PROJECT

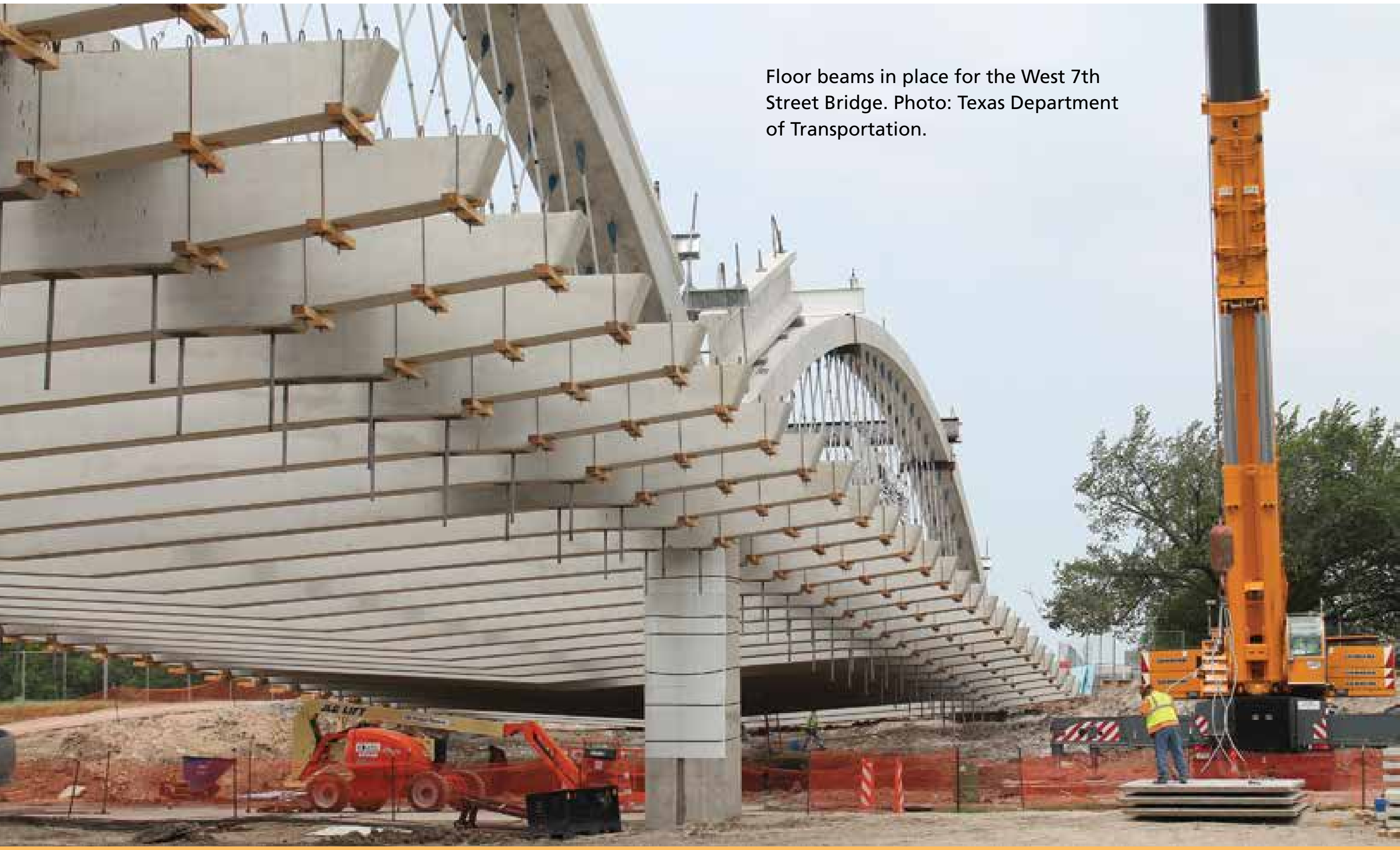
West 7th Street Bridge

Creating a new gateway in Fort Worth

by Dean Van Landuyt, Texas Department of Transportation

When the city leaders of Fort Worth determined that the existing West 7th Street Bridge connecting downtown to the cultural district could not be rehabilitated, they turned to the Texas Department of Transportation (TxDOT) for ideas. The route serves as a gateway to museums designed by such luminaries as Phillip Johnson, Louis Kahn, Tado Ando, and Renzo Piano. Increased development and pedestrian traffic mandated that in addition to carrying four lanes of traffic, two 10-ft-wide sidewalks be added for an overall width of 88 ft. Adding to the challenge was the requirement that the bridge be out of service for no more than 150 days and the cost be kept to approximately \$200/ft^2.

The selected superstructure consists of precast, post-tensioned concrete arches; precast, pretensioned concrete floor beams; precast, pretensioned



Floor beams in place for the West 7th Street Bridge. Photo: Texas Department of Transportation.

profile

WEST 7TH STREET BRIDGE / FORT WORTH, TEXAS

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

GENERAL CONTRACTOR: Sundt Construction Inc., San Antonio, Tex.

CONSTRUCTION ENGINEER: Infinity Engineering USA Inc., Tampa, Fla.

PRECASTER: Heldenfels Enterprises Inc., San Marcos, Tex., a PCI-certified producer

READY-MIX CONCRETE SUPPLIER: TXI Inc., Fort Worth, Tex.

POST-TENSIONING CONTRACTOR: VSL Structural Inc., Hanover, Md.

concrete deck panels; and a cast-in-place concrete deck.

Precast Arches

Precast concrete girder bridges currently account for 95% of the newly constructed spans in Texas. TxDOT engineers thought it possible to design what is believed to be the world's first precast concrete network tied-arch bridge that could be cast off site and assembled quickly. It would be important to utilize as many of the existing precast concrete girder bridge ideas as possible, namely pretensioned concrete floor beams and precast, stay-in-place concrete deck panels, but the real key was developing a buildable precast concrete arch.

Through arches, rather than deck arches, were selected for clearance over the Trinity River, a park, and a city street, as the six spans would create a rhythmic, processional approach for motorists as they traveled between the two districts. Two planes of tightly spaced diagonal hangers would create a psychological barrier for pedestrians and act as diffusers for a series of light fixtures embedded between them.

The 4-ft 9¾-in. hanger spacing allowed each floor beam to be supported by four hangers, but most importantly, eliminated the need for longitudinal stringers; a standard 8½-in.-thick deck could easily span the 9 ft 7½ in. distance between beams. The tight weave also lowered the force on each hanger and reduced the flexural stresses in both the rib and tie so they could be lighter and a pedestrian-friendly scale could be maintained. Stainless steel was chosen for the hangers because of its clean and tactile quality, reflective properties, low maintenance, and ability to be cast partially into concrete without fear of corrosion.

The obvious challenge was to determine how to economically precast and transport a 163.5-ft-long, 280-ton concrete arch. Solutions began to appear after recognizing that casting an arch on its side is simpler than casting it upright and that contractors are becoming more comfortable undertaking heavy, unusual lifts. Every attempt was made to make the elements as slender as possible to minimize weight. Furthermore, the span-to-rise ratio was set at only 0.13 to keep the center of gravity very low and to minimize stability problems on the four-block route from the casting yard to the bridge site. The shallow 23.5 ft height at the crown also made rotating the arches less difficult.

Because nearly all the elements are precast, precision casting was essential, especially for the arch and floor beams. Making all the spans the same length and managing roadway vertical curve geometry demands with adjustable floor beam plinths made the concept possible—all 12 arches could be identical. One of the largest obstacles to overcome was ensuring that the diagonal hangers were able to pass cleanly through steel tubes cast into the tie at a 55-degree angle. The tube lengths ranged from 2.1 to 4.3 ft making their location and orientation critical if the 1¾-in.-diameter hangers were to connect from the tie beam

The arches were erected on both sides of the existing bridge to minimize closure times. Photo: Texas Department of Transportation.

Transporting the arch on the existing bridge. Photo: Texas Department of Transportation.

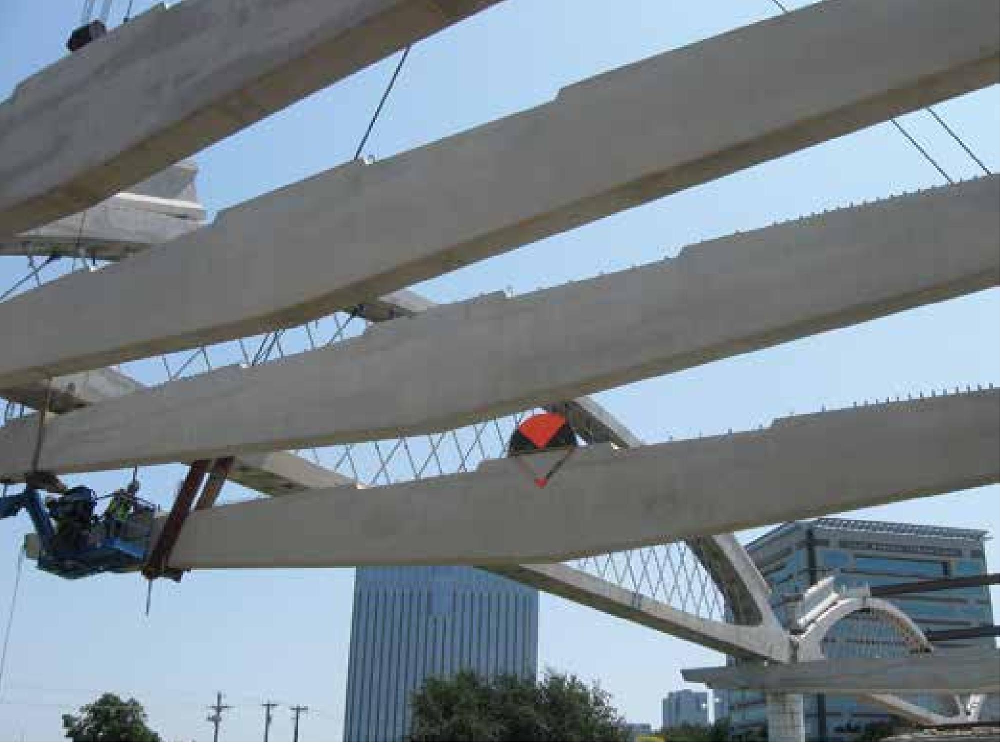
CITY OF FORT WORTH, OWNER

OTHER SUPPLIERS: Stainless steel fabrication: GST Manufacturing, Haltom City, Tex.; arch rotating and transport: Burkhalter Rigging Inc., Columbus, Miss.; arch and column forms: Aluma Systems Inc., Toronto, Ontario, Canada; floor beam forms: Hamilton Form Company, Fort Worth, Tex.; bearings: RJ Watson Inc., Alden, N.Y.

BRIDGE DESCRIPTION: A six-span, 981-ft-long bridge with precast concrete arches, precast concrete floor beams, precast concrete, stay-in-place deck panels, and a cast-in-place concrete deck

STRUCTURAL COMPONENTS: Twelve 4-ft-6-in.-wide arches, one-hundred and two 86-ft 4-in.-long floor beams, 4- and 6-in.-thick precast concrete deck panels with a nominal 4½-in.-thick cast-in-place concrete deck, 7-ft-3-in. by 5-ft-6-in. oval columns, and 7-ft-diameter drilled shafts

BRIDGE CONSTRUCTION COST: \$209/ft^2



Floor beam setting. Photo: Texas Department of Transportation.

to link plates cast in the rib as much as 25 ft away. Another challenge was ensuring that 1¾-in.-diameter, post-tensioning rods that would connect the floor beams to the arch could pass through galvanized-steel tubes.

TxDOT bridge designers were well-aware that cracking the arch was a real possibility during handling and, if it occurred, would lower the rib-buckling limit. As a result, two 19-strand, 0.62-in.-diameter-strand tendons were added to the rib and four 19-strand, 0.62-in.-diameter-strand tendons were added to the tie. The contractor used a specially designed lifting tower with multiple spreader beams to distribute the lifting forces. Vibrating wire gages installed by researchers at The University Texas at Austin confirmed that stress levels have so far been in reasonable agreement with design calculations and the few areas that were in tension were well below the modulus of rupture. The arches were moved by self-propelled modular transporters and used the narrow existing bridge as a haul road.

Another major design challenge centered on the fact that the arches would be set end-to-end with only a 4-in. gap, thereby leaving no opportunity for field post-tensioning. As a result, 100% of the longitudinal tie post-tensioning (3666 kips total stressing force) needed to be installed while the arches were still in the casting yard. Because the arch self-weight generated less than 25% of the axial service tension in the tie, the slender element experiences tremendously high compression forces prior to placing floor beams and other subsequent gravity loads. In order to reduce the unbraced length and prevent any lateral movement of the 2 by 4.5 ft tie during stressing, a series of small curves were added to the ducts causing regular contact with the tendons.

For speed, cost, and appearance, no rib cross-bracing was used. Fortunately, the 4.5-ft width required in the tie and knuckle to accommodate all the embedded elements proved sufficient; a three-dimensional non-linear buckling model, that included the hangers, floor beams, and deck, verified the stability of uncracked, unbraced ribs.

Floor Beams

Designers chose to use pretensioned concrete floor beams for their quick installation, durability, cost, low-maintenance, and aesthetics. The floor beams have a constant width of 1 ft 4 in., a nominal depth of 5 ft 6 in. at midspan, and a minimum depth of 3 ft at the arch with a taper down to 1 ft 9 in. at the end of the cantilever. Two different strand layouts were used: thirty-two ½-in.-diameter strands in the first two and last two beams in the span and twenty-four ½-in.-diameter strands in the interior 13 floor beams.

The connection of the floor beam to the arch is a critical component of the bridge as it needs to carry both tension and moment, reconcile two non-match-cast concrete surfaces at each end of the floor beam, and prevent the intrusion of water. The solution was to cast two rectangular steel-tube sleeves into the beam 3 ft 2 in. apart. Companion rectangular tubes were cast into the arch tie and knuckle at the same spacing but rotated 90 degrees about the longitudinal tube axis. This allowed for the largest possible range of misalignments that will house a 1¾-in. diameter, post-tensioning bar.

Workers install the precast concrete deck panels on the West 7th Street Bridge. Photo: Texas Department of Transportation.

To account for non-planar surfaces, an approximately ½-in.-tall bed of epoxy grout was placed on top of the floor beam plinths located underneath both arches. The floor beams were then raised up until contact with the arch was made all around the 1-ft 4-in. by 4-ft 2-in. bed of epoxy grout. After the grout reached a compressive strength of 4 ksi, the two post-tensioning bars at each arch were stressed to 105 ksi and the steel tubes grouted.

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EDITOR'S NOTE

Strand with a diameter of 0.62 in. per ASTM A416 is now available on a limited basis and engineers should contact their local strand suppliers in the project area to determine hardware and strand availability.