Condition Evaluation of the JFK Causeway Post-tensioned Segmental Bridge

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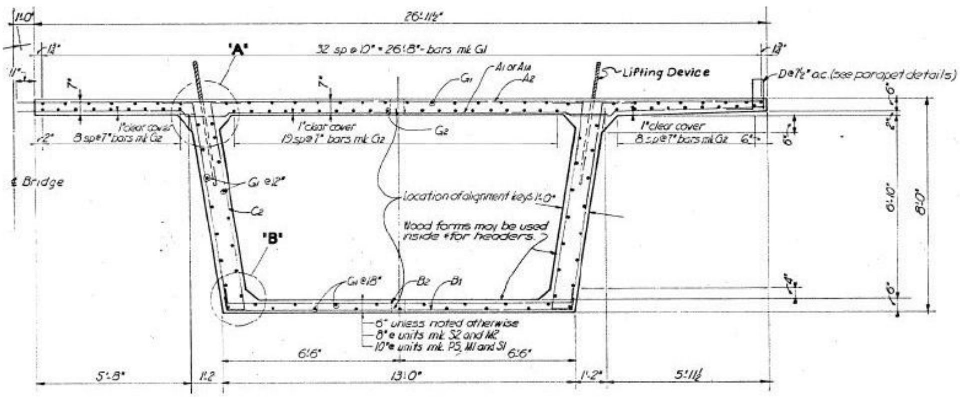
The John F. Kennedy (JFK) Memorial Causeway Bridge, completed in 1973, carries Texas Park Road 22 over the Gulf Intracoastal Waterway (GIWW), connecting Corpus Christi to North Padre Island, Tex.

The original causeway was built in 1950 as a two-lane toll road with swing bridges across two channels. In 1973, it was replaced with a four-lane public roadway that consists of 36 prestressed concrete beam approach spans and a continuous three-span segmental unit over the GIWW. The 3280-ft-long, 60-ft-wide bridge carries two lanes in each direction. The main span continuous unit was the first precast concrete post-tensioned (PT) segmental bridge built in the United States to carry vehicular traffic and was primarily designed by the University of Texas at Austin (UT) with assistance from the Texas Department of Transportation (TxDOT). This article reports on the thorough condition investigation and service-life modeling of the structure that was conducted in 2019 to determine rehabilitation strategies to extend the bridge's service life by at least 25 years.

Research, Design, and Construction

The project started with a TxDOT research project conducted in 1969 by Dr. John E. Breen of UT to identify a viable concrete alternate to structural steel bridges in the 130- to 350-ft-span range. The research project identified concrete PT segmental bridges as a viable candidate based on studies of bridges recently constructed in Europe.[1] TxDOT then extended UT's contract to investigate other design and construction aspects of segmental construction in four subsequent studies: epoxies for segment joints, design and optimization studies, computer analysis, and load tests of a scale-model bridge.[2–5] The studies culminated with a final report, *Minimizing Construction Problems in Segmentally Precast Box Girder Bridges*.[6] The JFK Causeway was actually the second precast concrete segmental

The John F. Kennedy Memorial Causeway Bridge over the Gulf Intracoastal Waterway was completed in 1973. The 400-ft-long (200 ft main span with 100 ft back spans) continuous main unit was the first precast concrete post-tensioned segmental box-girder bridge built in the United States. Photo: Texas Department of Transportation.



Details of the typical box-girder section. Post-tensioning duct locations are not shown. Figure: Texas Department of Transportation (from original construction plans).

The precast concrete segments were erected using balanced-cantilever construction. A custom-designed erection jig was used to hold a segment in place for application of the joint epoxy to the mating faces is visible. Photo: Alan Matejowsky.

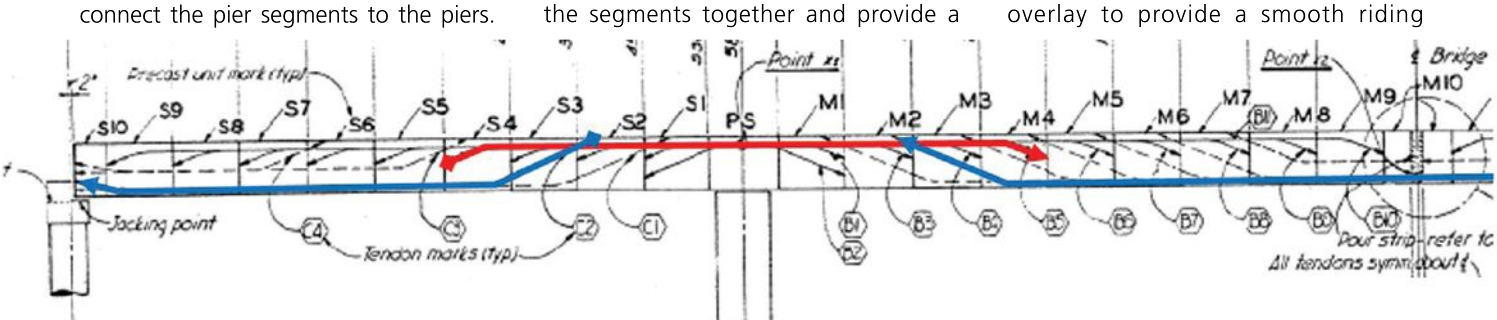
bridge built in the United States; the first was the ⅙-scale model constructed and tested by UT.[5] UT held several meetings with prospective contractors during scale-model construction and testing to help in understanding the challenges to be faced during construction.

The segmental unit has a 200-ft-long main span over the GIWW, with 100-ft-long back spans for a total continuous unit length of 400 ft. The unit consists of a pair of segmental precast concrete box-girder sections that are 13 ft wide at the base, 28 ft 8 in. wide at the wings, and have a constant depth of 8 ft. The bridge is supported by two reinforced concrete columns at each interior pier, with the pier supported on large pile footings. The ends are supported on three-column transition bents.

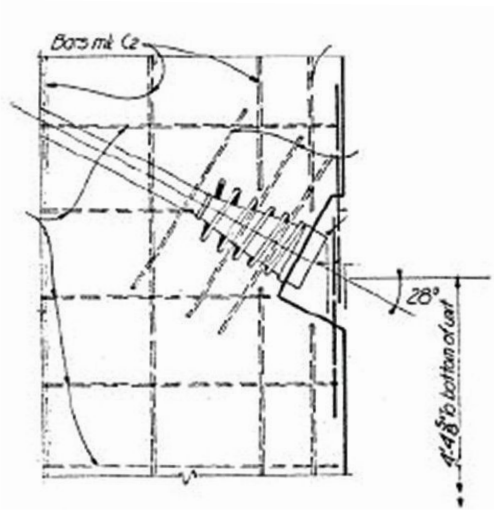
The precast concrete segments were match cast and fabricated by PCI member Heldenfels Brothers Construction Corporation at their Corpus Christi precast yard. The main unit was constructed by first erecting the two 5-ft-long pier segments on top of the reinforced concrete piers and engaging hold-down bars to temporarily connect the pier segments to the piers. The span segments were transported to the site and lifted into position using cranes and a custom-designed erection jig to hold the segments in place for application of the epoxy. The mating faces of the segments were coated with epoxy before joining them together. The epoxy serves as a lubricant when the segments are brought together, and as a permanent joint seal between the precast concrete segments. The span segments were erected on alternating sides of the piers so that the span remained no more than one segment out of balance at all times during construction—a process known as balanced-cantilever construction. The precast concrete segments included large shear keys in each web to transfer vertical shear loads between adjacent segments, and an alignment key in the top and bottom slabs at the box centerline to aid in segment alignment during erection. No permanent moment connection was made between the span and the main piers.

PT tendons, consisting of a varying number of prestressing strands, were inserted through metal ducts cast in the segments (see tendon layout below). The tendons were tensioned to hold the segments together and provide a minimum level of compression over the full cross-sectional area of the box sections under service loads. During segment erection, cantilever tendons in the top slab were used to hold the segments in place as subsequent segments were erected. Once the full complement of segments was erected, a cast-in-place closure pour was made at the middle of the main span. Continuity tendons were then inserted into metal ducts that extended from the deck down into the bottom of the box segments to produce a fully continuous structural unit. The pier hold-down bars were then released and abandoned. The cantilever tendons were anchored in the box webs near the large shear keys. The continuity tendon anchors were located at the ends of the unit and in the top slab.

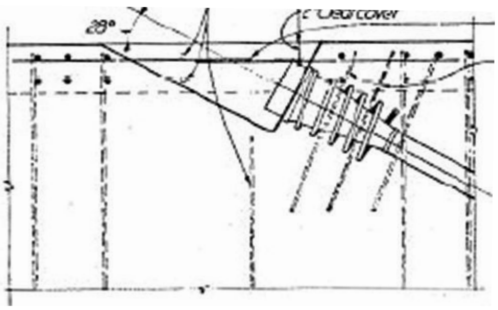
The bridge design for both the approach and main spans did not include any of the corrosion mitigation provisions that are typically employed in modern designs for similar marine-exposure locations, such as high-performance concrete, epoxy-coated or other corrosion-resistant reinforcing steel, or additional concrete clear cover to the embedded reinforcement. The segmental unit's original design included a 1½-in. asphalt overlay to provide a smooth riding



Post-tensioning tendon layout schematic for half of the bridge. The red line indicates a typical cantilever tendon, and the blue line indicates a typical continuity tendon. The main span continuity post-tensioning tendons have varying numbers of strands. Figure: Texas Department of Transportation (original plans) with annotation by Wiss, Janney, Elstner Associates Inc.



Cantilever tendon anchor in web.



Continuity tendon anchor in deck.

Typical post-tensioning anchor details as shown in original plans. Figure: Texas Department of Transportation.

surface, but no overlay was provided for the prestressed concrete beam approach spans. In the 7-in.-thick segment top slabs, the design clear cover was 1⅛ in. for the top mat of reinforcing steel and 1 in. for the bottom mat. For the 12-in.-thick webs and the 6-in.-thick bottom slab, the interior and exterior clear covers were both 1½ in.

Condition Assessment

In November 2019, a condition assessment of the main span continuous unit was performed. It included the following tasks: visually assessing 100% of the interior and exterior of both box sections; locating PT ducts using nondestructive evaluation methods to identify potential grout anomalies (for example, voids); opening selected tendons or anchorages for visual inspection and grout sampling; coring at various locations on the box girders for chloride and carbonation testing; using ground-penetrating radar to survey reinforcing bar cover; and performing half-cell corrosion potential testing. The goal of the assessment was to develop repair recommendations for a target service-life extension of at least 25 years.

Deck tendon after excavation and opening of ducts for inspection.

Continuity tendon anchor in deck exposed for inspection.

Borescope image of small void in deck tendon near post-tensioning anchor.

Moderate corrosion of continuity tendon anchor at end of box girder.

Photographs from the condition assessment of the main span continuous unit that included visually assessing 100% of the interior and exterior of both box girders; locating post-tensioning (PT) ducts using nondestructive evaluation methods to identify potential grout anomalies; and exposing selected tendons or anchorages for visual inspection and grout sampling. The PT tendon survey indicated that the PT system was generally in very good condition. Photos: Wiss, Janney, Elstner Associates Inc.

Spalling on the exterior face of the box girder exposed corroded supplemental (not indicated in original plans) wire-mesh reinforcement with insufficient clear cover. Photo: Wiss, Janney, Elstner Associates Inc.

The exterior visual survey identified diagonal cracking in the webs that had occurred during tensioning of the cantilever tendons and had been sealed with epoxy, spalling in the pourback mortar at the end anchorages of the continuity tendons, and isolated surface spalling with exposed reinforcing steel. No distress was observed at the previously sealed web cracks, and spalling that exposed corroded reinforcing steel occurred only at locations where it appeared that supplemental (not indicated in the plans) wire-mesh reinforcement had been installed with insufficient clear cover.

The visual survey of the interior of the box girders revealed diagonal cracking at the diaphragms in the pier segments, web cracking reflecting the cracks on the exterior face of the webs, and some evidence of moisture intrusion at the deck anchorages. An important observation was that no segment joint had any evidence of leaking.

The PT tendon survey indicated that the PT system was generally in very good condition. Very few grout voids were detected, and the strands that were uncovered in the deck or box web ducts were in like-new condition. There was some evidence of regrouting, likely to fill voids left during initial grouting. No evidence of PT system distress was observed, except for moderate corrosion of the end anchors where the pourback concrete failed to protect them from the corrosive environment. No distress was observed to be associated with the moisture intrusion at the deck anchorages. It was apparent that great care had been taken during construction to ensure the ducts were fully grouted.

Chloride ingress was evaluated at several locations on the bridge: top of deck, underside of wings, inside and outside webs, and the bottom slab. Chloride concentrations for all cored locations were well below the corrosion threshold at the level of the reinforcing steel. Clear cover of the main reinforcing steel was uniform across the box sections with little variation, except for the previously mentioned supplemental steel and isolated miscellaneous steel pieces left in the forms.

Conclusion

The condition data and the clear cover measurements were used to develop an in-house service-life model, which indicated that the structure could easily attain a 25-year service-life extension with the following treatments:

- Replacement of the asphalt overlays using a waterproofing membrane or with a polyester polymer concrete overlay
- Spot repairs to the isolated corrosion spalling
- Addition of a water-repellant coating to the exposed box-girder surfaces
- Replacement of the pourbacks at the end tendon anchorages
- Possible addition of a cathodic protection system to the substructure

The JFK Causeway Segmental Bridge is in overall good condition considering its marine-exposure environment and the lack of corrosion-mitigating features included in its original design. There were minor occurrences of corrosion, which were mainly related to initial construction defects, but the PT system was in like-new condition.

References

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