Tappan Zee Hudson River Crossing

The New NY Bridge Project

Figure 1. New NY Bridge rendering.

By Michael D. LaViolette, P.E.

The Tappan Zee Hudson River Crossing (or "New NY Bridge") is perhaps the largest and most challenging bridge project currently under construction in the US. The project includes two parallel, 3.1 mile-long bridges crossing the Hudson River between Rockland and Westchester Counties, approximately 25 miles north of New York City. Each of the two bridges consists of a 1,200-foot cable-stayed navigation span with common foundations and diverging towers, along with a series of 350-foot continuous, steel girder spans supported on seismic isolation bearings.

Construction of the bridges is currently ongoing and is scheduled for completion in 2018 by Tappan Zee Constructors, a design-build LLC composed of Fluor Enterprises, American Bridge Company, Granite Construction Northeast and Traylor Bros. HDR is serving as the lead designer for the project, with significant contributions from Buckland & Taylor, URS, GZA and a diverse array of nearly 40 sub-consultants. The bridge is owned by the New York State Thruway Authority and represents their first design-build project.

The project requirements dictated that the primary structural components of the crossing be designed and constructed to provide a 100-year service life before major maintenance will be required. These components include the foundations, substructures, superstructures and bridge decks. The design of bridge systems and components using materials with proven long-term performance characteristics was critical in meeting this requirement. A sophisticated probabilistic approach to the service life was implemented in the design phase to assure a reasonable certainty of satisfying the desired service life criteria.

In addition to the demanding design and construction challenges – poor foundation soils, large variation in geotechnical design parameters, moderate seismicity, and ice loading – the bridge is designed to support a future third parallel bridge to carry dual-track railway traffic. The future construction of a commuter or light rail bridge in the narrow gap between the two highway bridges, and without the need for additional foundation construction in the water, required that all foundations and the main span towers be analyzed, and conceptual details developed, to ensure the feasibility of this future load condition. Significant ongoing challenges facing the design-build team include the very aggressive schedule and the need to maintain the full traffic capacity of the existing bridge throughout the project.

The iconic main span structure forms the centerpiece of the new crossing, comprising twin cable-stayed bridges, with 1,200-foot main spans and 515-foot side spans. Each deck will carry four traffic lanes and have wide inner and outer shoulders that provide operational redundancy and flexibility.

The main span decks are carried by a semi-fan, parallel-strand, stay cable system anchored to distinctive, outward leaning, V-shaped reinforced concrete towers. The inclined legs of each tower are straight, open box sections connected by single, below-deck cross beams. The future rail transit deck will be supported by a future cable anchorage unit and cross beam that will connect the inner legs of the two towers. The bridge foundations are designed to carry the future rail structure without modification.

Each superstructure consists of stiffened steel edge girders and transverse floor beams supporting high performance precast concrete deck panels made composite with the steel using cast-in-place infill joints. To minimize deck width and weight, the stay cables are eccentrically anchored outside of the edge girders.

Substructure

Highly variable foundation conditions at the site represented one of the largest risks to the design-build team. Approximately one-third of the piers on the crossing are underlain by alluvial deposits of normally consolidated organic clay up to 180 feet deep, above lightly over-consolidated glacial lake deposits of varved silt and clay that extend up to 750 feet deep. Due to the extreme depth of these deposits, end-bearing piles were seen as impractical and, consequently, friction foundations consisting of 48-inch diameter, open-end pipe piles extending to 330 feet below the Hudson River were selected. A cast-in-place concrete plug is used to transfer foundation loads to the piles and provide an additional measure of redundant corrosion protection.

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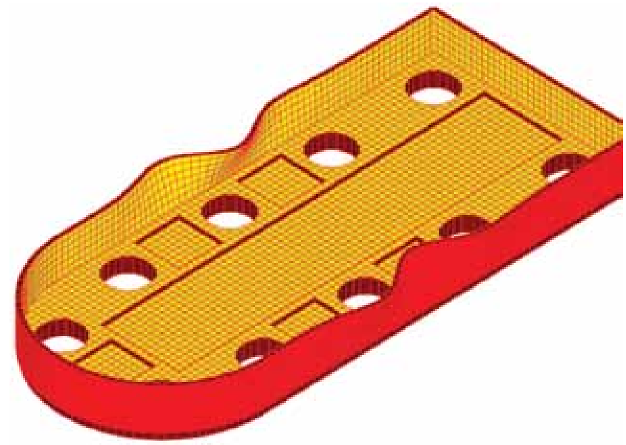

Figure 2. Precast pile tub buckling analysis model (deformations exaggerated).

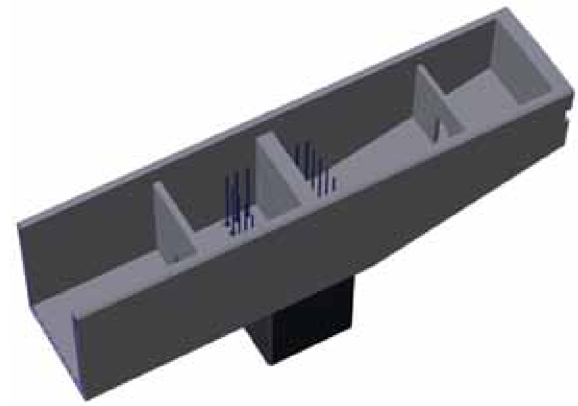

Figure 3. Solid model of precast pier capbeam tub.

The remaining foundations, from Pier 19 to the Westchester abutment, are supported primarily on a combination of 48-inch and 72-inch piles driven to end bearing, with a limited use of 36-inch piles and drilled shafts near the shoreline. Piles are currently being preassembled into 160- and 180-foot subassemblies and driven with both vibratory and hydraulic hammers in order to minimize noise and environmental impacts to surrounding property owners and endangered aquatic species.

While the main span tower foundation utilized a precast concrete soffit system, the approach span foundations consist primarily of precast concrete tub-style footings that will be filled with cast-in-place concrete once the tub is placed over the driven piles. The heavily reinforced precast tubs are made composite with the infill concrete through an extensive network of embedded reinforcing and roughened interior surfaces. Extensive three-dimensional finite element analyses using SAP and Xtract were performed to investigate lifting and shipping stresses, temporary support conditions, buoyancy and wave action, staged concrete placement and time dependent effects including differential shrinkage. An exaggerated buckling model of the precast pile tub footing is shown in *Figure 2*.

Precast concrete capbeam shells – up to 92 feet long, 10.5 feet wide, and 13 feet deep and weighing 280 tons each – are used for 59 of the approach piers. These tub-shaped precast elements minimize over-water formwork and provide a safe work space for tying of reinforcement (*Figure 3*). The design features of the capbeam shells were chosen to minimize pick weights, standardize details and to provide fully-composite behavior with the infill concrete. A detailed time-dependent analysis of the staged construction sequence was performed to evaluate the effects of differential creep, shrinkage and locked-in stresses between the precast shell and the cast-in-place infill concrete. Prestressing was provided in the precast pier cap shells to eliminate concrete tension during the second stage cast-in-place infill concrete placement, and to minimize cracking due to long-term differential shrinkage.

Superstructure

A girder-substringer framing system was chosen for the nominal 350-foot approach spans, most of which are arranged in five-span continuous units. This type of system typically provides an estimated cost savings of 10 to 20 percent compared to a multi-girder system for spans in this range. In addition, this relatively light structural system reduces loads on the foundations, a criteria that was particularly important for the western approach spans which are supported on long friction piles.

The use of large-scale prefabrication is a critical part of the bridge construction. The Left Coast Lifter, one of the largest floating cranes in North America, with an 1,800 ton lifting capacity, will be used to install pre-assembled two or three girder groups, one full span at a time, which eliminates nearly all temporary falsework in the river, improves worker safety, and saves time and construction costs for operations on the water.

Hybrid girders, with girder flange plates consisting of a mixture of Grade 50W and HPS 70W steel, are used to reduce girder weight and maintain high fracture toughness in support of the 100-year service life objective, with due consideration of the limited availability of this material. All thickness changes for the top flange plates are accomplished by varying the web depth and recessing the flange plate changes into the web to accommodate the use of precast deck panels. Girder web depths are transitioned only at the bolted field splice locations.

Precast concrete deck panels, approximately 12 feet long and varying from 42 feet–3 inches to 46 feet–9 inches in width, utilize a single longitudinal closure pour between panels. The panels consist of high-performance concrete with 5 ksi compressive strength and mild reinforcement (no post-tensioning). In order to eliminate the need for form stripping, the transverse joints feature a permanent, integral bottom form ledge. The joint utilizes overlapping hairpin reinforcement projecting from each adjacent panel and a number of transverse reinforcing bars that are inserted through the hairpins to provide a continuous mechanical connection between panels.

To validate the reinforcement-only option for the cast-in-place deck joints, a SAP2000 finite element model was used to evaluate the service-level stress condition of the bridge deck for a fully continuous superstructure. The SAP2000 analysis included staged construction, time-dependent effects and non-linear post-cracking behavior of the reinforced concrete deck and joints.

Structural Additions

In consideration of the extensive public involvement and visual quality processes for the New NY Bridge, the project requirements included the incorporation of a shared use path (SUP) for pedestrians and bicycles as part of the permanent westbound bridge configuration. In addition, one of the intermediate construction stages includes a period of time when westbound vehicular traffic is allowed to utilize the future SUP portion of the cross-section as a travel lane. Additional special structure details include:

Belvederes – the westbound bridge incorporates six 12- x 60-foot belvedere structures cantilevered from the north face of the exterior girders. The belvedere structures are supported through a cantilever connection from the exterior girder web and rigidly braced to the interior girder to eliminate torsional girder deformations.

Permanent Crossovers – will be provided between the eastbound and westbound structures at three locations along the crossing to facilitate public evacuation and turnaround capabilities in the event of an extended delay from a traffic obstruction. These simple-span structures are supported on brackets attached to the interior girders of the opposing bridges.

Conclusion

Perhaps the greatest benefit of the design-build method is that it allowed the engineers to interact directly with the contractor throughout the design phase. The innovations resulting from this collaboration not only met all the project requirements and design criteria, but did so by incorporating the contractors' means and methods to generate cost-savings and provide the greatest schedule benefit.

The New NY Bridge project is an outstanding example of using the design-build contracting method to deliver an innovative and cost-effective project. The Tappan Zee Constructors team worked together during the design phase to validate and compare various structural systems, ultimately developing a cost-effective design solution that is quickly being realized as a new, iconic bridge for the New York area.▪

All photos courtesy New York State Thruway Authority.

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