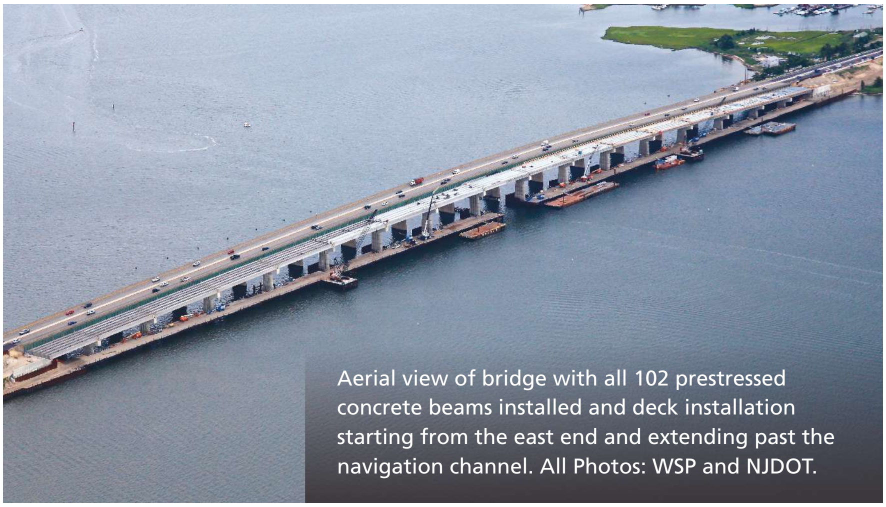
PROJECT

NEW JERSEY ROUTE 72—
Eastbound Over Manahawkin Bay Bridge

by Joseph Mumber, David Rue, and Steve Esposito, WSP, and
Pankesh Patel, New Jersey Department of Transportation

Owned and maintained by the New Jersey Department of Transportation (NJDOT), the causeway carrying New Jersey Route 72 over Manahawkin Bay is the only access from the New Jersey mainland to the beach communities of Long Beach Island (LBI), an 18-mile-long coastal barrier island. LBI is home to 20,000 year-round residents in six separate municipalities. During the peak summer tourist season, the population swells to more than 150,000. Therefore, a safe, reliable, and resilient highway connection is essential for residents and visitors, as well as for the local economy.



Aerial view of bridge with all 102 prestressed concrete beams installed and deck installation starting from the east end and extending past the navigation channel. All Photos: WSP and NJDOT.

Resilience Needed

By the early 1990s, many of the fatigue-sensitive details in the existing steel stringer-floorbeam bridge, which was designed in the 1950s, had failed or were failing. NJDOT considered the following alternatives for this critical corridor: total replacement of the bridge; providing dual structures by building a new parallel bridge for one direction and rehabilitating the existing bridge for the other direction; and rehabilitation. To satisfy NJDOT's desire for resiliency, the dual-structure alternative was selected.

The new concrete superstructure is designed to offer distinct advantages over the older design by eliminating the fatigue-prone details. Also, when coupled with the superstructure replacement of the existing bridge, the new, parallel eastbound structure provides operational redundancy in the corridor. If either bridge needs to be closed for any reason (such as hurricane, earthquake, or vessel impact), the other structure will be adequate to carry both directions of traffic.

This approach was validated in 2012, when Superstorm Sandy made landfall near Brigantine, N.J., causing widespread damage to the state's infrastructure. Although the structures on Route 72 were not severely damaged, the storm did cause scoured conditions at several locations, and NJDOT maintenance stabilized the affected structures by installing riprap. The scour design was updated for the project to prepare for hurricane-strength storm-surge conditions suggested in the post-Sandy Federal Emergency Management Agency flood insurance study for the project area. Hydraulic models were updated to include new fathometer survey information that accounts for poststorm conditions. The new bridge was designed to withstand the predicted scour depths without countermeasures. Articulated concrete block mattresses were incorporated to protect the existing bridge's scour-sensitive abutments, and the existing piers were found to be stable for the design storm.

Other Design Features

The new structure was designed to accommodate two lanes of traffic in the eastbound direction, while the existing bridge will carry two lanes westbound once the rehabilitation is completed in 2019. The eastbound structure is 2400 ft long and 52 ft 9.75 in. wide, with six lines of prestressed concrete girders made

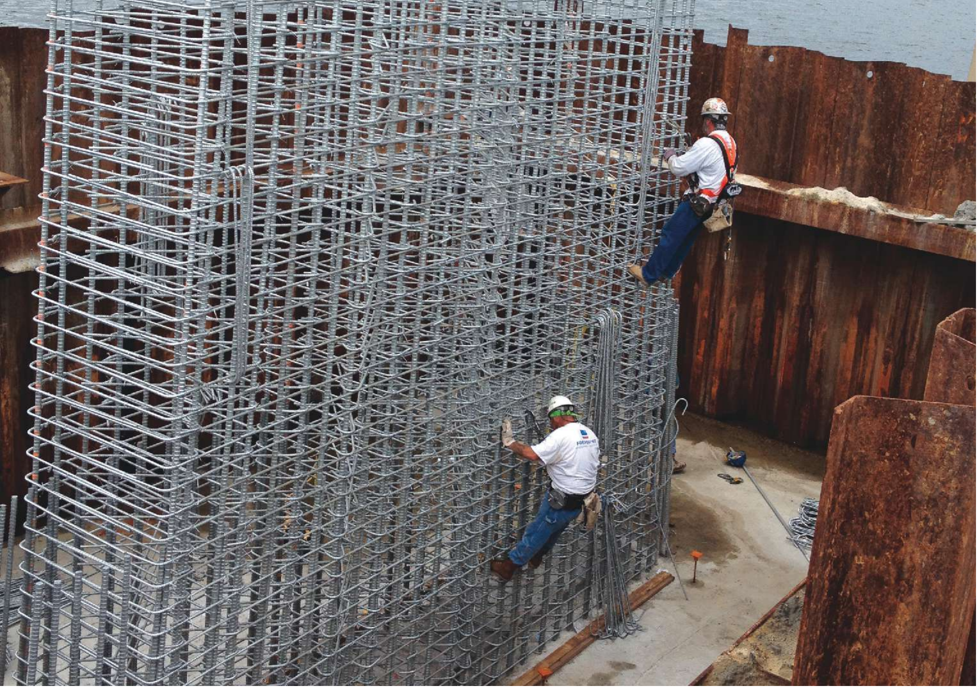
profile

NEW JERSEY ROUTE 72 EASTBOUND OVER THE MANAHAWKIN BAY / STAFFORD TOWNSHIP AND BOROUGH OF SHIP BOTTOM, OCEAN COUNTY, NEW JERSEY

BRIDGE DESIGN ENGINEER: WSP Inc., Lawrenceville, N.J.

PRIME CONTRACTOR: Schiavone Construction Co. LLC, Secaucus, N.J.

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



Galvanized reinforcement cages were assembled on barges and lifted into place, extending up and out of the sheetpile cofferdams.

continuous for live load. There are 17 spans that range from 98 ft 8 in. to 147 ft 7 in. from center-to-center of bearings, totaling 102 girders. The concrete girders are among the longest prestressed concrete girders used on any NJDOT project. The final lane configuration on the new bridge includes two 12-ft-wide lanes, a 13-ft-wide inside shoulder, and a 12-ft-wide outside shoulder.

Options considered for the new bridge included both steel and concrete multigirder superstructures with various span lengths. Based on the results of a life-cycle cost estimate for future maintenance costs, NJDOT selected concrete for its durability—an important factor considering the corrosive coastal environment of the bridge location—and its relatively low future painting and maintenance costs as compared to the expenses required for maintaining steel bridges. Furthermore, due to advances in the concrete industry, simply supported precast concrete girders could span the distance needed for the new piers to be set in line with the existing piers, eliminating new obstructions for navigational traffic. Also, NJDOT realized that a concrete bridge made sense because many precast concrete producers in the region have the capability to provide concrete with high compressive strengths and low permeability, and to produce and ship large prestressed concrete beams.

Girder Design

Efficient precast concrete girder sections were selected, in accordance with the Federal Highway Administration's (FHWA's) prestressed concrete economical fabrication (PCEF) initiative, to standardize beams and forms for production. Six XB 79 x 48 PCEF prestressed concrete bulb tees were spaced at 9 ft 3 in. on center for the superstructure. The 79-in.-deep beams used a high-performance concrete mixture with a design compressive strength of 8.5 ksi. The standard 7-in.-thick web was increased to 8 in. to accommodate NJDOT's concrete cover requirements and increase durability, resulting in a total top flange width of 48 in. All mild reinforcement used in the beams was galvanized to match the deck steel and increase corrosion resistance; prestressing steel was plain and not coated. To protect against galvanic corrosion, dielectric insulators were used to avoid contact of dissimilar metals within the beams.

Prestressed concrete beams being erected at Span 15. These 79-in.-deep beams are 150-ft-long and weigh 90 tons. The beams were fabricated in Virginia, shipped by barge to a marina in Camden, N.J., and finally trucked to the project site.

NEW JERSEY DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: New 2400-ft-long bridge over the Intracoastal Waterway, prestressed concrete beam superstructure with cast-in-place deck and piers with galvanized reinforcement

STRUCTURAL COMPONENTS: Twelve 100-ft 4-in.- long, 79-in.-deep prestressed concrete beams; twelve 124-ft-long, 79-in.-deep prestressed concrete beams; seventy-eight 149-ft-long, 79-in.-deep prestressed concrete beams.

BRIDGE CONSTRUCTION COST: $89.8 million (cost of eastbound bridge and approach roadway tie-ins)

AWARD: American Council of Engineering Companies of New Jersey honor award – large project

As required by NJDOT's bridge design practices, the girders were designed for zero tension within the precompressed tensile zones to provide an increased factor of safety against cracking. To minimize the number of deck joints (often a source of chloride attack from deck runoff), the deck was made continuous for live load over all but four piers. At piers where continuity for live load was specified, the strands extended out of the beam ends into cast-in-place concrete diaphragms, and additional longitudinal reinforcement in the deck slab over the piers provided negative moment reinforcement for continuity and structural integrity.

As part of FHWA's "Every Day Counts" initiative, precast concrete piers were evaluated for their potential to shorten the construction schedule. To ensure that economy was achieved, precast concrete piers were included as an alternate bid item to the conventionally constructed concrete hammerhead piers.

Considering Options

One of the primary goals for the project was to attain geometric/aesthetic similarities between the two structures. The existing hammerhead bridge piers consisted of a tapered wall column with a hammerhead cap. The wall columns were tapered in two directions. For the new bridge piers, as recommended by precast concrete manufacturers during design, the pier column segments were designed and detailed to be solid, rather than hollow, and tapered in only one direction to reduce formwork costs and complexities of the pier shapes wherever possible. Solid segments also reduced congestion of reinforcement and eliminated spaces where water might intrude and accumulate inside the piers. Galvanized post-tensioning bars were detailed for the pier segments and were terminated within the footing to eliminate corrosion concerns with post-tensioning near the waterline. After studying several options for precast concrete pier caps, a precast concrete voided shell filled with cast-in-place concrete was incorporated in the bid documents. Precast concrete segment geometry was repeated to simplify fabrication and improve economics. Precast concrete piers and caps were ultimately not selected for construction by the successful bidder, but their inclusion in the bid documents ensured a competitive price and demonstrated that precast concrete pier construction was a viable option.

The span configuration is comprised of two end units with three spans (100, 125, and 150 ft, center-to-center of piers), two interior units with three spans (150 ft each, center-to-center of piers), and one middle unit with five spans (150 ft each, center-to-center of piers, with the center span located over the Intracoastal Waterway), for a total of 17 spans. Making each unit continuous for live load further economized the design and allowed for elimination of 12 deck joints. The largest continuous segment is the five-span unit over the navigation channel, with a total length of 750 ft. Modular deck joints were used to accommodate the large thermal movements and account for creep in the beams. The piers were founded on six 6-ft-diameter drilled shafts that terminate 70 to 85 ft below the bay bottom.

The east pier at the navigation channel extends more than 55 ft above the water to provide a 100-ft-wide by 55-ft-high navigation clearance for the Intracoastal Waterway.

The twin-bridge configuration allows future maintenance of the bridges to be performed offline while maintaining all lanes of traffic on the opposite structure. Although staged-construction requirements typically dictate placing a girder at the middle of a bridge's cross section, the twin-bridge arrangement did not require a center girder, allowing for larger girder spacing and an even number of girders to save costs. Use of modestly sized beams helped limit superstructure dead load on the foundation, allowing a more efficient foundation design and further cost savings. The concrete structure achieved all primary project objectives, including providing redundancy, enhancing safety, and improving traffic operations.

Design for Hazards

Seismic vulnerability was another important factor in designing the new bridge for resiliency. Because the new structure would be the single point of access to and from LBI, its operational classification was deemed "critical"; therefore, ground motions consistent with a design return period of 2500 years were incorporated into the design.

The substructure units were also designed to withstand vessel impacts. A vessel survey was conducted to determine the appropriate design vessel for the bridge. It concluded that the 200-ton barge minimum load per American Association of State Highway and Transportation Officials' specifications governed the design because the predominant ships in the bay are pleasure crafts. The piers and foundations were designed for winds as high as 110 mph and ice as thick as 5 in. drifting in the bay, which is commonly observed to freeze over during the winter.

To protect the fish species that inhabit the environmentally sensitive Manahawkin Bay, the environmental

Featured Lighting

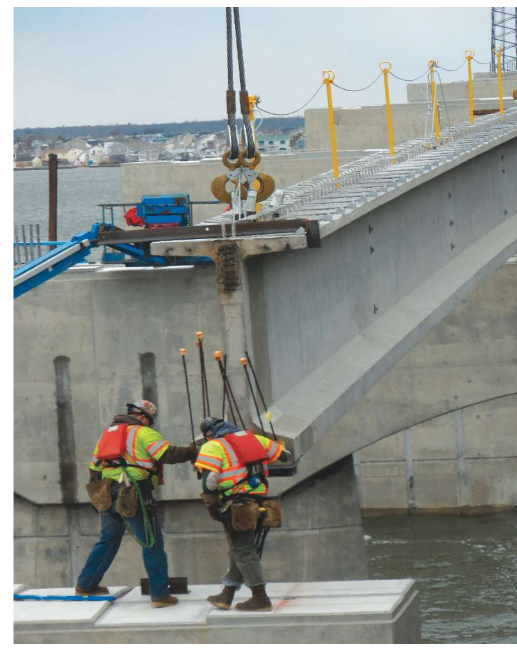
One of the most distinctive features of the existing bridge is that the roadway lighting fixtures are built into the bridge railing, making the view of the bridge at night unique. The bridge is formally named the Dorland J. Henderson Memorial Bridge, after the NJDOT engineer who designed the in-rail lighting system more than 50 years ago. As a tribute to Henderson's contribution to the original design, NJDOT has replicated the railing lighting in the new bridge by attaching linear lighting to the outside of the south parapet of the new bridge and the north parapet of the existing bridge; this lighting is strictly aesthetic.

permits prohibited in-water work from January 1 to June 30 each year, with the caveat that work occurring inside a steel cofferdam would not be considered in-water work. Once the steel cofferdams were installed for the piers, work could proceed unrestricted on the pier foundations.

Construction for this project began in May 2013, and the new bridge over the Intracoastal Waterway opened to traffic on April 22, 2016.

Close coordination between the design team, owner, and precast concrete industry ensured that the bridge details were resilient, efficient, and economical. This partnership with the precast concrete industry facilitated the successful construction of the project, which was completed with minimal modifications proposed by the fabricator, and maintained the desired schedule for opening the bridge to traffic.

Joseph Mumber is vice president, senior technical principal, and structures department manager; David Rue is a senior supervising engineer and senior technical principal; and Steve Esposito is supervising structural engineer and senior technical principal all with WSP in Lawrenceville, N.J. Pankesh Patel is the project manager for the New Jersey Department of Transportation in Trenton, N.J.



One of the 79-in.-deep prestressed concrete beams being erected. Strands extend out of the beam end and are incorporated into the cast-in-place concrete diaphragm for continuity at the pier.

AESTHETICS COMMENTARY

by Frederick Gottemoeller

Since it was built more than 50 years ago, the Dorland J. Henderson Memorial Bridge has been a distinctive bridge, recognized in architectural circles as well as among engineers. It has been noted for its graceful, tapered piers as well as its innovative "string of pearls" lighting. The New Jersey Department of Transportation (NJDOT) is justifiably proud of it. The agency's decision to keep it and build a new similar bridge parallel to it is thus a double win. The original bridge is both preserved and amplified.

The aesthetic value of these bridges begins with their tapered piers. It is amazing how much the basic decision to batter the piers in both directions can improve the appearance of a structure. The reason traces back to people's intuitive impressions of vertical structures. A structure that is wider at the bottom than at the top looks (and is) more stable, and thus seems more satisfying. Nature provides a model: tree trunks are always thicker near their bases than at their tops. (The appearance of retaining walls can be improved the same way, and for the same reason, by simply battering their faces.) A taper can get out of hand if the structure is very tall, but that can be avoided by decreasing the degree of taper. Nature again offers a model: the degree of taper of a redwood trunk is much less than on a live oak, but they are both attractive trees.

The piers borrow another feature from nature: the hammerheads join the pier shafts by means of a curve. Tree branches similarly curve as they join their trunks. It is nature's way of minimizing the higher stresses of a re-entrant corner, a problem engineers also must resolve. The team's development of a precast concrete construction option proves that these features can be applied even with precasting, though the contractor chose not to employ that technique.

Finally, NJDOT's decision to reinstate the string of pearls lighting using modern LED technology must be very heartening to the long-time residents of this recreational area. People come to Long Beach Island to relax and enjoy the attractive natural environment. When we insert something into such environments, there is a heightened responsibility to make sure that the new object adds to, and does not detract from, that environment. The new Manahawkin Bay Bridge meets that standard.