 to 11 meters (30 to 35 feet) into bedrock and extracted 3 meters (10 feet). It was only possible to drill the casing through the rock by using an under-reaming system. For this project, Posillico chose to use the Roto Loc system by Center Rock, Inc.

Figure 7. Construction of MER A foundation was performed with small rigs within tight constraints. The photo shows the installation of mini-caissons battered 1 on 4 (horizontal to vertical). Also shown, upper right, are the active electrical ducts just above the drill rig mast. The headroom restrictions required the use of 5-foot long casing and drill rods.

POST-AWARD VALUE ENGINEERED ALTERNATE: 457-MILLIMETER (18-INCH) DIAMETER 10,850 KILONEWTON (1200-TON) "MINI"-CAISSONS

Working in and around existing active facilities involved many logistical challenges. These included coordination of traffic patterns with the NYC Department of Transportation (DOT), the location/protection/maintenance/relocation of active utilities, as well as existing structural conditions – many of which were not understood fully or even discovered in some cases until the demolition and construction in an area began. These “verify-in-field” situations lead to many changed conditions and redesigns throughout this project. The net result of these changes was an increase in scope of the foundation construction work. As a result of this increased scope, the owner authorized compensation for acceleration of the schedule (i.e. working overtime). In addition to the acceleration to make up for changed conditions and redesigns, the owner simultaneously sought to reduce the overall duration of the base contract. The contractor was repeatedly requested to present additional ideas to expedite the foundation construction.

The support for the new River Campus building required the installation of deep foundations between the FDR Drive and the esplanade. According to the Geotechnical Report, the FDR Drive and the esplanade are constructed on a pile supported relieving platform while a granite block faced concrete gravity retaining wall serves as the bulkhead along the river shoreline. Contract requirements included maintenance and protection of all 6 travel lanes on the FDR Drive. It also required maintaining a 2.4-meter (8-foot) wide portion of the esplanande between the work zone and the river (left side of figure 7) open to pedestrian traffic. Any required shutdowns would have to be done during night shifts. To further complicate matters, there were several other major construction projects being performed simultaneously along other sections of the FDR Drive. This lead to weekly coordination between the DOT and all of the general contractors to “hash out” competing logistical concerns.

Figure 7. Maintaining vehicular traffic on the FDR Drive and pedestrian traffic on the esplanade, shown at left, while rock drilling with air-flush required planning and constant vigilance to prevent property damage and injury to the public. The Roto Loc under-reaming system can be seen in the photo on the right.

Maintaining vehicular and pedestrian traffic limited the width of the work zone for the foundation construction to between 2.4 and 5.5 meters (8 and 18 feet) with very limited access. Equipment and materials were brought to the site during evening lane closures. Compressors and grout plants were situated on service barges off shore. The limited width of the work zone, in turn, also limited the size of the drill rigs that could be safely utilized. When the owner asked the contractor for any and all ideas to reduce the duration of foundation construction (in addition to adding second and third drill rigs), the approach was simple: what are the largest drill rigs we can utilize and what is the greatest pile capacity that can be installed with such rigs?

The original base bid design called for 60 each 5,425-kN (600-ton) 340-mm (13-3/8-inch) diameter mini-caissons. Posillico proposed replacing 48 of these with 28 each 10,850-kN (1200-ton) 457-mm (18-inch) diameter caissons. Twelve caissons would remain unchanged. Thus, the total quantity of piles was reduced from 60 to 40. This is estimated to have saved approximately 2 weeks off a 6-week critical path schedule item. Every week was critical in the eyes of the owner. The intent was to begin steel erection as soon as the prefabricated modules were available.

Due to the age, design and construction, and condition of the existing seawall, the piles would be required to handle the lateral loads imposed on the new structure under seismic code considerations. The original contract drawings called for casing embedded 1.5 meters (5 feet) into bedrock with a socket diameter larger than the casing outside diameter, lower right in figure 8. This embedment was required in order to provide enough base shear resistance – especially for piles where bedrock was shallow, say, on the order of 6 to 9 meters (20 to 30 feet) below pile cut off elevation. Figure 8 also shows the final shop drawing for the alternate 10,850-kN (1200-ton) caisson.

Additionally, static lateral load tests were performed on both size piles to confirm that lateral soil/pile responses were within acceptable limits. One-third of the piles were battered at a slope of 1 on 6 (horizontal to vertical) in the east-west direction, perpendicular to the seawall, in order to provide required resistance to lateral movement towards the river and prevent side-loading the seawall. This lateral capacity was achieved through the tensile capacity of the caissons. Additionally, one-third of the piles were battered 1 on 5 north-south.

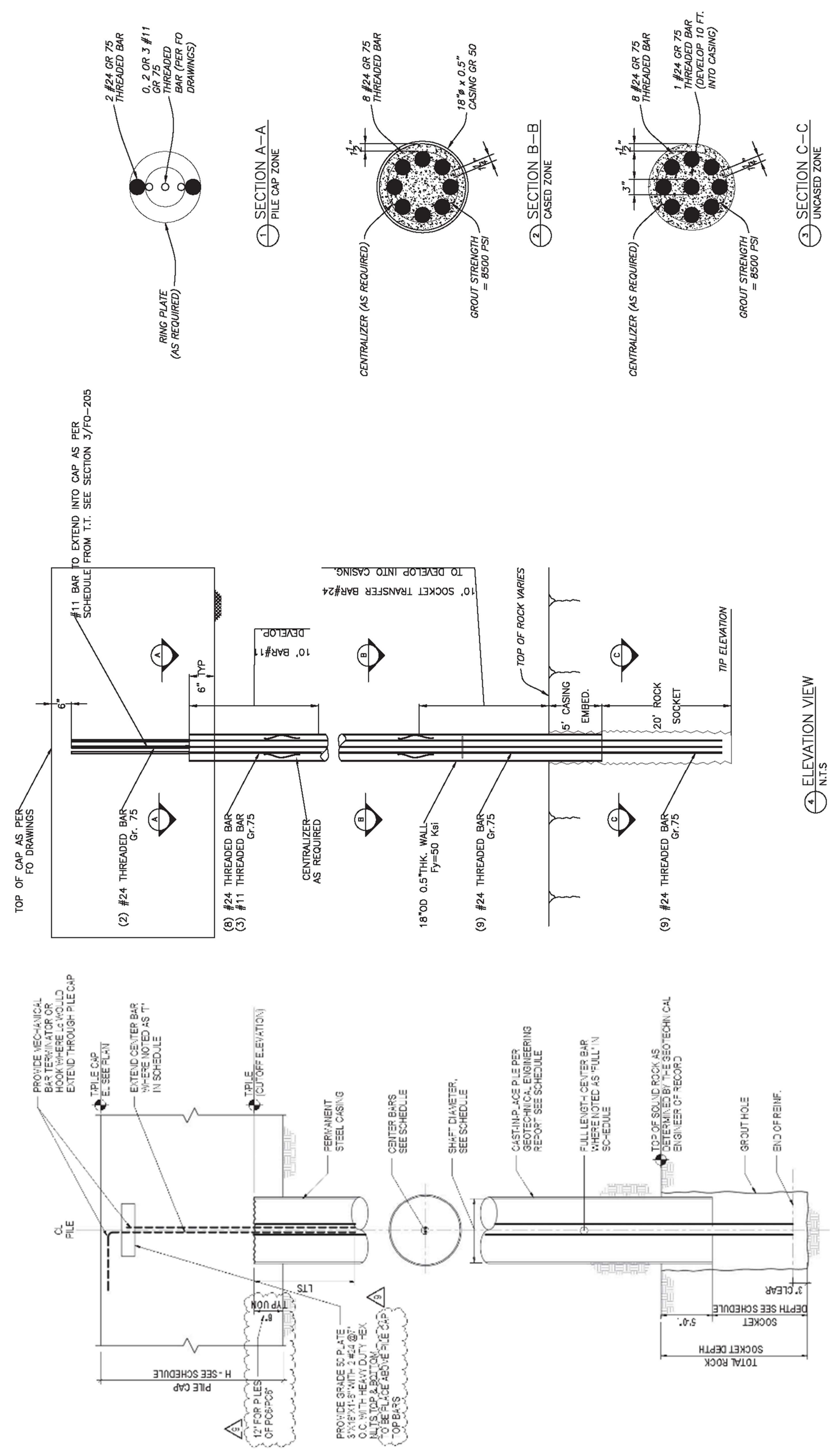

Figure 8. Pile details for the base bid 340-mm (13-3/8-inch) diameter mini-caisson and the alternate 457-mm (18-inch) diameter caissons.

In order to provide this casing embedment into bedrock, Posillico again chose to use Center Rock's Roto Loc under-reamer. In this case, Center Rock custom-built their system to 457-mm (18-inch) diameter to accommodate the contractor's requirements. As was the case in the MER A foundations, using an under-reamer reduces the torque requirements on the drilling equipment which, in turn, makes it possible to drill relatively larger diameter piles to greater depths with relatively smaller drill rigs. This torque reduction was even more critical as the casing diameter was increased to 457 mm (18 inches). Figure 9 shows a detail of the Roto Loc operating principle. It is noteworthy that the increased rock socket diameter turned out to be critical in meeting the 2014 New York City Building Code's requirements for clear grout cover of reinforcement in the rock socket.

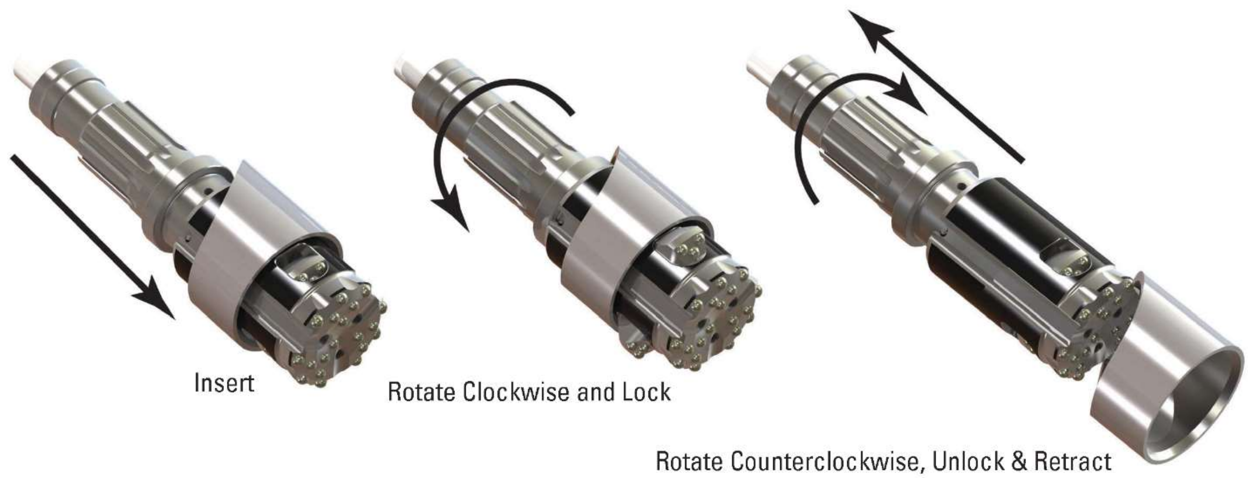

Figure 9. Expanded detail view demonstrating the operating principle of the Roto Loc under-reaming system manufactured by Center Rock, Inc.

CLOSING REMARKS

In closing, this case history provides an example of a contractor with specialty knowledge in the area of pile design and construction collaborating with an owner, their design engineers, and their construction manager to reduce construction costs and durations. Although the two alternate caisson designs were only part of the overall project, they represented a disproportionate safety, quality, schedule, and cost risk exposure for all stakeholders. These alternates contributed toward meeting the owner's goal of commencing steel erection per the originally anticipated schedule milestone despite a 2-month late start and numerous redesigns and scope increases. Figure 10 shows one of the pre-fabricated 2-story steel frame building modules, 24 meters by 15 meters (80 feet by 50 feet) in plan, being set at night over a closed FDR Drive with one of North America's highest capacity crane barges.

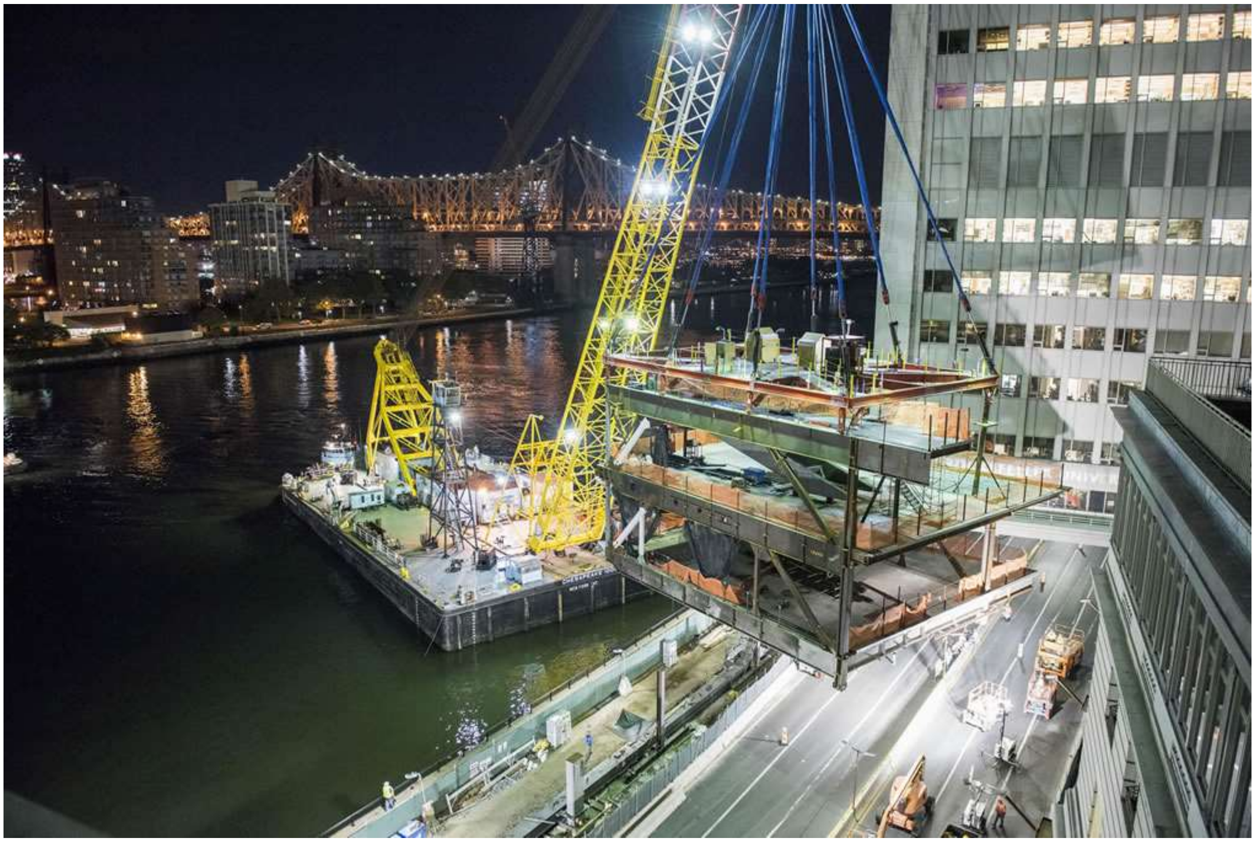

Figure 10. Foundations installed east and west of the FDR Drive supported prefabricated building modules set during night time highway closures. In all, 19 such sections were set over a 2-month period.