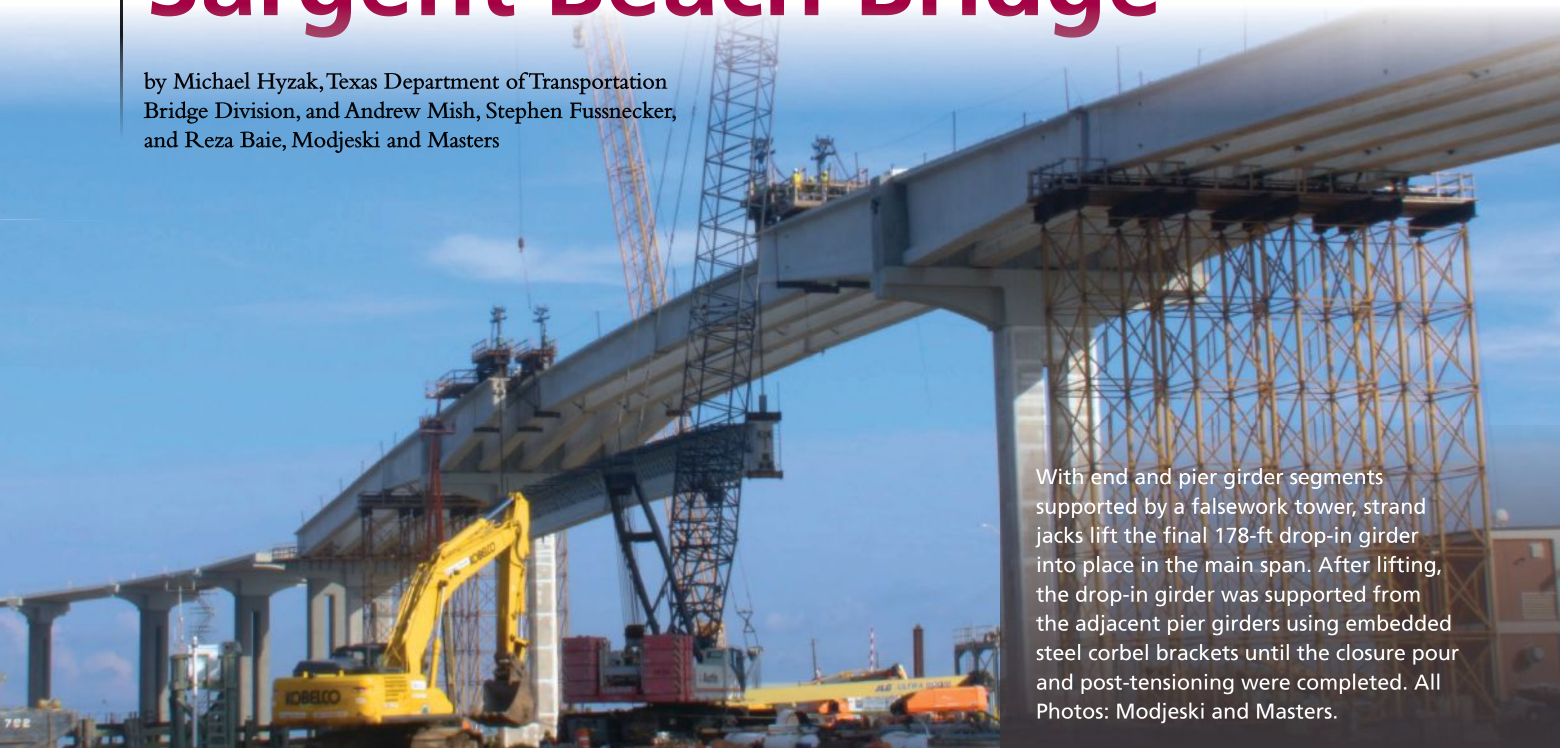
PROJECT

Sargent Beach Bridge

by Michael Hyzak, Texas Department of Transportation Bridge Division, and Andrew Mish, Stephen Fussnecker, and Reza Baie, Modjeski and Masters


With end and pier girder segments supported by a falsework tower, strand jacks lift the final 178-ft drop-in girder into place in the main span. After lifting, the drop-in girder was supported from the adjacent pier girders using embedded steel corbel brackets until the closure pour and post-tensioning were completed. All Photos: Modjeski and Masters.

Located on the middle of the Texas Gulf Coast is Sargent Beach, a community south of Houston on a barrier island at the end of Farm to Market Road 457. Sargent Beach has a few hundred residents and is separated from the Texas mainland by the Gulf Intracoastal Waterway (GIWW), a major waterway used primarily for barge traffic.

The original crossing carrying roadway traffic from the mainland to the island was a barge swing bridge, which was first built in the 1940s and replaced in 1974. This structure had a limited horizonal clearance of approximately 140 ft and was struck by barges about once a month, making it the second-ranked impediment to navigation on the Texas portion of the GIWW.

Project Concept and Site Constraints

In 2013, Texas Department of Transportation (TxDOT) staff in the Yoakum District and Bridge Division began collaborating on a concept that would provide a two-lane, high-level crossing of the GIWW at Sargent Beach with required 225-ft horizontal and 73-ft vertical navigation clearances. At this location, the GIWW banks are approximately 250 ft apart and the island is only about 500 ft wide.

Reinforcement being placed for a precast concrete bent cap. The column-to-cap connection, which used corrugated metal pipes to improve constructability, was a critical part of the design.

profile

GULF INTRACOASTAL WATERWAY BRIDGE / **SARGENT, TEXAS**

BRIDGE DESIGN ENGINEERS: Modjeski and Masters, Littleton, Colo., and Texas Department of Transportation, Austin

CONSTRUCTION ENGINEERS: Summit Engineering, a Modjeski and Masters Company, Littleton, Colo.

CONTRACT ENGINEERING INSPECTION: CivilCorp, Round Rock, Tex.

SERVICE LIFE ANALYSIS: Pivot Engineers, Austin, Tex.

PRIME CONTRACTOR: Austin Bridge & Road, Irving, Tex.

PRECASTER: Bexar Concrete Works, San Antonio, Tex.

POST-TENSIONING CONTRACTOR: DYWIDAG-Systems International, USA Inc., Bolingbrook, Ill.

The last 178-ft drop-in girder being erected. Each drop-in girder was cast in two segments, which were transported to the site and then spliced before erection.

The 120-ft-long, variable-depth pier girder is erected onto the pier and stabilized with a tie-down plate connection to the end girder at the falsework tower.

Project constraints included avoiding construction in the San Bernard National Wildlife Refuge to the north, which would require significant environmental coordination. In addition, the swing bridge needed to remain operational during construction, and temporary works needed to be minimized in the GIWW channel clearance zone. Structural risks at that location on the Texas coast include hurricanes and storm surges, as well as long-term exposure to a marine environment.

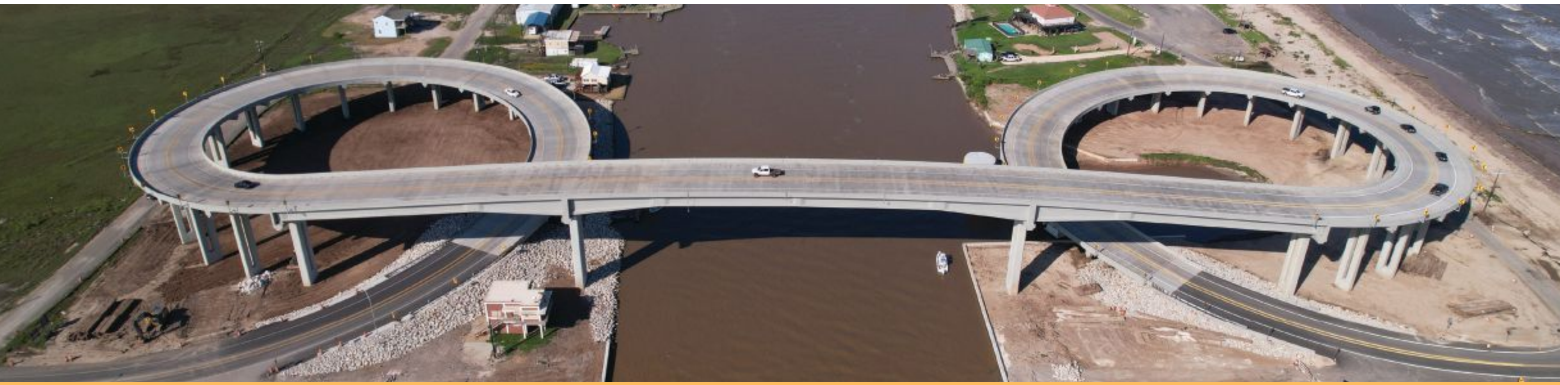
Extensive public involvement and conceptual designs resulted in a unique structural geometry. The main bridge navigation unit would require a 300-ft main span to keep the piers out of the water and minimize pier protection requirements and durability issues. The 300-ft span would be flanked by 195-ft end spans to gain the structural benefit of continuity over the piers. Beyond the 195-ft main-unit end spans, the approach spans on both sides minimize the footprint of the structure with a tight 150-ft centerline radius that forms a nearly 360-degree curve in a corkscrew configuration.

Main-Span Unit

The main-span unit needed a structural system geared for the marine environment and the long spans. Pretensioned and post-tensioned concrete with enhanced durability measures provided the solution. Bridges constructed using spliced pretensioned concrete girders with post-tensioning are still in their infancy in Texas, with only five TxDOT projects using this technology in the last 10 years. TxDOT has recently adopted the spliced precast, prestressed concrete girder as a standard bridge type and provides guidance in the TxDOT *Bridge Design Manual—LRFD*[1] for both I-girders and U-girders.

A span of 300 ft is relatively long for spliced girder bridges—325 ft is currently the longest in the United States—and typically requires a variable-depth section. Part of the challenge of these

The completed bridge with its three-span main-unit configuration of 195-300-195 ft, which is flanked by 150-ft-radius corkscrew approaches. The required 225-ft horizontal and 73-ft vertical navigation clearances accommodate barge traffic on the Gulf Intracoastal Waterway.



TEXAS DEPARTMENT OF TRANSPORTATION, OWNER

OTHER MATERIAL SUPPLIERS: Reinforcing steel: Harris Rebar Nufab, Dayton, Tex.; formwork: EFCO Forming/Shoring, Des Moines, Iowa, and PERI Concrete Column Forms, Fort Worth, Tex.; expansion joints: CMC Commercial Metals, Houston, Tex.; bearings: D.S. Brown, Athens, Tex.

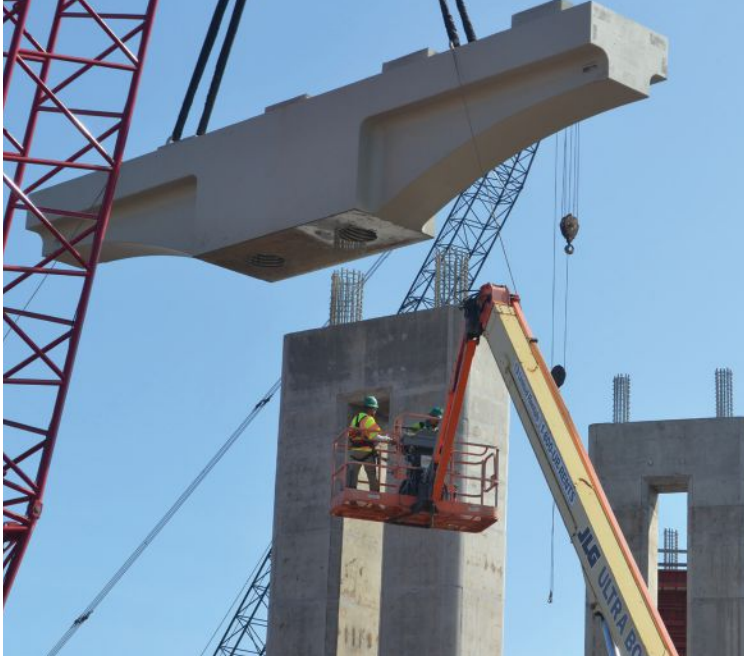
BRIDGE DESCRIPTION: 690-ft-long, cast-in-place, prestressed concrete spliced-girder unit with 300-ft main span and 1675 ft of shallow precast, prestressed concrete slab beam approach spans in 43-ft-long spans on a 150-ft-radius centerline curve

STRUCTURAL COMPONENTS: 41 cast-in-place concrete pier columns; 39 precast concrete approach and transition bent caps; two main-span interior bent caps with precast concrete and cast-in-place concrete portions constructed in two stages; three hundred fifty-one 15-in.-deep prestressed concrete approach span beams; 8-in.-thick cast-in-place reinforced concrete deck on approach spans; 3408 ft of precast concrete spliced girders comprising the five-girder lines with 30 total individual precast concrete girder segments; 4-in.-thick precast concrete subdeck panels on spliced-girder unit with 4.5-in.-thick topping slab

BRIDGE CONSTRUCTION COST: $42.1 million

AWARD: 2021 Best Projects Award of Merit from Engineering News-Record in the Highway/Bridge category, ENR Texas-Louisiana Region.

The pier shafts are generally rectangular with rounded chamfers and an open-window configuration to minimize bulk and add aesthetic appeal.



The T-shaped cap section significantly reduced weight for shipping. The caps were cast with two corrugated metal pipe voids in the midsection that fit over the two reinforcing bar spirals projecting from the columns.

span lengths is ensuring that the piece weights, lengths, and depths are manageable for shipping and erection. TxDOT recommends piece weights be 200 kip or less for shipping and 300 kip or less for erection, and lengths should ideally be 170 ft or less. With a main-span length of 300 ft, the girder depth at the piers is typically about 14 ft.

Because most Texas precasters are based inland with no navigable water access, the pier girder segment depth posed a constraint for local producers. This depth was unlikely to allow for passage under bridges for land-based transport (12.5 ft is typically the maximum depth allowed for shipping). However, because the project was located on the GIWW and barge transport was available, TxDOT proceeded with a design using 14-ft-deep pier girder sections with a parabolic soffit for aesthetic appeal.

Because of the shipping concerns for the spliced girders, TxDOT also allowed an alternate bid for the main-span unit of a single-cell, variable-depth segmental box girder built in a balanced-cantilever manner.

Approach Spans

The challenge of the approach spans was largely geometric because of the tight radius. The superstructure selection was seen as a balancing act of span length, structure depth, number of bents, and complexity. To minimize structure depth and use techniques familiar to contractors, TxDOT opted for short-span 15-in.-deep prestressed concrete slab beams that chorded the curve, with a composite cast-in-place (CIP) concrete deck that incorporated a variable-width overhang. This shallow, smooth profile minimizes the storm surge impact on the structure.

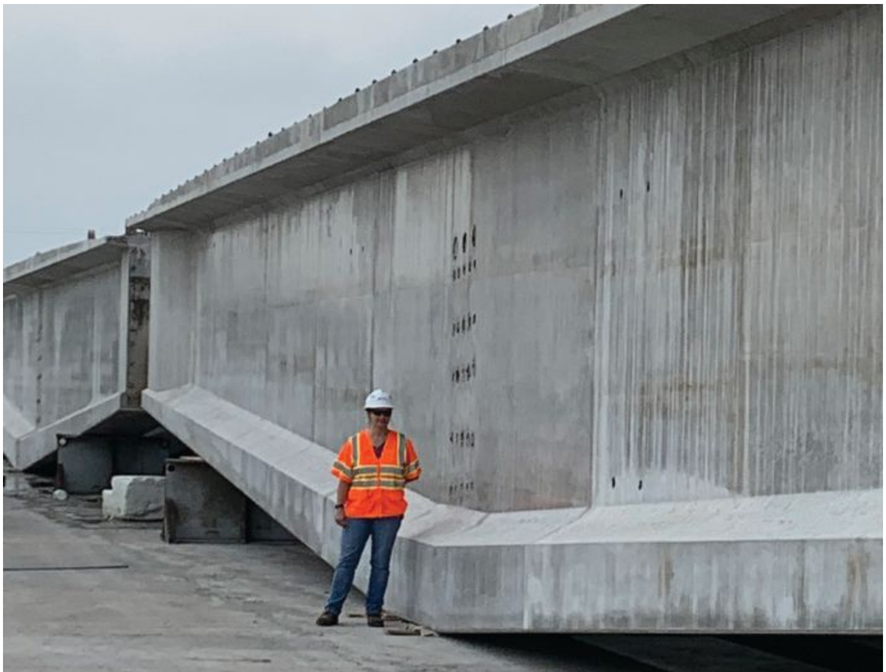
Substructure

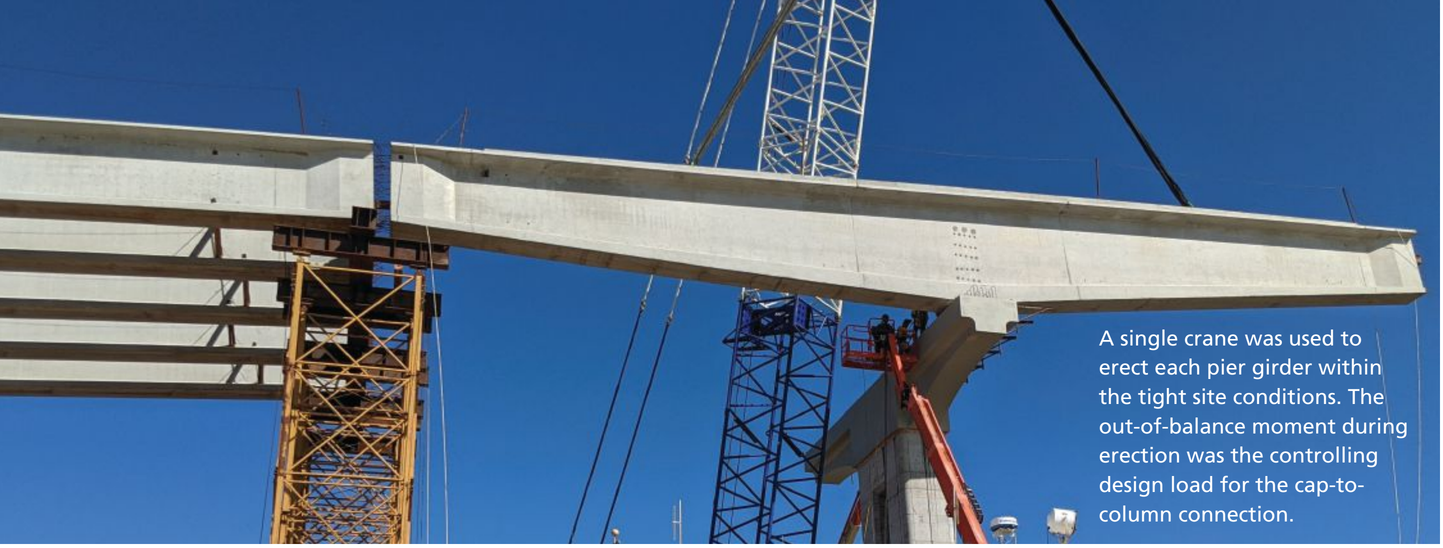
Single-column hammerhead pier caps were chosen for the substructure, with 37 nearly identical bents on each corkscrew approach. The reinforced concrete pier caps are 50 ft long and 4.5 ft wide with depths ranging from 4 to 8 ft accomplished with a parabolic soffit.

The two main-unit bents are also 50 ft long but 6.5 ft wide with variable depths of 8 to 12 ft. The pier shafts are generally rectangular with rounded chamfers and an open-window configuration to minimize bulk and add aesthetic appeal. Multi-pile CIP concrete footings support the single columns.

Depending on the location in the bridge, corrosion-resistant reinforcement could be either hot-dipped galvanized, low-carbon/chromium steel or stainless steel; stainless steel reinforcement was required near splash zones closer to the ground.

The girder sections over the piers are 120 ft long and have variable depths of 8 to 12.5 ft to accommodate the negative moment caused by continuity while reducing girder weight.





A single crane was used to erect each pier girder within the tight site conditions. The out-of-balance moment during erection was the controlling design load for the cap-to-column connection.

The CIP concrete construction used TxDOT's high-performance concrete,[2] which includes supplementary cementitious materials to counter the risks of alkali-silica reaction and delayed ettringite formation and to also reduce permeability.

Alternate Designs

TxDOT allows post-let alternate designs for select concrete elements to provide avenues for innovation with atypical precast concrete components.[3] On this project, TxDOT recognized the replication of form of the substructure caps and provided a plan note allowing substitution of precast concrete caps—instead of the CIP concrete pier caps in the original TxDOT design—for review and approval. In addition, the superstructure plans allowed for contractor alternates for the spliced-girder unit considering the range of cross-section forms and construction or design techniques that might surmount the transport limitations, as well as the segmental concrete box-girder alternate. The Sargent Beach Bridge was let to contract in July 2017 with nine bidders. Of the nine bidders, the six lowest bidders selected the spliced-girder option.

Alternate for the Spliced-Girder Unit

Before project letting, a precaster worked with an engineering firm to investigate an alternate spliced-girder design. After the project was awarded, the two parties worked with the general contractor to present the alternate design concept to TxDOT. The intent was to reduce the girder weights to within the handling and shipping weight limits of the precaster's equipment. All of the pier locations and span lengths from the original TxDOT design were maintained.

Considering the shipping route and available equipment, the maximum shipping weight for the girder sections was determined to be 280 kip. To maintain girder weights within this limit, the girders were designed with a cross section based on the TxDOT "Long Span Precast I-Girder" standards[4] so that the forms could be used on future projects that incorporate the same standards. The girder sections over the piers are 120 ft long and have variable depths of 96 to 150 in. to accommodate the negative moment caused by continuity while reducing girder weight. The bottom-flange thickness is tapered from the pier to the splice location at the end of the pier segment to provide a sufficient compression block over the piers. The end girders of the main-span unit are 133 ft long with a constant depth of 96 in. Owing to the structure's geometry, the main-span drop-in girder is 178 ft long. To maintain the established girder weight limit, each drop-in girder was cast in two segments and spliced on site before erection.

Because the navigation channel had to remain operational during construction, temporary falsework supports in the channel were not allowed. Therefore, the main-span drop-in girder had to be supported by the pier girders during erection using specific erection sequencing and staged PT details for the alternate design. A detailed analysis was performed for all stages of construction to ensure that the temporary stresses in

AESTHETICS **COMMENTARY**

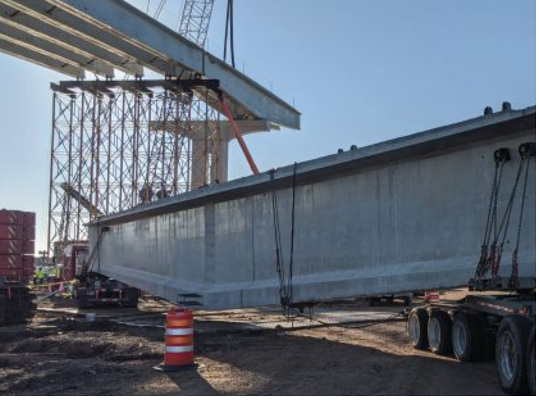
by Frederick Gottemoeller

Simple, direct design solutions always have immense appeal because observers of the structure can immediately understand both the challenges and the solutions. Visually, the Sargent Beach Bridge is about as simple and direct as it gets.

Neither the island nor the mainland has room for linear approach viaducts? Fine, we'll bend the viaducts into spiraled corkscrews. The main span is too long for standard girders? Fine, we'll splice in deeper, tapered sections over the piers to accommodate the greater forces there. The pier caps are too heavy to ship? Fine, we'll carve away all of the unnecessary concrete and create an elegant shape in the process. The pier shafts look too massive? Fine, we'll pierce them with a wide vertical slot.

As I've often pointed out, attractive bridges use their shapes to illustrate how they work: they are thick where the forces are the greatest and thin everywhere else. People intuitively understand the reasons for these shapes, and this understanding results in a positive feeling of engagement and satisfaction. Here, the tapered haunches of the main span, the tapered arms of the pier caps, and even the vertical slots in the pier shafts reflect this differentiation of forces, making the bridge elegant as well as efficient and economical.

In the flat, Gulf-side landscape, I can imagine that this structure is the tallest thing around, making it a signature landmark for the community and its visitors. I predict that Sargent Beach residents are going to be proud of this structure for a long time to come.



One of the 280-kip, variable-depth pier girders arrives on the jobsite. The girders were shipped over 210 miles to the jobsite with specialty trucking equipment.

the girders were within acceptable limits and that allowed erection elevations to be calculated at different phases. The erection sequence of the three-span main unit is as follows:

- End girder segments in spans 1 and 3 were erected onto the approach pier and falsework.
- Next, the pier girder segments were erected onto the main-span piers and the same falsework, with a tie plate connection to the end girder segment for stability. These two girder segments were then spliced by placing concrete in the closure joint and tensioning the first-stage (top) post-tensioning tendon, which used fifteen 0.6-in.-diameter strands.
- Once this procedure was performed on both sides of the channel, drop-in girders were erected and supported by the pier girders. The drop-in girders were temporarily supported using embedded steel corbels that had been cast into the segments at the splice. After the drop-in girders were erected, concrete was placed in the final splice locations and second-stage post-tensioning consisting of four full-length tendons, each with fifteen 0.6-in.-diameter strands, was tensioned.

Alternate for Precast Concrete Bent Caps

An alternate precast concrete bent cap design was also developed for the substructure. Using precast concrete minimized risk with the amount of high-performance concrete that the contractor needed to cast on site. In addition, using precast concrete bent caps shortened the schedule by allowing up to six caps to be erected per day.

The alternate design incorporated pretensioning to enhance the caps' long-term durability, which was very important given the marine environment and the desired 100-year service design life of the bridge. With the addition of pretensioning in the bent caps, the design team investigated using black carbon steel reinforcement instead of the stainless, hot-dipped galvanized, or low-carbon/chromium steel called for in the original design. The pretensioned bent caps were designed to maintain a fully compressed section under all permanent loads, eliminating the likelihood of flexural tension cracks. A service-life study for the precast concrete bent caps concluded that increasing the clear cover for the reinforcement from 3 to 3.5 in., incorporating a corrosion-inhibiting admixture into the concrete mixture, and pretensioning the cap would provide sufficient durability and corrosion resistance to meet the 100-year design life requirement while using black reinforcing bars and strands.

As with the girders, the bent caps were designed for all stages of construction. A variable-depth T-section was used as the cantilever arm of the hammerhead with a rectangular cross section over the column. Using the T-section significantly reduced weight for shipping: the approach span caps weighed 144 kip and the main-span bent caps weighed 246 kip, compared with 207 kip and 504 kip, respectively, in the original design.

The column-to-cap connection was a critical part of the alternate design, and constructability was a primary focus. The connection details were based on TxDOT standards[5] with project-specific modifications. The caps were cast with two corrugated metal pipe voids in the midsection: 21-in.-diameter voids for the approach caps and 30-in.-diameter voids for the main-span caps. Two reinforcing bar spirals projected from the top of each column, and each bent cap was erected with the corrugated voids encompassing the protruding reinforcing bar spirals from the columns. The 2- to 3-in. joint between the column and cap was filled with high-strength grout, and the corrugated voids were filled with the same concrete mixture as the column to complete the connection.

The connection was designed to account for all construction loadings; the critical load case was found to occur during girder erection. The main-span girders were erected from west to east starting with the exterior girder, creating a significant out-of-balance service moment with the first two girders erected. The precast, pretensioned concrete bent cap and its constructable, robust connection with the column had sufficient capacity for the task.

Results

On the Sargent Beach Bridge project, TxDOT's allowance for alternate design, coupled with the ingenuity of an engineer, precaster, and contractor, helped the project team successfully navigate site constraints and transportation challenges. The result was savings of materials, costs, and time.

References

1. Texas Department of Transportation (TxDOT). 2020. "Bridge Design Manual—LRFD." Austin: TxDOT. http://onlinemanuals.txdot.gov/txdotmanuals/lrf/lrf.pdf.
2. TxDOT. 2014. "Item 421: Hydraulic Cement Concrete." https://ftp.txdot.gov/pub/txdot-info/cmd/cserve/specs/2014/standard/s421.pdf.
3. TxDOT. 2020. "Standard Operating Procedure for Alternate Precast Proposal Submission: Bridge Division." https://ftp.txdot.gov/pub/txdot-info/brg/design/alternate-precast-proposal-submission.pdf.
4. TxDOT. 2019. "Long Span Precast I-Girder Sections." Accessed October 29, 2021. https://ftp.txdot.gov/pub/txdot-info/brg/long-span-i-girders.pdf.
5. TxDOT. 2019. "Prestressed, Precast Bent Cap Options for Round Columns." https://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/standard/bridge/ppbcstd1-19.pdf.

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