Dallas Area Rapid Transit’s (DART’s) Irving 1 and Irving 2 segments of the 14-mile Orange Line will extend from Bachman Station in northwest Dallas (on the Green Line) to Belt Line Road at the southern portion of Dallas-Fort Worth International Airport. This will complete 90 miles of DART’s rail network by 2014. The 9.3-mile segment includes six stations and eight bridges; one of them is a 7000-ft-long structure over the Trinity River.

The project had its challenges, specifically the design and construction of the Trinity River levee crossing, a three-span, post-tensioned, spliced, precast concrete girder structure. The alignment is vertically constrained by adjacent overhead power lines and a U.S. Army Corps of Engineers (USACE) levee below. These limitations required a structure capable of spanning 260 ft without any temporary supports or placement of heavy equipment on the levee. Through an integrated approach, the design-build team developed a constructable and economical solution.

**Alternatives Considered**

The completed dual-track structure is a three-span, continuous unit with span lengths of 145, 260, and 145 ft. Each of the six girder lines comprises five girder segments. Girder segments B and D are balanced over the central piers and are stabilized with a temporary support tower beneath the end spans, as shown in the girder layout. The remaining girder segments—A, C, and E—are supported using overhead steel, strong-back beams. The construction sequence, developed in concert with the contractor, during design, ensured that the levee remained undisturbed during construction.

**Critical Design Aspects**

Because of the tight project schedule and the need to begin construction activities as soon as possible, it was critical for the design of the foundations to be completed before the superstructure design. The foundation for all piers consisted of a single, 108-in.-diameter drilled shaft below each column. This foundation design was rapidly constructed and cost effective. The foundations and substructure were designed, approved by the owner and the USACE, and then constructed well in advance of the girder erection.

Although precast concrete girders are used extensively in Texas, the deepest of the Texas Department of Transportation standard girders was 70 in., which would not be sufficient for the selected structural configuration. The 70-in.-deep standard girder was modified by increasing the web depth by 12 in. and the web thickness from 7 to 8 in. This newly created girder is designated the TX82.

The increased web thickness was used to help with shear capacity and, more importantly, to accommodate the longitudinal post-tensioning tendons located within the web. This girder section is used for segments A, C, and E. The middle segment of the levy span is 160 ft long, and at the time of construction, was the longest precast concrete girder ever erected in Texas. For girder segments B and D, located over the main piers, the standard girders were once more modified by utilizing a variable depth that increased the maximum depth by an additional 4 ft, resulting in a 10 ft 10 in. total girder section depth at the pier.

The transportation, construction, and final configuration of the segments posed a challenge for the prestressing design, requiring a combination of pretensioning and post-tensioning, as well as temporary prestressing. A number of different support methods were used during transportation and erection, requiring a delicate balance of stresses for each of the configurations. Standard (7-wire) precast concrete girder pretensioning...
strand was used in all the prismatic girder segments, providing the compression needed for the handling of the segments before splicing the segments together.

For the variable-depth segments over the piers, permanent post-tensioning was used at the top of the section for the negative moments. This avoided the need to provide pretensioning at the level of the top flange. A single, temporary tendon was required in the bottom of the pier segments to handle positive moments during storage and transport when the support points were located close to the ends of the girders. Similarly, external temporary prestressing was used for C segments to mitigate the negative bending, at the ends, during transport and lifting.

Other critical design aspects requiring close coordination between the design-build team and construction groups included the following:

- Determination of the maximum size of the girder segments
- Location of cranes for critical girder lifts
- Location of the temporary support frames
- Location of the splice points

The construction sequencing, the location of temporary supports, and the location of the girder splice points were an integral part of the analysis model. The layout of the girder segments and the location for the temporary support tower at the side-span end of the variable-depth, pier girder segment required the tower to resist a significant amount of uplift prior to the completion of the girder splicing and post-tensioning.

Tie-down bars from the girders to the top of the tower frame, allowed the uplift to transfer through the steel frame to the large concrete spread footing. The footing distributed the compression loads in the tower from segments A and E before the drop-in segment C was set. After setting segment C, the footing’s weight was used as a deadman to resist the uplift.

Construction of Segment C

Of the five girder segments slated for erection, segment C proved the most challenging. With a girder length slightly longer than 160 ft and weighing more than 214,000 lb, its erection was further complicated by the proximity to underground utilities. Specifically, a 48-in.-diameter water main and 4-in.-diameter, high-pressure gas line, combined with very limited working space.

The first challenge was identifying a crane that could safely make the single-point lift and offer the smallest footprint and ground-bearing pressure.

The selected crane, a CC9600 750-ton Versa Crane, met the performance and small footprint requirements, but concerns about its bearing-pressure and impacts to underground utilities at
full load required evaluation. The crane would exert a total force of 1.6 million pounds. Compromising the water main would be catastrophic, shutting down water service to large portions of the cities of Dallas and Irving, Tex. The design of the crane pad went through extensive analysis and peer review to ensure the crane would not overload the underground utilities. Further complicating the girder segment lifting operation was the proximity of the 345-kV overhead transmission lines.

The contractor developed a lift plan for the safe rigging and execution of the segment C girders and positioned the crane on-site a week prior to the scheduled set date. The weight and quantity of the individual crane components, combined with the transportation requirements, required 68 truckloads to haul all of the lifting components to the construction site. The transportation and assembly of the crane took five days and a separate 240-ton support crane.

When the crane was fully assembled and readied, the segment C girders were loaded and hauled to the jobsite. Two trucks were modified to transport the girders; meaning only two girders could be delivered every other day. Two, however, would prove challenging enough to get into position, rig, and set within the allotted traffic-closure time frame. All deliveries of the segment C girders followed the same route to the site, with an against-normal, traffic-flow pattern.

The strong-backs rested on the ends of segments B and D girders. The high risk of the pick, given the proximity to the overhead transmission lines, warranted many precautions. Air tuggers, mounted on the crane counterweights and cabled to each end of the girder segment enhanced girder control and placement.

Once each segment-C girder was set into place (so that the strong-backs were supported from segments B and D), the crew installed the tie-down rods and applied the required torque to each rod. After the rods were torqued and independently verified by the design team, segment C was released from the crane.

Once all the C segments were set in place, they were then connected to segments B and D with cast-in-place (CIP) concrete closures. Post-tensioning of the girder segments began after all CIP closures and diaphragms were constructed, curing was completed, and concrete strength achieved. More than 40 miles of post-tensioning strand were installed in the project, and a standard CIP reinforced concrete deck slab completed the structure.

The Value of Integration

The DART Orange Line project had many key aspects, but none more significant than the design and construction of the Trinity River levee crossing. The difficult horizontal and vertical clearance restrictions due to the levee and the overhead power lines, the limited access available for large girders, and the need to get the structure completed early to allow for rail installation made this bridge a challenging design task and critical to the overall success of the project. Construction also posed many challenges, including site access, night work requirements, a massive crane resting on utilities, and a variety of temporary works. Successfully meeting all of the design and construction challenges required an innovative design and construction approach, effectively integrated through the design-build team delivery process.

Thomas W. Stelmack is principal project manager, Parsons, Denver, Colo., and Jonathan Kempfer is DART Orange Line I-3 project director, Kiewit Infrastructure South Co., Dallas, Tex.

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