DESIGN AND CONSTRUCTION OF THE ROUTE 36 HIGHLANDS BRIDGE OVER THE SHRESWBURY RIVER, NJ

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ABSTRACT

The Route 36 Highlands Bridge over the Shrewsbury River provides for the on-line replacement of a 1,240-ft long low-level double leaf bascule bridge with a mid-level fixed segmental concrete bridge. The new bridge consists of twin precast segmental concrete box girder structures, each 1,610-ft long, to carry eastbound and westbound traffic respectively. The bridges are being built by the balanced cantilever construction method using barge mounted and land based cranes. The substructure for each box girder structure features single column precast post-tensioned hollow box section piers. The river piers are supported on waterline footings founded on 54-inch diameter prestressed concrete cylindrical piles. Precast concrete cofferdam cells are used for casting the waterline footings. The two structures are built in stages to enable the existing bridge to carry a minimum of two traffic lanes throughout the construction period.

Keywords: Precast, Segmental, Balanced Cantilever, Post-Tensioning, Waterline Footings

INTRODUCTION

The Route 36 Highlands bridge project entails the replacement of the existing 77-year old double-leaf bascule bridge with a mid-level fixed bridge. The existing bridge carries Route 36 over the Shrewsbury River connecting the town of Highlands with the town of Sea Bright and Sandy Hook Gateway National Recreation Area, in Monmouth County, New Jersey. Structural deterioration and functional obsolescence prompted the New Jersey Department of Transportation (NJDOT) to replace the bascule bridge. The bridge is part of the coastal evacuation route from Sea Bright and other coastal towns onto Route 36 in the Highlands.

NJDOT hired JACOBS to design the replacement project. Besides the bridge over the Shrewsbury River, the replacement project includes: Ramp J structure from the National Park Service Road westbound onto Route 36; Approach roadway and intersection improvements in the towns of Highlands and Sea Bright; Modifications to the existing toll plaza at the Gateway National Recreation Area toll plaza at Sandy Hook Park; Pedestrian/bicycle access paths on and off the bridge; Two prestressed concrete pedestrian bridges over Ocean Avenue; A fishing pier and landscape improvements to South Bay Avenue Park; and two precast concrete sand filter structures at each end of the bridge to collect and treat rainfall water per Category 1 Stream Stormwater requirements.

EXISTING CONDITIONS

The existing Route 36 Bridge, built in 1932, is 1,240-ft long and consists of a 12-span low-level structure with nine concrete-encased steel girder approach spans supported on a three-girder system, two steel plate girder flanking spans to the main span supported on a two-girder system, and the simple-trunnion double leaf bascule main span.

Fig. 1 Existing Route 36 Highlands Bridge

The length of the bascule span is 140 feet providing for a 100-ft wide navigation channel, while the approach spans vary in length from 60 to 100 feet. The bridge carries two 11-ft wide lanes in each direction and lacks shoulders and a median barrier. The restrictive 35’ vertical bridge clearance over the Shrewsbury River requires the bascule span to open twice an hour for maritime traffic creating extensive delays and congestion, particularly during the summer months when the beach lots are filled in Sea Bright and Sandy Hook. Because of its advanced deterioration and physical and design deficiencies, the structure is being replaced.

PROPOSED BRIDGE

The existing bridge is being replaced with a mid-level fixed bridge providing for a minimum navigation vertical clearance of 65’ above MHW EL 1.81. The structure will provide for two 12-ft wide traffic lanes, 3-ft inside and 8-ft outside shoulders, and an 8-ft wide sidewalk in each direction. The out to out width of the bridge is 92’-3” and provides for a center split median.

Fig. 2 Proposed Route 36 Highlands Bridge (Rendering)

To minimize right-of-way impacts, the bridge is being constructed on a “nearly on-line” alignment with a slight shift to the south so that the new navigation channel span clears the bascule span to enable the existing bridge to remain operational during construction, while the approach spans on each side merge over and into the existing alignment to the east and west abutments in Sea Bright and Highlands.

BRIDGE DESCRIPTION

The new bridge consists of twin precast segmental concrete box girder structures, each approximately 1,610-foot long, designed to be built by the balanced cantilever method of construction. To enable the existing bridge to carry a minimum of two traffic lanes throughout the construction period, the bridge is being built in two halves with the south (eastbound) structure constructed first while portions of the existing bridge remain in service. Upon completion of the south bridge, all traffic will be re-routed from the existing bridge to the south bridge. After completing demolition of the existing bridge, the north bridge will be constructed. The traffic then will be re-routed to normal eastbound and westbound traffic for the new bridge.

The south bridge measures 1,606’ in length and consists of a nine-span continuous structural unit with span lengths of 112’, 177’, 184’, 237’, 230’, 199’, 168’, 167’, and 132’ oriented from the west abutment in Highlands to the east abutment in Sea Bright. The north bridge measures 1,610’ in length and consists of two structural units. Unit 1 consists of a seven-span continuous structural unit with span lengths of 112’, 169’, 176’, 227’, 230’, 201’, and 100’ oriented from the west abutment to Pier 9. Unit 2 is a three-span continuous structure with span lengths of 88’, 167’, and 140’ from Pier 9 to the west abutment in Sea Bright. Ramp J is 211’ long and consists of a two-span continuous structural unit with span lengths of 99’ and 112’ from Pier 9 to a north abutment in Sandy Hook. The variation in span lengths in the three structures was required so that the new piers are located to clear the existing bridge pier foundations and minimize the number of piers in the river.

SUPERSTRUCTURE

The south bridge has a constant out-to-out deck width of 46 feet from abutment to abutment carrying two 12-ft wide traffic lanes along with a 3-ft and 8-ft wide inside and outside shoulders, and an 8-ft wide sidewalk. The north structure is 46-ft wide and has the same deck cross-section as the south bridge from the west abutment up to Pier 6 where it then begins to widen to accommodate the split into Ramp J to the north and Ramp K/L to the south. The deck cross-section of the north structure from Pier 6 to the east abutment towards Ramp K/L consists of one 12-ft wide traffic lane flanked by 3-ft and 8-ft wide inside and outside shoulders for an out-to-out deck width of 26 feet. Ramp J consists of an 18-ft wide traffic lane flanked by a 2-ft left shoulder and 8-ft right shoulder and 8-ft wide sidewalk for an out to out deck width of 39.5 feet. A 3 inch gap is provided between the two structures.

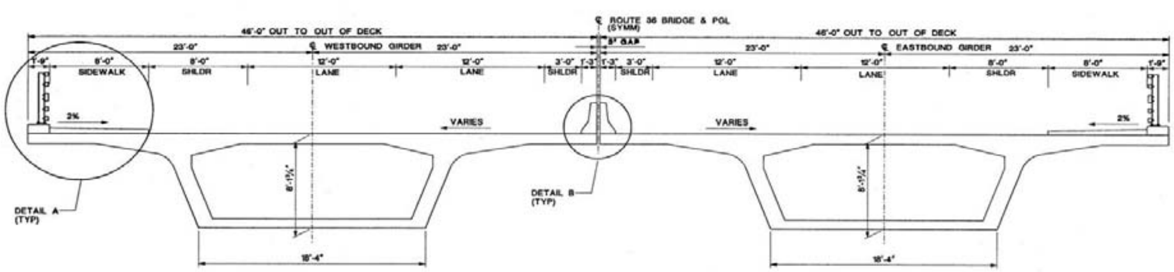

Fig. 3 Deck Cross-Section

Each of the twin structures and Ramp J feature a single cell trapezoidal box girder to support the roadway. The depth of the box girder is typically kept constant at 8’-1 ¾”, except in longer spans 3 to 6 where it varies from a maximum of 11’-1 ¾” at Piers 3 to 5 to a minimum of 7’-0” in spans 4 and 5 and to 8’-1 ¾” in spans 3 and 6. The 7’-0” depth was dictated by vertical navigation clearance requirements in span 4. A parabolic variation is provided to transition from a haunch at Piers 3 to 5 to a constant depth superstructure section at approximately the quarter point of the spans.

The typical segments are 10’-0” long except for six variable depth segments on each side of Piers 3 to 5 that are made 8’-0” long to reduce the weight of segments for shipping purposes and to standardize lifting equipment. Also the pier segments which are heavier than a typical segment because of a diaphragm are cast in two 5-ft segments. These lengths along with the varying closure joint widths are combined to produce the different span lengths that are required to build new foundations to clear the existing bridge pier foundations. A typical 8’-1 ¾” deep by 10’-0” long segment weighs 65 tons.

With the webs inclined at a constant slope of 2.586 to 1 (vertical/horizontal), the bottom flange of the 46-ft wide box girder is 18’-4” for a girder depth of 8’-1 ¾” and 16’-0” for the 11’-1 ¾” deep girder at Piers 3 to 5. The top slab cantilever overhangs are 11’-5” long. For the 26-ft and 39.5-ft wide box girders the bottom flange width is 11’-10” while the deck overhangs are 4’-8” and 11’-5” long respectively.

The box girder segments are being cast with an additional ½” of concrete in the top slab, so that when erection is complete, the riding surface can be milled to meet NJDOT’s rideability criteria. An additional 1 ¼” of sacrificial concrete is also cast into the top slab to provide for an integral wearing surface. No second course wearing surface will be provided, however the additional 1 ¼” concrete can be removed and replaced with an overlay if required in the future. The thickness of the top slab is accordingly set at 10 ¾” and provides for a concrete cover of 3 ¾” to the top mat reinforcing steel. The webs are 1’-4” thick while the bottom flange is typically 9” thick and varies from 9” to 1’-6” over three segments on each side of the pier table at each pier.

Longitudinal post-tensioning required for the balanced cantilever construction of the superstructure segments consists typically of 19 x 0.6” diameter Grade 270 Ksi strand tendons for the cantilever tendons in the top slab and 18 x 0.6” diameter strand tendons for the continuity tendons in the bottom slab. Cantilever tendons are placed in a single layer to the left and right over each web and are anchored at a fixed center anchor over the web. Continuity tendons are anchored in an anchor block (blister) on the interior of the segments. Transverse post-tensioning in the top slab consists of 4 x 0.6” diameter strand tendons typically spaced at 2’-6” center to center.

The superstructure segments utilize high performance concrete (HPC) with a minimum compressive strength of 7,000 psi. HPC provides for a dense mix with good resistance to freeze thaw conditions and permeability for long-term durability.

SUBSTRUCTURE

The substructure for each box girder structure consists of the abutments at each end and single column piers constructed from precast hollow box sections that are post-tensioned together. Out of 18 piers for the three structures, 12 piers are in the river and six piers on land. The precast hollow box sections for the piers are typically 16’-4” by 8’-4” feet with a wall thickness of 13 inches, and vary in length from 5’ to 10’. Solid 5-ft thick precast pier caps, measuring 18’-10” by 8’-4” at the expansion bearing piers and 16’-4” by 8’-4” at the fixed bearing piers (Piers 4 and 5 in the south structure and Piers 3 and 4 in the north structure) are placed at the top of the piers. The piers vary in height to follow the profile grade line with the tallest Pier 4WB reaching El 64.6. The precast concrete is high performance concrete with a compressive strength of 6,000 psi at the expansion bearing piers and 8,000 psi at the fixed bearing piers.

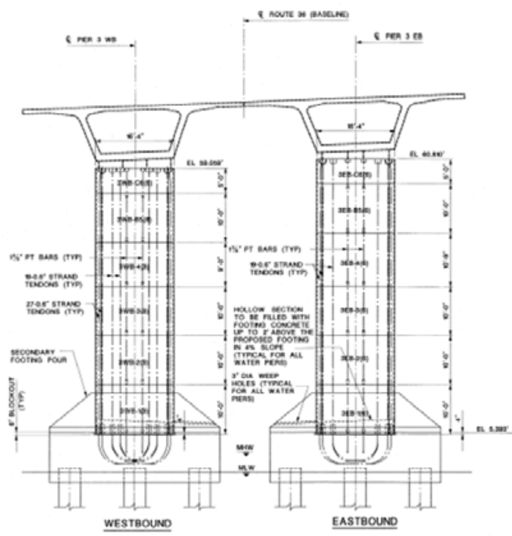

Fig. 4 Precast Piers Elevation

The river piers are supported on waterline footings, typically 35’-6” x 35’-6” x 10’ deep, and founded on nine 54-inch diameter prestressed concrete cylindrical piles spaced at 13’-6” center to center. With MHW at El 1.81 and MLW at El -2.48, the top of the river footings is set at El 5.4 and the bottom at El – 4.6. A schematic of a precast concrete cofferdam cell was shown in the contract drawings for casting the waterline footings, with the final type to be determined by the Contractor’s means and methods.

The land footings are typically 24’ x 30’ x 8’ deep and are supported on twenty 24” square prestressed concrete piles spaced at 6’ center to center. The top of the land footings is set a minimum of 2 feet below ground line. The abutments are conventional cast-in-place concrete supported on 14-inch square prestressed concrete piles.

High performance concrete was specified for all the footings and the precast concrete cofferdam cells for better resistance to waterway abrasion and chloride intrusion.

BRIDGE DESIGN

The bridge was designed in accordance with the AASHTO LRFD Bridge Design Specifications and the AASHTO Guide Specifications for Design and Construction of Segmental Concrete Bridges.

The bridge was designed for a 100-year service life and designated for design purposes as an “Essential Bridge”.

In addition to zero tension required for longitudinal stresses through joints in the precompressed tensile zone, zero tension was also prescribed for transverse stresses in the deck. For transverse deck design, the HL-93 vehicle was limited to the design truck or design tandem.

The design of the precast piers and foundations was controlled by seismic loads which were calculated from multimode spectrum dynamic analysis on the basis of seismic zone 2 and an acceleration coefficient of 0.15. To reduce the effects of seismic loads, seismic isolation bearings were incorporated into the design. Schematic details were detailed on the plans, with the Contractor required to select and design the bearing system based on the seismic isolation bearing schedule (loads and movements) and seismic isolation bearing properties tables (characteristic strength friction force due to seismic movement and thermal movement, post elastic stiffness, peak elastic forces at maximum seismic movement, etc.) provided.

AESTHETIC FEATURES

As the bridge is a gateway to the New Jersey shore towns of Highlands and Sea Bright, as well as the Gateway National Recreational Area at Sandy Hook, aesthetics were of paramount importance towards achieving a new bridge which responds to the historic setting and character of the existing bridge. Architectural features incorporated into the design include two monuments (pylons) at the west abutment in Highlands and two pylons at the East Abutment in Sea Bright. The pylons will feature decorative fish tiles replicated from the existing bridge, placed at the base of the pylons. The roadway lighting poles, required every 150’, will be supported on concrete pilasters that also feature decorative fish tiles replicated from the existing bridge.

A 5-bar open steel rectangular railing has been selected to enhance the openness of the bridge to the motorists and pedestrians and provide unobstructed views of the Atlantic Ocean. Other architectural features include rustications/reveals in the pier columns and form liners on the waterline footings. The architectural features were developed by an aesthetic task force convened under the auspices of NJDOT.

CONSTRUCTION

The project was competitively bid with four bids received on December 21, 2007. J. H. Reid General Contractor of South Plainfield, NJ was the low bidder at $124.6 million. Notice-to-Proceed was given to the contractor on January 28, 2008.

With a temporary hold on construction activities on the bridge until June 1, 2008, the contractor’s early activities involved utility relocations, construction of temporary intersections, construction of the north pedestrian bridge in the National Park Service Area, barge deliveries to jobsite and assembly including setting up of a casting yard to the northeast end of the project in National Park Area to begin casting of the precast concrete cofferdams for the river piers.

Demolition of the south half of the existing bridge started the week of July 14, 2008 proceeding with the demolition of girders and deck slab span by span from the west to the east abutment, while traffic was re-routed to the north half of the bridge to carry one traffic lane in each direction throughout construction. Demolition of the south half of the bridge was completed the week of September 15, 2008. Early foundation activities included load testing of piles, driving sheeting for land piers and abutments, begin casting of precast cofferdam cells with the largest cofferdam weighting about 240 tons, and installation of temporary support steel frames required to support the precast cofferdam cells at the river piers.

The first precast cofferdam cell was installed at Pier 3 the week of September 22, 2008. The installation procedure provided for floating the cofferdam below a temporary support steel frame, the cofferdam was then lifted into proper elevation and supported temporarily off the frame with post-tensioning bars anchored into the 10” thick walls of the cofferdam. The 21” thick base of the precast cofferdam included a fabricated steel ring at each pile location. The Contractor used the cofferdam as template to drive the nine 54” diameter cylindrical piles, followed by the installation of underwater grout seal between piles and cofferdam, dewatering, cutting the piles at proper elevation, and completing the pile ring connection. Construction followed with a 1-ft thick pour of footing concrete and removal of the post-tensioning bars so that the cofferdam was supported directly off the cylindrical piles. Footing construction was completed with the installation of reinforcing bars in the piles, top and bottom reinforcing bars in the footing, placing ducts for the post-tensioning loop tendons and bars, and pouring the remaining footing concrete. The top of the footing included a 6” recess to support the base segment for the precast columns.

Fig. 5 Pier 3 Precast Cofferdam Cell

To limit the maximum temperature (after placement) of concrete to 160 degrees F, and temperature difference to 35 degrees as stipulated for mass concrete in the special provisions for the project, the Contractor utilized closely spaced internal cooling pipes with river water flowing thru the 1” diameter pipes and returned back to river. Insulating blankets were also used at the top surface to further reduce the temperature difference. Intellirock temperature monitoring devices were used to ensure that temperatures and temperature differences did not become excessive. The thermal control was carried for about 15 days.

Prior to driving the 54" diameter prestressed concrete cylindrical piles, the Contractor chose to pre-drill in the permanent pile location with a 42" diameter steel "digger" pipe (the same as the inner diameter of the 54" diameter pile) vibrated to a depth of eight feet above the estimated minimum tip elevation. The digger pipe was used to remove the plug of upper material at each pile location and then a length of 42" diameter pile was placed in each pre-dug hole to maintain stability of the holes. The steel pipes would then be withdrawn as a concrete pile was loaded in the template and driven in that location. The concrete piles were driven to pile tip El -60 to El -70 with ultimate pile driving resistance varying from 1,100 to 1,300 tons. One of the 54" diameter prestressed concrete production piles at Pier 3 was initially used as test pile.

While foundation construction activities continued on-site, Unistress Corporation began precasting the pier segments and superstructure box girder segments off-site in Pittsfield, Massachusetts, allowing the project to proceed quickly. Following the fabrication of the casting cells within a few months from notice to proceed, casting of pier segments started by September, 2008 to ensure that pier erection can start when the foundations are completed. The precast segments are match-cast using the short line method which uses a casting cell to match cast a segment against the previously cast segment. After a segment is cast, it is positioned adjacent to the casting cell to be used as a bulkhead for the next segment. The desired vertical, horizontal, and superelevation geometry are achieved during casting of the segments.


Fig. 6 Unistress Casting Yard: Segment Casting and Storage

Unistress fabricated two casting cells for precasting the superstructure segments providing for a production cycle of 2 segments per day. A total of 383 superstructure segments are required for the project, with the first segment cast on October 28, 2008. A total of 99 pier segments are required, with the first segment cast on September 4, 2008.

Following casting, the segments are cured and then stored at the casting yard where the pier caps are post-tensioned and also transverse post-tensioning of the superstructure top slab takes place, followed by grouting of the post-tensioning ducts. From the plant in Pittsfield, the segments are transported via truck approximately fifty miles south to the Port of Coeyman's for temporary storage due to the limited space at the site for storage. The segments are then barged down the Hudson River to the bridge site as they are needed for construction in a typical one-day trip.

The typical procedure for constructing the precast piers consists of placing the 10' base segment into a 6" recess atop the footing and support it atop four hydraulic jacks, make proper vertical and horizontal adjustments to achieve proper line and grade, install post-tensioning (PT) strand ducts and PT bar couplers, and place 2" non shrink grout (matching the column strength) between footing and base segment. After the grout reaches 2,500 psi strength, release the jacks, apply 1/8" thick epoxy atop the base segment and start stacking the remaining hollow segments with a 1/8" thick epoxy being applied to each lower segment before the next segment is erected. After all the hollow segments are erected, install four 1 3/8" diameter PT Bars, couple bars to footing base and stress, and pour back large blockout at base segment with concrete along with hollow section in-fill concrete. Erect pier cap, couple and stress the four 1 3/8" diameter PT Bars, followed by installation and stressing of PT strand tendons in a prescribed sequence, and proceed with grouting of tendons and bars.

The piers range in height from 15 feet to 60 feet. Piers 3 and 4 which are the tallest piers were constructed in two days. The expansion bearing piers use six 19x0.6" diameter loop tendons and four 1 3/8" PT bars, while the fix bearing piers use four 19x0.6" diameter and four 27 x0.6" diameter loop tendons and four 1 3/8" PT bars. The loop tendons are made of epoxy coated seven-wire strands.

Fig. 7 Precast Piers

The superstructure is built by the balanced cantilever method using barge mounted cranes. Upon erection of the pier table segments at each pier, construction proceeds by installing in a symmetrical fashion one segment on each side of the pier table with the use of cantilever post-tensioning tendons and bars. Once adjacent pier cantilevers meet in the middle, a closure segment will be erected and closure joints poured, followed by the installation and stressing of the continuity tendons in the bottom slab and top to complete the cantilever unit. Longitudinal post-tensioning consists of 19 x 0.6” strand tendons internal to the concrete section.

The construction of the pier table at each pier consists of the erection of a cantilever falsework tower supported atop the footing, installing the bearings along with four 100-ton jacks on the pier cap, followed with the erection and positioning of pier segment (pair of pier segments stressed together on ground) using barge mounted crane. After the jacks are engaged, the segment is released from the crane. Construction proceeds with the erection of starter segment 1W with the crane and positioned at a 1’ gap to the pier segment, installing and coupling of PT bars to pier segment, applying epoxy, bringing the segments into contact and followed with stressing of the PT bars. After engaging the 660 ton locking-ring jacks placed below the segment and supported on header beams on the cantilever falsework, release the segment from the crane. These steps are repeated for the opposite starter segment 1E, followed with the release and removal of the 100 ton jacks, aligning and grade the pier table per erection geometry and tightening lock rings. Construction proceeds with casting of the bearing plinths. After the plinth grout reaches 4,000 psi, stress pair of cantilever tendons (C1), followed with release of the 660 ton jacks on falsework (jacks to remain in contact with bottom of segment), and installation of temporary bearing restraint


Fig. 8 Pier 3 Pier Table Construction

Following the erection of pier table and starter segments, the typical cantilever construction cycle proceeds following the steps used for the erection of starter segments, i.e. erect segment with epoxy applied on ground, position segment to 1’ gap to the previously erected segment, install and couple PT bars to previous segment, bring the segments into contact, stress PT bars and release the segment from the crane. Repeat steps for the opposite segment, and stress pair of cantilever tendons from opposite ends. Repeat these steps for the remaining segments in the pier cantilever.

The Contractor began superstructure construction with Pier 3 Cantilever in April, 2009, moved then to Pier 4 Cantilever construction, and completed span 4 by erecting the closure segment and casting 1' closure pours on each side of the segment. When the cast-in-place closures reached 2,000 psi, the Contractor stressed one top and one bottom continuity post-tensioning tendons, followed by stressing a second group of continuity tendons when the closure pours reached 4,500 psi strength, and proceeded then to release the stability shoring jacks and bearing restraints at Piers 3 and 4, with the remaining bottom continuity PT tendons in span 4 to be stressed after closure of adjacent span 3 is made. Construction will proceed with Pier 2 Cantilever, erect closure segment and cast span 3 closure pours, repeating above stressing steps following closure, proceeding next with Pier 1 Cantilever construction, cast span 2 closure pours, erect span 1 end segments at Highlands abutment on falsework, cast span 1 closure pour and complete stressing of post-tensioning continuity tendons.

Fig. 9 Pier 3 Cantilever

Superstructure construction of the south structure is to proceed then with Pier cantilevers 5, 6, 7, 8 with corresponding span closures 5 to 8, erection of span 9 end segments at the Sea Bright abutment on falsework, casting of closure pour at span 9, and construction completed with deck patching, grinding, and barrier construction. The south structure is expected to open to traffic in November 2009, followed by complete demolition of the existing bridge and construction of the north structure with project completion on/or about December 2010.

When completed, the proposed Route 36 Highlands Bridge will become NJDOT's first precast segmental concrete box girder bridge built entirely by the balanced cantilever method of construction.

CONCLUSIONS

An aging low level bascule bridge is currently being replaced with twin precast segmental concrete box girder bridges. By using carefully staged construction and merging into the existing alignment, two lanes of traffic are being maintained throughout construction towards minimizing impacts to the communities and maintaining an emergency evacuation route. The precast segmental concrete box girder bridge lends itself for rapid construction and will provide for a long service life and unparalleled durability resulting in low life cycle costs and maintenance costs to NJDOT. The new Route 36 Highlands Bridge is expected to become a landmark structure in the heart of the New Jersey shore towns of Highlands and Sea Bright, as well as the Sandy Hook Gateway National Recreational Area.

PROJECT CREDITS

Owner: New Jersey Department of Transportation
Sponsoring Agent: Federal Highway Administration
Designer: Jacobs Engineering Group Inc
Contractor: J. H. Reid General Contractor
Segment Casting: Unistress Corporation
Construction Engineer: McNary Bergeron & Associates
Construction Management & Engineering Inspection: NJDOT with Greenman Petersen