Sarah Mildred Long Bridge Tower Foundation Construction

by Joseph Orlando, Cianbro Corporation

The new Sarah Mildred Long Bridge, which spans the Piscataqua River from Portsmouth, N.H., to Kittery, Me., opened on March 30, 2018. The structure has two-level precast concrete segmental box-girder approach spans with a 300-ft-long lift span. Additionally, the 200-ft-tall towers of the lift span are vertically post-tensioned segmental towers, a first in the United States. The foundations for the lift span towers are 125 ft long, 65 ft wide, and 15 ft thick. The design of the foundation includes a precast concrete tub used as a cofferdam and form. An allowance of 18 in. for the tub-wall thickness and 3 ft for the bottom thickness was included in the design. Eight 10-ft-diameter drilled shafts socketed 35 ft into competent rock support each foundation. The top of the foundation is at elevation 8 ft, about 2 ft above the highest astronomical tide expected during construction. Each of the structural footings contains 3200 yd^3 of cast-in-place concrete and 500,000 lb of reinforcement along with 14 post-tensioning ducts for the segmental towers.

The project was jointly sponsored by the Maine and New Hampshire departments of transportation. The project delivery method was the construction manager/general contractor method, and the Cianbro Corporation of Pittsfield, Me., was the general contractor (for a profile of Cianbro, see the Spring 2017 issue of *ASPIRE*®). FIGG Bridge Engineers designed the approach spans, and Hardesty & Hanover designed the lift span and towers as a joint venture.

Tower Foundation Design Challenges

The Piscataqua River is a deep and fast-flowing tidal river, one of the fastest in the United States. This factor and others presented many challenges to the construction of the tower foundations. The following were among the primary considerations that influenced the ultimate method of foundation construction:

- The tidal current could exceed 4 knots.
- The maximum crane capacity at working radius using a Manitowoc MLC300 Lattice Boom Crawler, which was the largest crane the contractor had in its fleet, on a 72 ft by 200 ft deck barge was 180 tons.
- The foundation had to be submerged 13 ft at the highest astronomical tide.
- The water was 65 ft deep, with little overburden on the river bottom.
- There were significant construction and environmental loads, such as water pressure due to the tidal current alternating in direction.
- Worker and diver safety had to be ensured.

Sarah Mildred Long Bridge approaches, lift span, towers, and tower footings. Photo: Cianbro/Richard Hopley.

Others have approached the construction of these types of foundations using the following methods:

- Casting a complete tub and setting it on drilled shafts using a large capacity crane
- Casting and launching a complete tub, floating it over the drilled shafts, and then submerging it into place
- Suspending a precast concrete segmental soffit above high water, building a traditional cofferdam on the soffit, and using synchronous jacks to lower the system into place

Cianbro analyzed these options and ruled them out because it did not have sufficient crane capacity to lift 1100 tons, and a dry dock or launching system was not available to fabricate and launch such a large floating tub. Additionally, the Piscataqua River's extreme current and a slack tide of only 30 minutes made the prospect of floating and accurately positioning a large tub over the drilled shafts too risky. Similarly, slowly jacking a tub down into the current was not ideal.

Cianbro Solution

A precast, sand-lightweight concrete, segmental post-tensioned tub addressed the design challenges. The MLC300 crane could quickly erect the tub. The combination of strength and density of the sand-lightweight concrete was critical to the success of the design because loads were close to crane capacity. Additionally, each piece could be set quickly to the design elevation and secured during slack tide. The tubs were free draining, which gave workers two hours to work inside the tubs at low water. Workers grouted and bolted the tubs from the top. There was no need for divers to go beneath the tubs, thereby improving safety.

Each precast concrete segmental tub, one for each tower, was composed of nine segments: five drilled-shaft units and four fill units. The drilled-shaft units used strongbacks with hangers to support the segments from the top of the drilled shafts. For erection, the fill

Installation of the drilled-shaft units. Photo: Cianbro.

units were placed between the drilled-shaft units and were supported by an integral ledge cast into the drilled-shaft units. The drilled-shaft segments could be precisely located in elevation and plan by using threaded hangers and horizontal alignment fixtures cast into the concrete around the penetrations for the drilled shafts. The horizontal alignment fixtures also stabilized the segments from the pressure of the water current. A ¾ in. space between segments provided erection tolerance and space to grout and seal between segments. Grade 75, 1-in.-diameter sleeved all-thread bolts were spaced at 18 in. along the entire length of the joint between segments. Each all-thread bolt was post-tensioned to 30 kip after the joints were grouted, allowing the entire load of the fill unit (weight of first lift of concrete plus dead load of the fill

Fill unit installation. Photo: Cianbro.

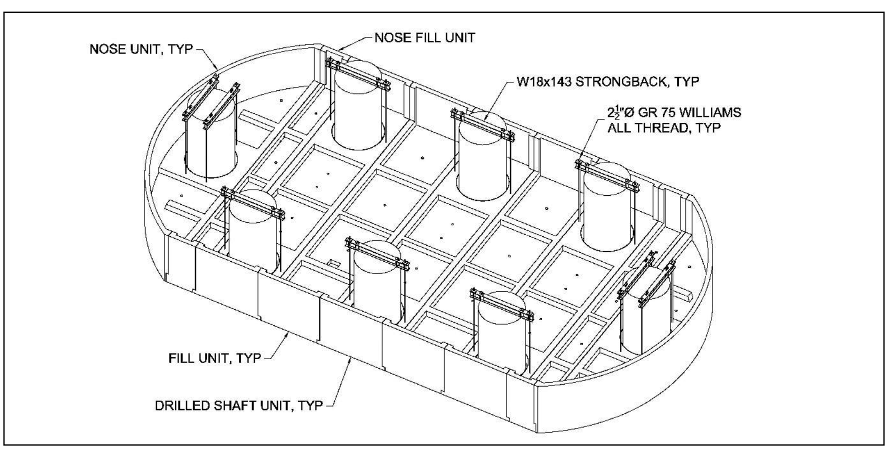
piece) to be transferred to the drilled-shaft unit through shear friction. An extensive finite element model was developed of the tub using RISA-3D software to determine the structural behavior of the tub.

The success of the system depended on the connection of the tub to the drilled shafts. The connection was required to transfer large uplift forces from the dewatered tub as well as the loads imposed from concrete placement. The design shear load transferred to each drilled shaft was 850 kip. A grouted shear key design, typically used in the offshore oil industry, provided the necessary capacity. The connection was designed using grouted pile-to-structure connection criteria from the American Petroleum Institute's *Recommended Practice 2A-WSD*.[1] Installing forms for grouting

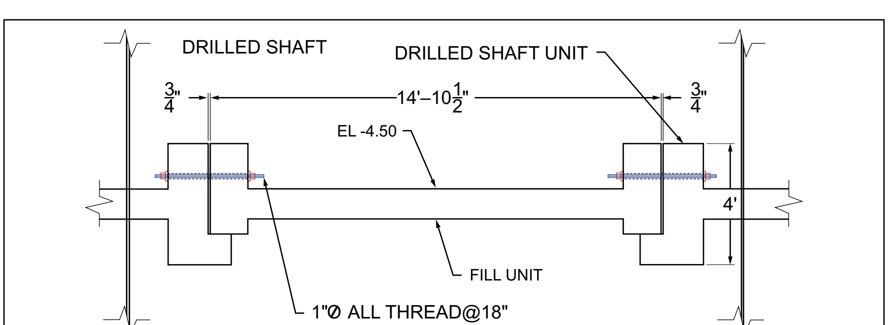
Nose unit installation over a drilled shaft. Photo: Cianbro.

The dewatered tub with the drilled shafts visible. The work platform has been attached to the top of the tub. Photo: Cianbro.

before a segment was set allowed the divers to grout the connection from the top. High-strength (8 ksi), structural underwater concrete, with washout additives, provided the required strength in a timely manner in the cold river water.



The precast concrete segmental tub. The use of sand-lightweight concrete for the segments allowed the tub to be installed using readily available equipment. Figure: Cianbro.



Typical segment joint detail. The fill unit of the tub was placed on an integral ledge of the drilled-shaft unit during erection. Later, the joint was grouted and post-tensioned. Figure: Cianbro.

Conclusion

The precast concrete, post-tensioned segmental tub provided a cofferdam/form system that was constructed using readily available erection equipment. Tub erection, grouting, and dewatering took only 30 days, which helped meet an aggressive project schedule. Exposure to the harsh environmental conditions was minimized, thereby reducing risk. The use of sand-lightweight concrete was also critical to the success of the design.

Reference

1. American Petroleum Institute (API). 2014. *API Recommended Practice 2A-WSD: Planning, Designing, and Constructing Fixed Offshore Platforms—Working Stress Design*. 22nd ed. Washington, DC: API.

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EDITOR'S NOTE

More information on the Sarah Mildred Long Bridge is contained in a Project article in this issue of ASPIRE *on page 24.*