PROJECT

U.S. Route 181 Harbor Bridge: Creating a New Coastal Icon for South Texas

by Joseph Briones, Texas Department of Transportation, Chris Ursery, Arup, and Justo Molina, Flatiron-Dragados LLC

Each precast concrete segment was fabricated off site and then delivered to its respective pylon, where a ground-based crane hoisted the segment to the bridge deck. A self-propelled modular transporter carried the segment along the southbound box girder to be installed at the cantilever front by a derrick crane. All Photos and Figures: Harbor Bridge Project.

The Harbor Bridge, located in the coastal city of Corpus Christi, Tex., carries U.S. Route 181 across the Corpus Christi Ship Channel. The name Harbor Bridge carries historical significance, honoring the bridges that preceded it and that helped spark and sustain the economic growth of the Coastal Bend. This important crossing has evolved from the original drawbridge of 1926 to a steel truss bridge, which opened in 1959 and was known as the Gateway to Corpus Christi, to the recently completed, signature precast concrete structure.

When it opened, the 1959 structure was considered an engineering marvel, at the cusp of innovation for bridge engineering, and it subsequently became a long-lasting icon for the local community. The Texas Department of Transportation (TxDOT) integrated several emerging technologies in that bridge that are still commonly used today, including the first application of prestressed concrete girders (for the approach spans to the main channel) and the first use of elastomeric bearing pads under girders in Texas.

As the years passed, maintenance costs for the Harbor Bridge rose due to the structure's deterioration in the harsh marine environment, traffic demands increased, and concerns about limited maritime accessibility grew. The combination of those factors led TxDOT to consider constructing a new bridge. In 2014, TxDOT accelerated efforts to replace the old Harbor Bridge with a taller, wider, and more durable structure capable of withstanding the region's demanding climate profile. The new bridge design would address TxDOT's priorities of improving regional mobility, maritime accessibility, and safety for motorists and pedestrians. Using the design-build-operate-maintain delivery model, TxDOT teamed with Flatiron-Dragados LLC and ultimately chose to replace the aged Harbor Bridge with a signature precast concrete segmental cable-stayed bridge. This option was selected over steel girder, cable-stayed proposals.

The new Harbor Bridge, which is located in a region susceptible to hurricanes, challenged the limits of precast concrete segmental design and construction. It achieved the longest precast concrete segmental main span ever constructed (1661 ft), as well as the widest delta-frame connected cross section (nearly 150 ft). Innovative materials were essential to protect the major structural components from the corrosive marine environment and meet TxDOT's sustainability goals. High-performance concrete mixture designs were engineered to achieve both the demanding 10-ksi design compressive strength requirement and the project's 170-year extended service life requirement, the pinnacle of sustainability for this project. Corrosion protection for the 270-ksi high-strength steel strand used for the stay cables was achieved by using epoxy-coated and filled strand, in which the internal voids among the strand wires are epoxy filled. This type of strand is relatively

profile

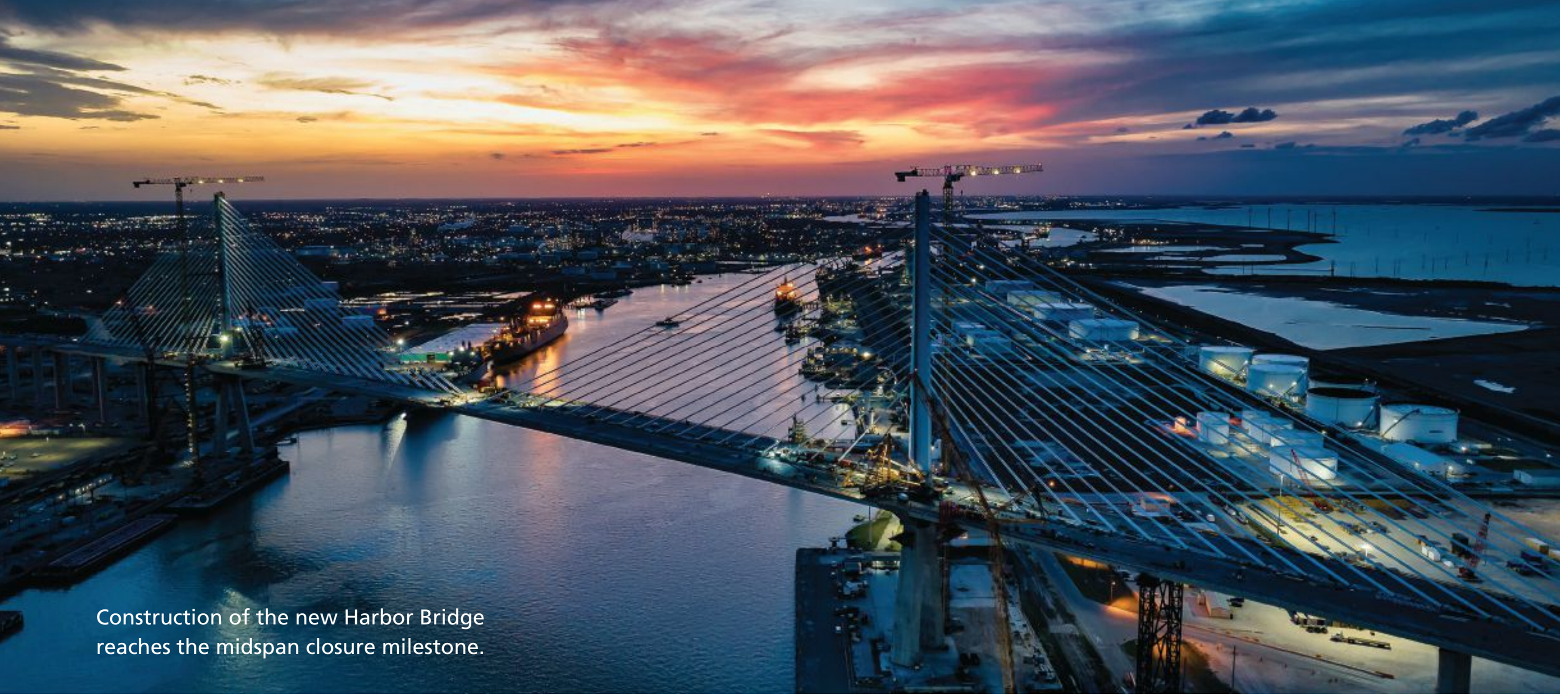
U.S. ROUTE 181 HARBOR BRIDGE / CORPUS CHRISTI, TEXAS

BRIDGE DESIGN ENGINEER: Arup & Carlos Fernandez Casado (CFC) – Design Joint Venture, Houston, Tex.

OTHER CONSULTANTS: Owner's engineers: HNTB, Kansas City, Mo., and Texas Department of Transportation Bridge Division, Austin; construction quality acceptance firm: Atlas Technical Consultants, Denver, Colo.; aesthetic lighting design: Reed Burkett Lighting Design Inc., St. Louis, Mo.

PRIME CONTRACTOR: Flatiron-Dragados LLC, Corpus Christi, Tex.

MATERIAL SUPPLIERS: Stay-cable system supplier and installer: DYWIDAG-Systems International (DSI), Long Beach, Calif.; post-tensioning suppliers: Structural Technologies (VSL post-tensioning products), Columbia, Md., and Williams Form Engineering Corp., Belmont, Mich.; reinforcement fabricator: Harris Supply Solutions, Seattle, Wash.; bearings and expansion joints: Mageba, New York, N.Y.; precast concrete segmental formwork: Ninive Casseforme, Garbagnate LC, Italy; derrick crane sleds: Somerset Engineering, Somerset, Pa.



Construction of the new Harbor Bridge reaches the midspan closure milestone.

A delta frame is installed using a custom support system.

new in the United States and is gaining popularity for stay cables and ungrouted external tendon applications.(For more information on epoxy-coated strands, see the Spring 2020 issue of *ASPIRE®*.)

Enhanced connectivity and safety improvements for motorists and pedestrians were key TxDOT requirements for the new bridge. The bridge has three lanes of traffic in each direction and includes 10-ft shoulders, a safety element missing from the old bridge. A protected 10-ft-wide shared-use path for pedestrians and cyclists is provided on the northbound side leading up to the scenic overlook at the center span, where visitors can observe unmatched views of this beautiful coastal region.

To accommodate the shared-use path, the northbound box girder is wider than its southbound counterpart, creating an asymmetrical cross section. The dual precast concrete box girders, connected transversely by precast concrete delta frames and a cast-in-place median slab, are supported by a central plane of twin, parallel stay cables. The cable-stayed portion of the bridge stretches 3295 ft with two 817-ft side spans and a 1661-ft center span. The navigational vertical clearance envelope for the new bridge has been increased to 205 ft (compared with 138 ft for the original bridge), allowing the passage of large modern cargo ships underneath.

The impressive, nearly 540-ft-tall, inverted Y-shaped pylons, which are the tallest structures in Texas south of San Antonio, have greatly enhanced the Corpus Christi skyline. The slenderness of the upper pylon allows the structure to seamlessly blend in with the surrounding built environment.

Arguably, concrete segmental bridges offer an enhanced aesthetic appeal when compared to conventional bridges. In a series of outreach events, the public selected "Corpus Christi: A Beacon of Coastal Beauty" as the aesthetic bridge theme. This concept identifies the public's preference that the bridge aesthetics be integrated with the built environment and the natural beauty of the greater Coastal Bend region. One highlight of the aesthetic design is the lighting system, which consists of fully addressable, dynamic LED devices installed on the towers, along the stay cables, and along the superstructure underside, providing an infinite number of color combinations for special lighting presentations.

TEXAS DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: Signature cable-stayed bridge featuring a 1661-ft center span and 817-ft side spans, supported by a central plane of dual stay cables and two nearly 540-ft-tall inverted Y-shaped concrete pylons. The nearly 150-ft-wide cross section uses two post-tensioned precast concrete box-girder segments transversely connected with precast concrete delta frames provided at each deck-level stay-cable anchor.

STRUCTURAL COMPONENTS: 698 post-tensioned precast concrete box-girder segments, 84 post-tensioned precast concrete delta frames, and 76 pairs of stay cables to support the superstructure. Each stay cable is anchored at its prescribed precast concrete delta frame along the bridge deck and steel anchor box within the upper tower. The pylons, back-span piers, and transition piers use cast-in-place concrete. The pylons are founded on 10-ft-diameter and 4-ft-diameter drilled shafts while the back-span piers and transition piers are founded on 24-in. square precast, prestressed concrete piles.

BRIDGE CONSTRUCTION COST: $517.3 million (cable-stayed bridge only)

AWARD: 2025 American Segmental Bridge Institute Bridge Award for Excellence

Back-span cantilever at temporary pier tie-in.

Construction of the new Harbor Bridge tower and superstructure.

Analysis

The structural analysis of the bridge consisted of both local and global models, each with different modeling approaches for specific design checks. Local models using three-dimensional (3-D) brick elements were used to determine the transverse design deck effects. The primary global model, consisting of 3-D grillage elements, included the construction stage analysis. A central database was used to store model input and output data and served as the sole source of authoritative information for the design partners.

The construction engineering team used a local 3-D brick model for the nodal regions of the delta frame and box girders, two-dimensional shell elements for the thin slab portions of the box girders, and one-dimensional frames for the delta-frame main members. The transverse stiffness in the global model was calibrated to resemble the behavior observed from the more granular local model. The local model was essential to capture local effects from post-tensioning, stay force tensioning, local live load, and transverse bending of the median slab, and this model could quickly investigate the effects of heavy equipment during construction. Separate local models were used in regions such as the back-span pier segments, the expansion joint segments, the tower table nodal zone, and the stay-cable anchor boxes.

Given the high risk for hurricanes in the Gulf Coast region, the project required a rigorous wind-loading analysis. Wind tunnel testing confirmed the bridge's satisfactory behavior. Additional wind-buffeting analyses were performed based on the modal behavior and

AESTHETICS **COMMENTARY**

by Frederick Gottemoeller

Corpus Christi is in the flat Coastal Bend region of Texas's Gulf shore. Prominent landscape features are visible for miles. The Harbor Bridge stands slightly apart from the downtown, so the bridge occupies its own visual space, clear of the city's skyline. Even so, it is near important regional landmarks, including Corpus Christi's minor league baseball stadium, Whataburger Field. Indeed, the bridge dominates the view from left field. So, it is no surprise that the community wanted it to be a "beacon of coastal beauty." And, wow, is it ever.

The bridge owes its beacon status in large part to a combination of improvements in concrete segmental construction. The most visible of these is the unusually wide deck system featuring two segmental box girders connected by delta frames. The system allows support from the median by a pair of cable planes emanating from single centerline towers. Visual simplicity is always important in creating landmark bridges, and this deck system is as visually simple as it gets. It is easy to understand from nearby and from a distance, and even from below. Even fans at Whataburger Field can enjoy the elegance of the solution between innings. And the designers solved the problem of installing a shared-use path on just one edge of the bridge in the simplest way possible: they made one box girder a bit wider than the other.

The innovations do not end there. Because of their V-shaped bases, the towers appear to be striding across the channel. Vertical tapers on the legs and tops of the towers, combined with the diagonal placement of the legs' square cross sections and the hexagonal cross sections of the tops (which make those elements appear narrower), give the whole structure a sense of elegance. The two-box system also contributes at each pier line, requiring only two slim piers, made to look even slimmer by their octagonal cross sections.

The Harbor Bridge is a masterpiece. Its designers, the Texas Department of Transportation, and the community are to be congratulated on their achievement.

specific wind climate definitions for the completed bridge and for critical stages of construction.

Much of the complexity in the global analysis model involved developing the construction stage analysis. Each stage required specific boundary conditions and construction-load assumptions. The intent of the staged analysis was to capture all locked-in effects in the structure as the cantilever construction progressed and cables were stressed. A specialized tuning effort was performed to control stresses in the structure; thus, stay cables were tensioned at the time of installation and midway through the following cycle. To prevent undesirable stresses and deformations after the main span closure, a third phase of tensioning was executed in the final three pairs of stay cables.

Construction

Segmental construction accelerated the project's pace by allowing concurrent fabrication of the precast concrete segments during the construction of the pylons. Precast concrete delta frames were fabricated as full pieces at the precasting facility where the box girders were fabricated. Off-site segment fabrication also facilitated the geometric precision and quality control needed for this structure. After each segment was delivered to its respective pylon, a ground-based crane hoisted the segment to the bridge deck. A self-propelled modular transporter would then carry the segment along the southbound box girder to be installed at the cantilever front. Derrick cranes mounted on sleds atop the northbound box girder moved sequentially with the advancing structure, lifting and placing each segment into position. After a segment was aligned and epoxy was applied to the joint, high-strength post-tensioning bars locked the segment into the permanent structure. Because segments were not lifted from the shipping channel, access to the Port of Corpus Christi remained uninterrupted during the project.

Each side of the cantilever required 19 construction cycles, with each cycle consisting of an approximately 37-ft-long section having four northbound box-girder segments, four southbound box-girder segments, one delta frame, a cast-in-place median slab, and twin stay cables. In total, 698 precast concrete box-girder segments, 84 precast concrete delta frames, and 76 pairs of permanent stay cables were used to assemble the bridge. During peak production, construction crews streamlined the process to achieve an impressive 11-day cycle time, clearly demonstrating the efficiency of segmental construction.

Underside view of twin box girders and delta frames.

A custom support system used for the delta-frame installation allowed the delta frames to be adjusted in all six degrees of freedom while hoisting. The delta frames were maneuvered to engage the shear keys, with their corresponding blockouts located within the webs of the adjoining segments. Minor manipulations were necessary to align the internal post-tensioning ducts and correctly position the stay-cable guide pipes. Placement of the cast-in-place concrete closures and tensioning of the continuity post-tensioning completed the assembly.

The post-tensioning design used center-span continuity tendons, back-span continuity tendons, and top-slab cantilever tendons. All tendons were composed of 0.6-in.-diameter strands. The center-span continuity post-tensioning used 62 tendons, with 19 to 27 strands per tendon, while the back-span continuity post-tensioning used 56 tendons in each of the two back

The completed new Harbor Bridge overlooks Whataburger Field, a minor league baseball stadium, in Corpus Christi, Tex. The bridge opened to traffic in June 2025.

spans with 16 to 27 strands per tendon. Finally, the top-slab cantilever tendons were installed during the initial cantilever construction, before the cable stay installation and consisted of 20 tendons per cantilever in the 8 cantilevers for a total of 160 cantilever tendons with 25 to 27 strands per tendon.

Most of the stay-cable tensioning occurred in two phases: at the conclusion of an erection cycle and halfway through the next cycle. This sequence was necessary to control the tension generated in the top deck during cantilever construction and the tension in the bottom slab generated during stay tensioning. After the main-span closure, the final three cables had a third tensioning phase, as previously mentioned, to control stresses and deformations in the completed structure.

Construction Engineering and Geometry Control

The construction engineer created a comprehensive erection manual that provided the details necessary to achieve the required internal forces and geometry after completion of construction without overstressing any of the bridge components during construction. In lieu of a fully prescriptive manual, construction rules were developed to allow the contractor to make on-site adjustments to a typical erection sequence without further evaluation. Compared to typical fully prescriptive manuals, these rules added a significant number of analysis permutations; however, this approach provided the flexibility needed to achieve and maintain production goals.

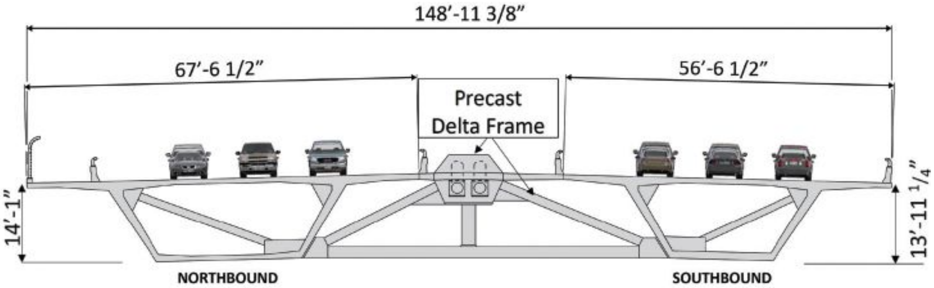
During construction, the box girders experienced multiple cycles of negative bending due to segment erection and positive bending due to stay-cable installation and tensioning. The critical location for peak flexural stresses was generally located approximately three cycles behind the leading edge. The optimum stay-cable installation forces and subsequent prestressing forces were calculated to keep the longitudinal tensile stresses within allowable limits.

Although much emphasis is placed on the assembly of bridge components, geometry control of the pylon and superstructure is of utmost importance and must be carefully monitored. Target geometry was set according to the design, using a reference condition of 70°F and 30,000 days after the end of construction to capture long-term effects.

To compensate for expected deformations, the tower pile cap foundations were designed to accommodate the predicted long-term settlement. The lower legs of the pylon compensated for longitudinal deflection, while the upper towers were constructed assuming a vertical precamber to preserve the distance between deck level and the upper stay anchors. Temporary towers were also installed halfway between the main towers and intermediate back-span piers to help stabilize the superstructure during construction. As for the box girders, the vertical and twist precambers were incorporated into the theoretical cambered geometry. Twist precamber was necessary to compensate for torsional deformation from the box girders being supported from a center plane of stays.

Recognizing that analysis models differ from on-site behavior, the

The delta frames were maneuvered to engage the shear keys, with their corresponding blockouts located within the webs of the adjoining segments (circled in the left photo with detail in the upper right photo). Precise manipulations were used to align the internal post-tensioning ducts and correctly position the stay-cable guide pipes (bottom right photo).



Typical cross-section geometry of the bridge with dual precast concrete box girders connected transversely by precast concrete delta frames and a cast-in-place median slab.

project team had to rely on a robust geometry control plan until the model stiffness could be adjusted to match the observed deflections during construction. Part of this plan involved weighing each segment, delta frame, and piece of large construction equipment. Early cycles included local surveys to ensure that the as-erected geometry reasonably agreed with the as-cast geometry established during fabrication. Global surveys were performed at night and provided a snapshot of the bridge's behavior for comparison with its corresponding construction stage. Stay-cable forces were measured during global surveys. Leading stays were measured using traditional liftoff procedures, while trailing stay forces were reported using the instrumentation installed at the top stay anchors.

Closures

The ultimate success of the geometry-control effort would be reflected when the cantilevers neared the back-span piers, transition piers, and center span. Although each closure had its own intricate set of constraints, the goal was to connect the superstructure within the established geometric and force tolerances.

The design allowed for some vertical and horizontal jacking, if needed. The temporary works for the closures were designed to resist all expected forces for short-term, critical stages of the closure operation. The precision and model confidence required at the phases just before each closure were paramount to achieving successful bridge alignment.

Conclusion

As home to both the oldest precast concrete segmental bridge in the United States (JFK Causeway, 1973, which is discussed in the Fall 2021 issue of *ASPIRE*) and now the longest precast concrete segmental span ever built (U.S. Route 181 Harbor Bridge, 2025), Corpus Christi represents more than five decades of progress in segmental bridge technology. As such, the Coastal Bend region is a beacon of transportation infrastructure excellence, bridge aesthetics, and sustainability.

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