The Gulf Intracoastal Waterway Bridge
AT MATAGORDA, TEXAS

by Dean Van Landuyt, Texas Department of Transportation

Combining superstructure types provides economical solution

Cattle drive across the previous floating swing bridge at Matagorda, Tex. Photo: Keith Dornak, TxDOT.

The Matagorda Peninsula in Texas is a largely undeveloped, 60-mile-long stretch of barrier islands known for its fishing, beautiful beaches, and cattle ranching. Only one of the two islands comprising the peninsula is accessible by vehicle. Formerly, that access was by a single, floating swing bridge across the Gulf Intracoastal Waterway at Matagorda. The bridge is used by vacationers and a few year-round inhabitants. Interestingly, ranchers owning property on both the mainland and island, also use it to drive their herds to the island for winter grazing.

The swing bridge was a retrofitted barge that opened using a cable and pivot to allow both commercial and recreational vessels to pass. It required frequent maintenance and operators on duty around the clock. After considering the operating costs of approximately $350,000 per year and time delays for inhabitants and emergency vehicles, a decision was made to replace the bridge with a tall, fixed structure.

A new, visually unique bridge replaced the floating swing bridge. The new bridge was required to provide 73 ft of vertical

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A three-span segmental box girder bridge was used at the waterway. Photo: Dean Van Landuyt, TxDOT.

profile

GULF INTRACOASTAL WATERWAY BRIDGE / MATAGORDA, TEXAS

ENGINEER: Texas Department of Transportation Bridge Division, Austin, Tex.

CONSTRUCTION ENGINEERS: Summit Engineering Group Inc., Littleton, Colo., and Frank W. Neal & Associates, Ft. Worth, Tex.

PRIME CONTRACTOR: Midwest Foundation Corporation, Tremont, Ill.

CONCRETE SUPPLIER: Alamo Concrete Products Ltd., Bay City, Tex.

PRECASTER: Texas Concrete Company, Victoria, Tex.

SEGMENTAL FORMWORK SUPPLIER: Mexpresa, Mexico City, Mexico clearance for shipping. A long span was also needed in order to locate piers on land and away from possible vessel impact. Appearance was important. The new bridge would be the most imposing structure in this town of just 1400 people and would visually convey the community's mind-set toward visitors and the environment.

The Segmental Concrete Spans

Cast-in-place concrete segmental spans were selected early in the design process for the center portion of the 3387-ft-long bridge. This type of structure was chosen because it can span the required 320 ft and is durable and aesthetically pleasing. With adjacent side spans of 180 ft, the 46-ft-wide segmental concrete box girder unit has a total length of 680 ft.

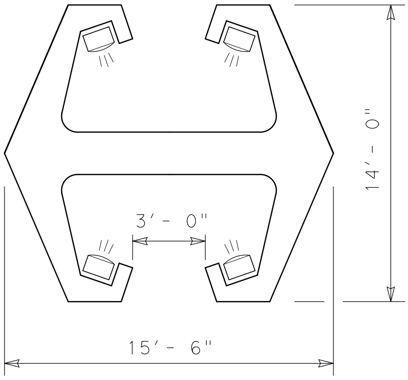
A haunched section and tapered V-hull soffit were used at the piers. Photo: Dean Van Landuyt, TxDOT.

The large scale and tremendous force demands on the bridge, particularly during construction, required non-standard formwork. This gave the designer freedom to create unique shapes. Two primary artistic concerns were visually integrating the substructure and superstructure so they appear as a single unified element—something all-too-frequently absent from slab and beam bridges—and creating a column shape that could serve as an architectural beacon.

The idea began by altering the typical segmental box shape. The typical flat-bottom shape gradually gives way to a V-hull shape as the girder approaches the columns. The bevel is then carried directly into the columns with the same 3:7 bevel to form a perfectly mitered corner.

The main piers have a unique double-anchor shape that continues the heavily chamfered appearance of the superstructure. The tips of the anchors curl around to protect and hide light fixtures that illuminate an internal web. A 3-ft-wide opening between the tips is just wide enough for a man-lift to enter to allow for the installation and maintenance of the lighting system. With an overall longitudinal dimension of 15 ft 6 in. and with thick flanges, the pier had a large enough moment of inertia to meet the severe flexural demands of the unshored, balanced cantilever construction. The tips also provide enough area at the extreme lateral edges for the column to withstand 100 mph design winds in the transverse direction.

The superstructure details and construction method are, by contrast, rather conventional by segmental standards. A 27-ft 6-in.-long pier table segment with twin diaphragm walls crowns each of the main piers. Then, 15-ft-long segments, constructed one-half segment out of balance, were added until the ends of the cantilevers were within one full segment apart. Four top slab tendons are anchored in each segment to handle the cantilever stresses. Each tendon consists of fourteen 0.6-in.-diameter strands. Once the cantilevers were joined to form a continuous girder, bottom slab tendons



Cross section of the main piers in the segmental unit. Illustration: Dean Van Landuyt, TxDOT.

THREE-SPAN, CAST-IN-PLACE CONCRETE SEGMENTAL UNIT AND 19 APPROACH SPANS WITH PRECAST, PRESTRESSED CONCRETE I-GIRDERS / TXDOT, OWNER

MAIN PIER FORMS: DOKA USA, Tomball, Tex.

POST-TENSIONING MATERIALS: VSL, Grand Prairie, Tex.

REINFORCEMENT SUPPLIER: Katy Steel, Katy, Tex.

BRIDGE DESCRIPTION: 3387-ft-long and 46-ft-wide bridge consisting of a three-span 680-ft-long variable-depth, variable-soffit, cast-in-place box girder with a 320-ft-long main span and 19 spans of either 141-ft- or 145-ft-long, precast, prestressed concrete AASHTO Type VI girders

BRIDGE CONSTRUCTION COST: \$16.0 million (\$212/ft^2 for segmental box-girder spans and \$75/ft^2 for I-girder spans)

Cross section of the pier segment. Photo: Dean Van Landuyt, TxDOT.

The approaches were quite long, resulting in 125,000 ft^2 of bridge deck area.

consisting of eleven 0.6-in.-diameter strands were stressed to overcome future tensile stresses resulting from railing loads, live loads, and redistributed cantilever moments.

One unusual aspect of construction was the bottom soffit form. Flexible, rotatable "wings" mounted on a central spine allowed for a continuously changing bevel to be cast. In fact, the entire system was designed so that it could be warped. The back portion of the form was clamped to the underside of the previous segment while the leading edge, located 15 ft ahead, was opened to a wider angle.

The Approach Spans

One of the difficult decisions that owners must face when planning segmental bridges that span navigable waterways on flat landscapes is the structure type used for the approaches. Obviously, large spans are not necessary and therefore more economical short-span, multigirder superstructures can be utilized. Since the change in roadway elevation from the abutment to the segmental portion is approximately 75 ft, the approaches were quite long—19 spans—resulting in 125,000 ft^2 of bridge deck area. In Texas, the differential costs between a segmental superstructure and a precast, prestressed girder superstructure is about \$135/ft^2. Therefore the overall bridge cost could be reduced from \$33 million to \$16 million. The downside to this approach is aesthetics.

The transition from a segmental to a multigirder superstructure presents obvious visual discontinuity when viewed from below. Aside from placing ear walls on the bent cap to block the view of dark, cavernous openings between beams, little can be done to resolve the issue of dissimilar superstructure cross-sections. However, it was possible to improve another common architectural misstep—an abrupt section depth change to a shallow approach span. The overall slab and AASHTO Type VI girder depth for the 141-ft and 145-ft-long approach spans is 6 ft 9 in. Optimal depth for the thinnest portion of the segmental superstructure is about 8 ft; however, the Texas Department of Transportation (TxDOT) engineers were able to reduce the section to just 7 ft to make the depths appear nearly equal when viewed in profile.

The Arrival of Hurricane Ike

Hurricane Ike entered the Gulf of Mexico after the construction of the first set of cantilevers, but before the back span closure segment was cast,. Then, 3 days before landfall, with Matagorda directly in line

Night-time lighting of the main piers. Photo: Dean Van Landuyt, TxDOT.

The transition pier showing the ear walls to hide the ends of the precast, prestressed concrete beams. Photo: Dean Van Landuyt, TxDOT.

with the projected path, the channel-side travelers were inadvertently removed. While somewhat mitigating the wind effects, it further unbalanced the longitudinal moment on the main pier. The bridge was left with a 160-ft-long cantilever supporting a 100-kip traveler and a 152.5-ft-long cantilever with no traveler. Immediately upon discovery, the channel-side cantilever was counter-weighted with timber mats and concrete blocks.

While the longitudinal moment was brought back within design limits, a larger issue remained. The first severe hurricane in 50 years was heading toward Matagorda and the bridge was in full cantilever, supported only by a column with minimal torsional strength. While meeting the *AASHTO LRFD Bridge Design Specifications* requirements for wind, engineers were concerned that an absence of unbalanced wind loading requirements in the specifications left the structure vulnerable.

An analysis of the structure based on eccentric wind loading conditions established by ASCE 7 revealed that the pier could experience torsional moments equal to about twice the cracking moment. A cable guying plan was enacted that would reduce torsion to nearly half the cracking moment. The end of the side span cantilever was secured to the ear walls cast on to the transition bent. Fortunately for the bridge, the hurricane turned north shortly before landfall, leaving the bridge on the "good side" of the storm. The maximum sustained 1 minute wind speeds were only 58 mph and the bridge suffered no damage.

Lighting

Engineers wanted to produce a sliver of blue light on either side of the channel to make the bridge unique to Matagorda and recognizable by those using the waterway. After much consideration, including photometric studies, a series of individual induction florescent fixtures was located up the sides of each of the four openings. These fixtures were chosen because of their long life (more than 20 years) and light intensity. Unfortunately, they can only produce white light. There was a fear that because the lights were so bright and only located 4 ft from the center web, the light would reflect mostly white hot. However, this was not the case, helped in part by the shade of blue paint chosen.

The plans required that four large test panels of varying shades of blue temporarily be affixed before painting. A dark color was chosen for its ability to reflect a variegated light-blue/white fusion. The 46 fixtures and accompanying electrical materials cost $75,000—a small percentage of the $20 million project cost.

The bridge was opened to traffic in the summer of 2009 and the old swing bridge dismantled shortly thereafter. The frequent traffic stops that provided for the passage of barges and pleasure craft are now a thing of the past. The future of the town and peninsula will undoubtedly be influenced by the improved accessibility and distinctive architecture of the segmental bridge.

Dean Van Landuyt is a senior design engineer for the Bridge Division of the Texas Department of Transportation, Austin, Tex.

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AESTHETICS COMMENTARY

by Frederick Gottemoeller

"Having an attitude" is usually considered a negative. But, if designers want to accomplish something worthwhile, they have to "have an attitude" toward the features of their bridge. It's another way for saying that they have to have a vision of what they want to accomplish, not just for the technical features, but for the aesthetic features as well.

For girder bridges, and particularly for concrete box girder bridges, a key decision is the relationship of the pier to the girder. Does the designer want them to be seen as separate elements, with the girder floating above the pier? Or does the designer want them to be seen as a single monolithic shape, with the pier blending into the girder?

Actually, that decision should be made not on visual grounds, but on structural grounds. If the bridge is designed with bearings at the piers, then that fact should be evident, and the pier top should be attenuated to demonstrate the presence and role of the bearings. If the bridge is designed for the girder to act monolithically with the piers, the girder and piers should physically blend together. An excellent aesthetic result can be accomplished with either approach. Designs that fail aesthetically often do so because of an attempt to make one approach look like the other.

The box girder bridge at Matagorda is an excellent example of blending girder and piers together. The girder and pier are shaped similarly in a simple but sophisticated way. The planes of the girder soffit turn and become the planes of the pier shaft. The obvious similarities between the girder and the pier ensure that the bridge is perceived as a single integrated entity. At the same time the recess between the pier halves, perceived as a dark vertical line in the daytime and as a lighted vertical line at night, punctuate the bridge and give it an additional level of interest. All of this is accomplished with the shapes and sizes of the structural elements themselves, the elements that have to be there anyway. Nothing (except the lighting) is added solely for aesthetic effect.

The traveler and formwork for the segmental unit. Photo: Michael Mann.

The state of segmental construction just 2 weeks prior to the arrival of Hurricane Ike. Photo: Keith Kouba, TxDOT.

Cast-in-place concrete segmental spans were selected early in the design process for the center portion of the bridge.

Temporary cables were secured to the ear walls of the transition piers
to reduce column torsion expected from Hurricane Ike.
Photo: Keith Kouba, TxDOT.