Pensacola Bay Bridge

by Christopher M. Vanek, Victor Ryzhikov, and Charles Rudie, WSP

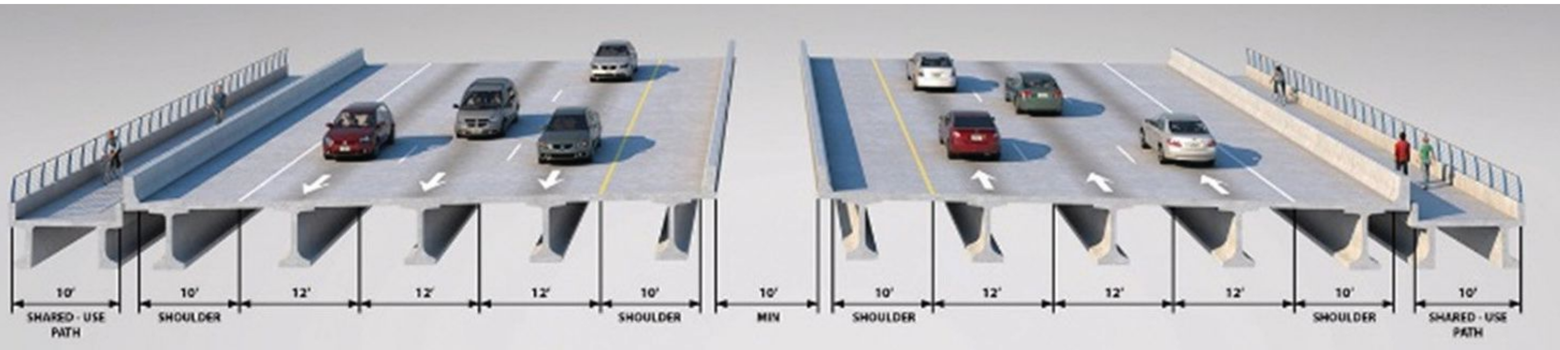
Aerial view of the new Pensacola Bay Bridge project. The parallel bridges use 103 spans of precast, prestressed concrete girders for the vehicular bridges, and single-piece, modular precast, prestressed concrete pi-shaped girder units that provide independent support for the multiuse path bridges that flank each vehicular bridge. Photo: Florida Department of Transportation.

A major east-west transportation corridor and primary hurricane evacuation route, the aging U.S. Route 98 (State Road 30) bridge crossing Pensacola Bay between Pensacola and Gulf Breeze, Fla., was nearing the end of its anticipated life span, and its more than 200 spans needed constant repairs. Also, because the four travel lanes were insufficient to carry the daily traffic count of approximately 55,000 vehicles, there was constant traffic congestion. Using life-cycle cost analyses, the Florida Department of Transportation (FDOT) concluded that replacement of the 1960s-era structurally deficient structure would be the most cost-efficient option.

To meet the increased traffic demands, FDOT decided that the new Pensacola Bay Bridge would be constructed on a predominantly tangent, parallel alignment west of the existing structure, with separate structures to carry eastbound and westbound traffic. Each 16,138-ft-long structure would provide increased traffic capacity with three 12-ft-wide travel lanes, alongside 10-ft-wide inside and outside shoulders. Recreational pedestrian and bicycle transportation modes would be supported on a dedicated multiuse path for each structure.

For the new Pensacola Bay Bridge, which was the largest single transportation project in the history of the northwest Florida region, FDOT selected a design-build procurement method and sought enhancements to a conventional long-water crossing that would include pedestrian features to enrich the users'

Cross section of the replacement side-by-side structures showing the custom precast concrete pi-shaped girder units for the multiuse path flanking the conventional Florida I-beams with cast-in-place deck for the vehicular portion of the bridge. Figure: WSP USA.



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PENSACOLA BAY BRIDGE / **PENSACOLA AND GULF BREEZE, FLORIDA**

BRIDGE DESIGN ENGINEER: WSP USA, Tampa, Fla.

PRIME CONTRACTOR: Skanska Civil Southeast, Pensacola, Fla.

CONCRETE SUPPLIER: Ready Mix USA, Pensacola, Fla.

PRECASTER: Skanska Civil Southeast, Pensacola, Fla.—a PCI-certified producer for pretensioned concrete elements

OTHER MATERIAL SUPPLIERS: Formwork: Ninive Casseforme, Italy; falsework: Mabey Inc., Elkridge, Md.; disc bearings and modular joints: R. J. Watson Inc., Alden, N.Y.

A pi-shaped girder unit for the multiuse path is removed from the forms in the precast, prestressed concrete production facility. To ensure that the multiuse path spans would match the framing arrangement for the vehicular spans, a custom-modified, 54-in.-deep Florida I-beam form was split in half and a drop-in pan was inserted to create a highly efficient double-stem girder shape resembling the Greek letter pi. Photo: WSP USA.

experience. Another primary project goal was removal of the deteriorated existing bridge.

The bridge design engineer partnered with the prime contractor to develop a best-value proposal for FDOT. The design-build team selected a concept that would optimize efficiency and maximize the ability to use precast concrete structural elements, while enhancing these elements with a modern, sleek design. The new Pensacola Bay Bridge has 106 spans that use nearly 4000 precast concrete elements fabricated at an on-site casting facility.

Superstructure

The first critical element in the design involved separating the pedestrian multiuse paths from the mainline vehicular bridges for the entire crossing. This physical separation would allow for a total precast concrete structural solution for the paths while enabling the mainline superstructure to be a more conventional structure with an 8.5-in.-thick cast-in-place (CIP) concrete deck.

To support the concept of a separate multiuse path along an entire bridge, two sets of superstructure types were used along the bridge length. The design called for a 59-ft 1-in.-wide typical section for the vehicular bridge and a 10-ft-wide multiuse path, and precast concrete was the preferred material choice for the site's aggressive environment.

For a typical approach span, five 72-in. Florida I-beams with 12-ft 6.25-in. spacing and a length of approximately 150 ft were the most economical choice. This span length would maintain clearance from the existing pile foundations. Because large design ship impact and wave loads would be transferred to the superstructure, an efficient system was needed.

To ensure that the multiuse path spans would match the framing arrangement for the vehicular spans, a custom-modified 54-in.-deep Florida I-beam form was split in half and a drop-in pan was inserted to create a highly efficient double-stem girder shape resembling the Greek letter pi. The top flange was placed monolithically with the girder stems to form the deck surface to which a monolithic 21-in.-tall barrier was attached as a secondary placement. Each custom pi-girder unit weighed approximately 200 tons and allowed each multiuse path bridge span to be erected in a single piece with small link-slab closures at the piers. To control end-zone cracking and flange distortion, and accommodate a top flange blockout used to connect spans with link slabs, as well as overlook slabs, a 1-ft 6-in.-thick end diaphragm was cast monolithically with the section.

V-Piers

A key aesthetic strategy for the project involved the substructure pier elements. The design-build team developed a two-stage, split twin curved V-pier, which offered benefits in fabrication and optimization of lower- and higher-level pier aesthetics. The V-piers proportionally increase in size as the pier approaches the higher-level areas, changing in geometry and construction methodology.

With two different geometric sets of V-piers, the construction methodology and associated design were adjusted to suit the scale of the required elements. In the approach structure area, to address the reduced height demands, the design team developed a monolithic precast concrete footing, column, and cap unit that could be erected in the field by a single crane pick. The typical 110-ton unit was erected atop a four-pile cluster, adjusted with ultra-high-molecular-weight plastic shims, sealed, and dewatered. Headed reinforcing bars were then grouted into preformed ducts in the piles; this was followed by a field closure

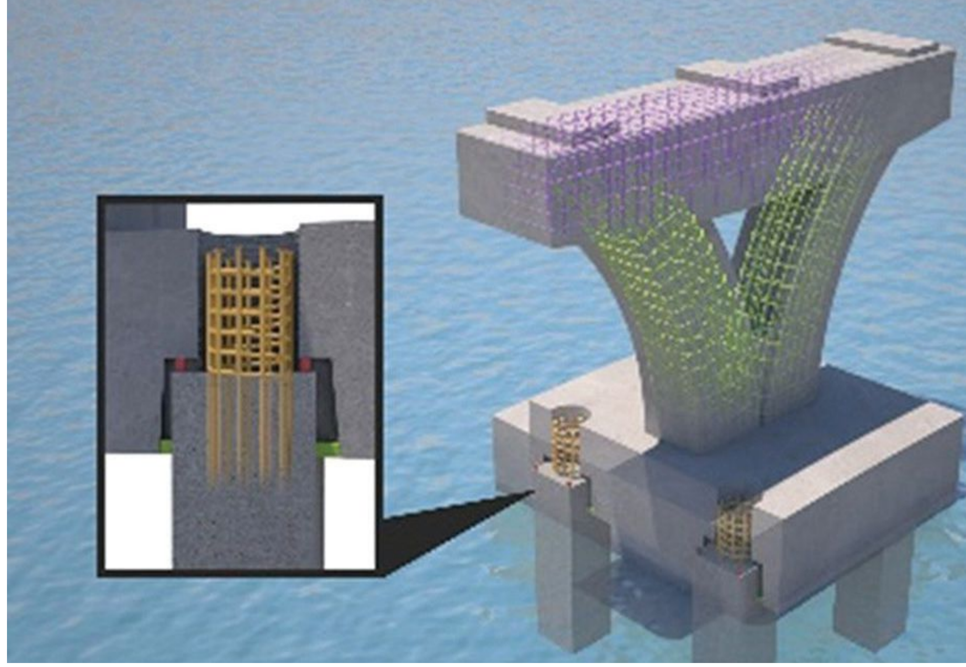
FLORIDA DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: Twin 16,138-ft-long bridges with 103 spans of precast, prestressed concrete girders with a main span unit composed of three-span, continuous steel welded plate girders. Single-piece modular precast, prestressed concrete pi-shaped girder units provide independent support for the multiuse path bridges flanking each of the vehicular approach spans, with steel girders and a 375-ft-span, wishbone tied-arch supporting the path in the main span unit.

STRUCTURAL COMPONENTS: 162,000 yd^3 of concrete (total for both cast-in-place and precast concrete), 23.6 million lb of reinforcing steel, more than 4000 precast concrete pieces including 1030 precast, pretensioned Florida I-beams, 206 precast, pretensioned concrete pi-shaped girder units, more than 2000 precast, prestressed concrete piles, and 416 precast concrete V-pier assemblies, plus other miscellaneous items

BRIDGE CONSTRUCTION COST: $398.5 million

Workers set a shorter V-pier unit, for which the cap, column, and footing were precast as a unit. Photo: WSP USA.



Rendering of a typical shorter V-pier precast unit set on the precast, prestressed concrete piles. The inset shows a detail section through the pile-to-footing connection. Figure: WSP USA.

pour to achieve a very small, highly efficient connection. The pile pocket connection, which partially extends into the footing to extend the pile above the water surface, develops a full flexural-shear connection. The transfer of forces in the system employs a combination of socket- and corrugated-duct-type connections to meet the required loading demands. The desire to use a conventional concrete connection with a reduced embedment depth dictated the use of headed reinforcement; at the time, the contractor determined that ultra-high-performance concrete was not an economical option in this case because of challenges in getting the materials to the site. The shorter, monolithic pier units were used for 91 of the 105 piers on the project.

As the vertical profile increased toward the higher-level section, a taller series of V-piers was designed for efficiency and to achieve a more balanced appearance. Due to the change in foundation demands for the taller piers, the pile groups increased in size as the +5% grade quickly increased member weights too. The pier details and construction process had to be modified to accommodate these changes. On the taller piers, precast concrete bathtub forms were used for CIP footings, which were connected together with a prestressed concrete pile strut. The precast concrete V-pier column and cap were erected on temporary falsework for a pressure concreted closure pour at the column-to-footing connection.

Mock-up Testing

Because of the unique nature of the connections and stringent tolerances needed for proper fit-up, the plans contained specific requirements for precast concrete fabrication and erection tolerances, along with a detailed set

AESTHETICS **COMMENTARY**

by Frederick Gottemoeller

This long, low bay crossing connects downtown Pensacola, Fla., to the islands of Pensacola Bay and their Gulf beaches. The bridge is the centerpiece of the downtown's bayfront views and the views from all the civic buildings along it. No wonder the owner wants to enhance its aesthetics.

The appearance of a long, low bay crossing is typically dominated by rows of multicolumn pier bents marching across the water. These repetitive column lines lack visual interest and stand one behind the other to block both the diagonal views through them and the longitudinal views along the bridge. With this in mind, the curved V-piers of this bridge are a revelation. Instead of the usual five or six columns of a typical pier line, there are only two columns which each split into two pieces that curve outward to meet the cap. With this creative detail, the expanse of the water's surface under the outer edges of the bridge will be open to view.

There is a second revelation: As the piers gain height approaching the navigation channel, the tall piers will have the same shape as the short piers. Only the pier stems will get longer. That consistency will give the bridge unity and openness over its entire length, which in turn will give the entire bay a unity and openness that was lacking with the previous bridge.

Placing the pedestrian and bicycle trails slightly lower than the roadways will give their users a greater sense of separation from the vehicular traffic and should increase their enjoyment of the crossing. This separation also creates the opportunity to change the trails' structural type at the main span. The arches will visually punctuate the midpoint of this over 3-mile-long and mark the channel location for both users of the bridge and observers on shore.

A taller precast concrete V-pier column and cap segment being set on falsework that will support it before a pressure concreted closure pour is placed to connect the unit to the footing. Photo: WSP USA.

Section cut through pile and footing after mock-up test to demonstrate that concrete could be successfully placed to make the pile-to-footing connection. Photo: WSP USA.

of mock-up requirements. Full-scale mock-ups detailing each connection type were required to help ensure that the proposed details, construction sequence, and personnel could produce a connection free of voids. The team was required to construct these mock-ups using proposed construction procedures before fabrication of any production elements. The construction procedures were amended based on satisfactory results of the mock-ups. To assess the performance of the concrete connection, each mock-up was cut into a minimum of two sections and measurements were taken of the voided areas to ensure that the total area of voids did not exceed 3% of the total sectional area of the joint. If a mock-up did not meet requirements, another mock-up would be constructed and retested with revised connection procedures, revised details, or both.

Piles

The project site has a highly variable subsurface condition. The soil profile consists of a very loose overburden layer of 30 to 40 ft of silty sand and medium-dense bearing layers located 120 to 250 ft deep. To meet the site challenges, avoid field-spliced piles, and obtain the required capacity at end-of-drive conditions, custom prestressed concrete pile solutions were developed to support the structure. The approach piers were founded on modified FDOT 30-in.-square precast, pretensioned concrete piles with additional prestressing strands. The piles were modified from the FDOT standard, which includes a void, by using a completely solid section along the pile length to permit piles up to 210 ft in length. The long pile lengths led to heavy piles, which pushed the limits of the very large cranes used on the project. The connections of the piles to the precast concrete substructure units used corrugated steel ducts cast in the head of the pile that could easily be modified to fit the connection in the field if bearing were achieved early or at the predicted depth, or used for field splices in the event that the pile did not achieve capacity as expected. To help reduce work on site, the lengths of the production piles, as well as these ducts, were adjusted based on the driving of test piles.

Conclusion

At this time, one bridge has been opened to traffic and the other parallel structure is scheduled to open later this year. The decision by FDOT to use a design-build contract for the Pensacola Bay Bridge project encouraged the design-build team to incorporate innovative precast concrete designs to achieve an efficient system. Because the engineers and contractors collaborated closely to deliver these durable and successful strategies, the U.S. Route 98 bridges over the Pensacola Bay will provide a low-maintenance, six-lane facility for the traveling public while also offering value-added features, including architectural shade structures, color-changing LED lighting, and decorative railings, that complement the enhanced aesthetics of piers and other structural elements.

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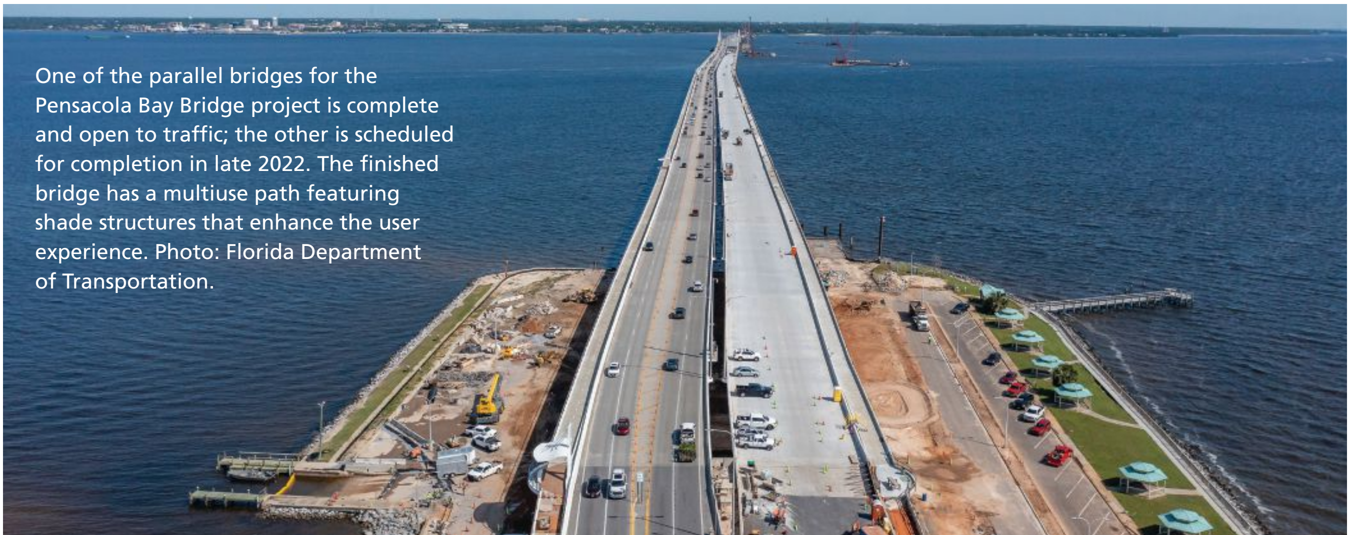

One of the parallel bridges for the Pensacola Bay Bridge project is complete and open to traffic; the other is scheduled for completion in late 2022. The finished bridge has a multiuse path featuring shade structures that enhance the user experience. Photo: Florida Department of Transportation.