# BAYONNE BRIDGE

## NEW BRIDGE ALLOWS LARGER CONTAINER SHIPS TO PASS

by Joseph LoBuono and Chester Werts, HDR

Tight constraints for erection of single-cell box-girder pier table segment. The 42-ft difference in the elevations of the old and new approaches is evident. All Photos and Figures: HDR.

The Port Authority of New York & New Jersey's (PANYNJ's) Bayonne Bridge carries Route 440 over the Kill Van Kull, the navigational entrance to the Ports of Newark and Elizabeth in New Jersey. The Bayonne Bridge connects the city of Bayonne, N.J., to the north with Port Richmond, N.Y., in New York City's Borough of Staten Island, to the south. Prior to reconstruction, the average daily traffic across the bridge was approximately 22,000 vehicles. Bids for the "Bayonne Bridge Replacement of Main Span Roadway and Approach Structures" contract were received in April 2013 and the construction contract was awarded on May 10, 2013, in the amount of $744 million.

Following the widening and deepening of the Panama Canal, including a third set of locks, and the advent of larger post-Panamax container ships, the restrictive 151-ft navigational clearance (air draft) of the Kill Van Kull would have resulted in container traffic seeking other ports of call. In addition, there have been frequent incidents of container ships' masts scraping the underside of the existing bridge structure. These issues created the need to increase the air draft of the Bayonne Bridge to maintain the ports' economic competitiveness, protect port-related jobs, maintain regional economic activities, and provide a safer bridge crossing for the traveling public.

The port facilities of Newark and Elizabeth are among the busiest in the world, with approximately 12% of all U.S.-bound international containers passing under the Bayonne Bridge. The U.S. Army Corps of Engineers estimated that raising the Bayonne Bridge would produce a $3.3 billion national benefit, and that the ports indirectly create approximately 270,000 jobs and generate $11 billion in annual national wages. The Bayonne Bridge Navigational Clearance Program will allow the largest post-Panamax ships, carrying more than 12,000 container units each, to pass under the bridge, increasing the overall capacity for the ports. Prior to the project, the largest ships allowed to pass under the Bayonne Bridge could carry only half that amount.

## profile

**BAYONNE BRIDGE** / STATEN ISLAND, NEW YORK, AND BAYONNE, NEW JERSEY

**BRIDGE DESIGN:** HDR-WSP, a joint venture, New York, N.Y.

**PRIME CONTRACTOR:** Skanska-Koch Kiewit (SKK), a joint venture, Carteret, N.J., and Woodcliff Lakes, N.J.

**PRECASTER:** Bayshore Concrete Products, Cape Charles, Va.—a PCI-certified producer

**POST-TENSIONING CONTRACTOR:** Schwager Davis Inc., San Jose, Calif.

**OTHER CONSULTANTS:** Arora and Associates P.C., Lawrenceville, N.J.; HNTB Corporation, Parsippany, N.J.; IH Engineers P.C., Princeton, N.J.; KPFF, Chicago, Ill.; and Thornton Tomasetti, New York, N.Y.

## Feasibility Study

A feasibility study was performed in 2008 to determine the most effective way to increase the air draft of the Bayonne Bridge to 215 ft. As part of the feasibility study, many alternatives were investigated, including raising the roadway within the arch, building a new bridge, creating a new tunnel below the channel, jacking the arch up, modifying the existing bridge to a lift bridge at midspan, and instituting non-bridge alternatives such as ferry services or lock and dam.

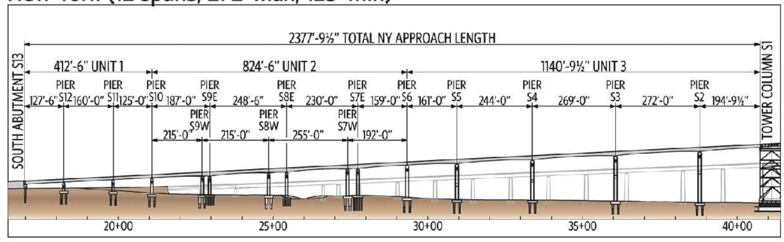
The study concluded that raising the roadway within the bridge's existing steel truss-arch span would be the most expedient and efficient method to achieve the increased navigational clearance while maintaining traffic on the bridge. Raising the roadway did not require any permanent right-of-way acquisition as the project remained within the existing bridge and approach right-of-way footprint. This limited the environmental and neighborhood impacts and made possible an environmental assessment in lieu of an environmental impact statement.

To achieve this goal, it was necessary that the steel trusses in the arch be strengthened, new arch portals be opened for the higher roadway in the arch span, and the existing arch portals be closed. Taller arch-transition towers were also needed to allow for the connection of the elevated roadway to the new arch portals.

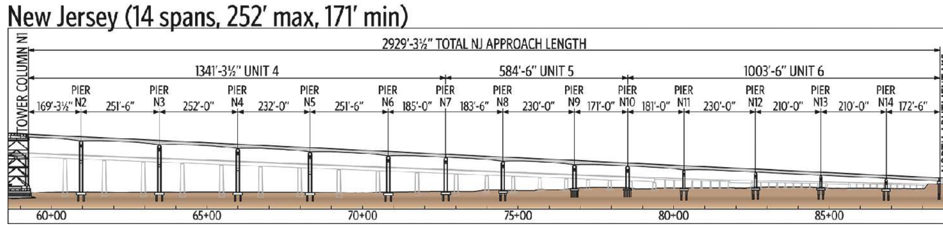
With the higher roadway elevation, the existing approach structures in New York and New Jersey required increased elevations and steeper grades to connect with the new arch span.

Project criteria required that the roadway be widened to provide roadway widths and shoulders to meet current American Association of State Highway and Transportation Officials (AASHTO) standards, provide a shared-use path for pedestrians/bicyclists, and accommodate potential future light-rail transit. Adding to the complexity of the project, contract criteria required that one lane of vehicular traffic in both the northbound and southbound directions be maintained during peak travel times throughout the project duration, thus requiring staged construction. Furthermore, construction zones for the approach structures were extremely tight, with private residences located within 30 ft of the bridge footprint. All these requirements were accommodated in the design and construction phases.

New York (12 spans, 272′ max, 125′ min)




New Jersey (14 spans, 252′ max, 171′ min)



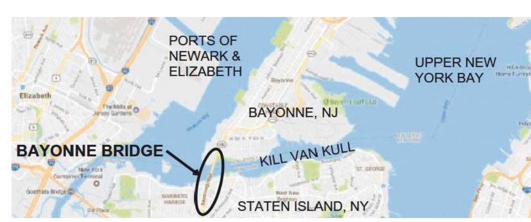

Pier layouts for the New York and New Jersey approach structures.

## The New Bayonne Bridge

With an arch span of about 1652 ft from pin-to-pin, the Bayonne Bridge was the longest arch bridge in the world when it was completed in 1931, and remained so for 46 years. The project limits of the approach ultimately determined the steeper grades of the new approach roadways. The New York approach was constrained by the Walker Street overpass, large retaining walls, a school, a church, and a cemetery, while the New Jersey approach was constrained by the existing multilane JFK Boulevard underpass and existing entrance and exit ramps. These vertical clearance constraints resulted in 5.00% and 4.85% approach grades in New York and New Jersey, respectively. The existing approach grades were 4%.

The new approach structures have 24 piers and 52 spans with approach lengths of approximately 2377 and 2929 ft in New York and New Jersey, respectively. The new layout reduced the number of piers by 14, thereby opening up the visual sight lines to residents and pedestrians.

The Design Development Report addressed the use of precast concrete segmental construction and steel-plate girder construction for the approaches. PANYNJ chose the precast concrete alternative based on reduced cost, improved aesthetics, improved durability, and reduced maintenance cost. From an environmental assessment perspective, precast concrete was favored due to reduced traffic noise in the final structure and the elimination of over 1000 concrete truck trips through neighborhoods to place a concrete deck slab for the steel alternative. Overhead gantry erection eliminated the need for cranes (noise, air quality, local traffic disruption), except for erection of the precast concrete pier tables.




Location of the Bayonne Bridge over the Kill Van Kull.

PORT AUTHORITY OF NEW YORK AND NEW JERSEY, OWNER

**BRIDGE DESCRIPTION:** Twin precast, post-tensioned segmental concrete box girders with a total single box length of 10,614 ft; precast segmental concrete columns and pier caps

**OTHER MATERIAL SUPPLIERS:** Self-launching gantries: Handan China Railway Bridge Machinery Co LTD, Handan City, China; Precast segment form systems: Ninive, Casseforme, Italy; Onsite segmental forms: Doka USA, Little Ferry, N.J.; Bearings and finger joints/modular deck joints: Mageba USA, New York, N.Y.; Segmental epoxy: Pilgrim Permocoat Inc., Tampa, Fla.; Segmental grout: Sika U.S.A., Lyndhurst, N.J.; Stainless-steel reinforcement in precast: CMC, Cincinnati, Ohio; Stainless-steel reinforcement in cast-in-place concrete: Salit Specialty Rebar, Niagara Falls, N.Y.; Post-tensioning grout: Five Star Products Inc., Shelton, Conn.

**STRUCTURAL COMPONENTS:** 512 precast concrete substructure segments, 1079 precast concrete superstructure segments, 5179 ft of 60-in.-diameter drilled shafts, 12,484 $yd^3$ of cast-in-place concrete footings

**BRIDGE CONSTRUCTION COST:** $744 million (low-bid cost); $1430/$ft^2$ (total project)

Balanced-cantilever construction for the Bayonne Bridge approaches.

The structure is designed for an additional 100 years of service life after the opening of the reconstructed facility. All reinforcement in the deck or anchored in the deck is stainless steel.

Precast concrete segmental construction is effectively being used for the balanced-cantilever superstructure as well as for the substructure piers and pier caps. Hollow precast concrete segments were used at all 24 of the two-column pier locations, as well as the post-tensioned precast concrete pier-cap segments. Precast concrete segmental construction was used for all 52 spans of the New York and New Jersey approach superstructures. All designs were in accordance with the *AASHTO LRFD Bridge Design Specifications*, 6th edition.

## Approach Design and Construction

The design of the hollow precast concrete columns and arched precast concrete pier caps included aesthetics and architectural face treatments to complement the existing architecture of the original 1931 Bayonne Bridge approach piers. Where the substructures support the typical 36-ft-wide roadway, a combined Type 1 two-column pier is used. In the areas adjacent to the abutments on each end of the bridge, where the acceleration and deceleration lanes add an additional 12 ft to the roadway template, side-by-side Type 2 single-column piers are used (see the CBT article in this issue for more information on the piers).

The superstructure is being cast and erected as twin single-cell box girders with variable width to accommodate acceleration and deceleration lanes. The northbound roadway accommodates a 12-ft-wide shared-use path, while the southbound roadway is designed to accommodate future light-rail transit.

All precast concrete segments are being cast in Cape Charles, Va. Precast concrete elements are barged 300 miles on the ocean to Bayonne, N.J., where they are off-loaded and stored until needed for erection. Superstructure segments are either 10- or 14-ft-deep, and the maximum haul weight is 112 tons.

AESTHETICS
**COMMENTARY**
**by Frederick Gottemoeller**

Talk about a challenge: significantly altering one of the iconic bridges of the twentieth century, designed by one of the century's master builders, Othmar Amman, and doing that while the bridge is in continuous use! I don't know how the design team slept at night. But they certainly rose to the challenge.

Let's start with the decision to use precast concrete segmental construction for the approach spans. It significantly changes the look of the bridge in comparison to the steel-plate girder spans of the original, but the longer spans and fewer piers open up views through the structure that didn't exist before, and create opportunities for new ground-level activities that will benefit all of those people who live or work near the bridge. Plus, the more massive concrete superstructure absorbs road noise, an underappreciated benefit of concrete segmental construction that will improve the local environment aesthetically as well as physically.

Then there are the new approach piers. The taller and wider piers are more prominent elements in the scene than were the original piers, but visual continuity with the original piers is established by borrowing their arched pier caps and the horizontal grooves of their columns.

I. M. Pei, the architect who redesigned the Louvre, stated the challenge of altering famous structures this way: "How do we make history live, and still point the way to the future?" The designers of the Bayonne Bridge reconstruction have shown how.

| Key Design Parameters and Principal Quantities | |
|---|---|
| Superstructure concrete strength | 10 ksi |
| Substructure concrete strength | 8.5 ksi |
| Superstructure concrete volume | 44,900 $yd^3$ |
| Substructure concrete volume | 15,600 $yd^3$ |
| Superstructure theoretical (average) thickness | 2.33 ft |
| Superstructure reinforcing bar density[2] | 192 $lb/yd^3$ |
| Superstructure post-tensioning (longitudinal) | 5.1 $lb/ft^2$ |
| Superstructure post-tensioning (transverse) | 1.0 $lb/ft^2$ |
| Substructure reinforcing bar density | 160 $lb/yd^3$ |
| Substructure post-tensioning steel density | 70 $lb/yd^3$ |

[1] Theoretical average thickness is the volume of superstructure concrete divided by the total deck area. It is a helpful parameter for conceptual estimation of concrete quantities as it varies with the average span length for a given project.

[2] Approximately 70% of the reinforcement was stainless steel, and the remaining 30% was epoxy coated.

Balanced-cantilever construction of the superstructure is performed with the use of overhead self-launching gantries. Superstructure erection is performed at night with the existing bridge closed to traffic, while the permanent post-tensioning is installed and stressed during daytime hours.

### Construction Status

On February 20, 2017, two lanes of northbound traffic were transferred onto the new upper roadway. Demolition of the existing suspended-arch floor system has commenced, with June as the target removal completion date. Larger container vessels will then be able to access the port facilities. Removal of the existing approach structure is now under way.

The first task for the southbound approach is the installation of the drilled shafts, followed by construction of the footings. Fabrication of the precast concrete segments for the southbound substructure is essentially complete and casting of the superstructure elements was approximately 65% complete as of April. It is anticipated that construction of the southbound structure will be completed in 2019.

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**EDITOR'S NOTE**

*Another article about the Bayonne Bridge project is included in this issue on page 28.*