1 Perfect segue

Crews work to piece together successful segmental bridge

Kanawha River Bridge
Kanawha County, W.Va.
Cost: $83 million
Length: 2,975 feet
Designer: T.Y. Lin International
Contractor: Brayman Construction Corp.
Owner: WVDOT

The completion of the closure segment of the 760-ft Kanawha River Bridge main span, a record segmental span over the Kanawha River between Dunbar and South Charleston, W.Va., was celebrated by the local community as a milestone in the widening of a 4.3-mile section of I-64 in Kanawha County.

T.Y. Lin International's bridge designers, working with the WVDOT Division of Highways (DOH), met the challenge of crafting a low-cost, durable and aesthetically pleasing structure that would alleviate traffic congestion for commuters in the Charleston area. The resulting eight-span segmental bridge now under construction is the first long-span segmental-box-girder structure built using the balanced cantilever method in West Virginia.

Boxing it up

The existing I-64 bridge over the Kanawha River between Dunbar and South Charleston is a steel-plate-girder structure with a 440-ft-long main span built in 1974 to carry four lanes of traffic. Preliminary highway design studies evaluated several alternatives for increasing the capacity of the existing Kanawha River Bridge, including widening the existing bridge, complete bridge replacement and the construction of a new eastbound bridge. The selected alternative was the construction of a new eastbound structure on an improved nonparallel alignment carrying three travel lanes and one auxiliary lane. This alignment has flatter and more gradual curves at each end of the Kanawha River crossing that will increase drivers' sight distances and therefore improve safety on this portion of I-64. The existing bridge will remain in place to carry four westbound lanes after undergoing repairs.

The bridge types evaluated for the new eastbound structure included a segmental-concrete-box girder, steel tied arch, steel-box girder, concrete cable-stayed bridge and a steel truss. The segmental-concrete-box girder and steel-arch alternatives were selected for the type, size and location study that recommended the segmental-concrete-box girder bridge for final design. This selection was based on the evaluation of construction costs, maintenance requirements, aesthetics and constructability. A continuous concrete-box-girder superstructure, designed to be built by balanced cantilever construction, was chosen for the full length of the bridge, including the approach spans and the river crossing, so that the same construction methods and equipment could be used for the entire structure. This design allowed for longer approach spans, which reduced the bridge's environmental and economic impacts and the right-of-way cost. The balanced cantilever construction method avoids the need for falsework or any other temporary supports that might hinder navigation during construction and also helps to limit disruptions to areas underneath the structure. The use of low-permeability concrete and a transversely post-tensioned deck will result in a highly durable structure.

Given the size and urban setting of the project, bridge aesthetics was an important design

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consideration. The bridge concept was developed to be compatible with both the existing steel-plate-girder bridge and a future twin parallel westbound bridge that will be built once the existing bridge is no longer serviceable.

Longest around

With a total length of 2,975 ft, the new Kanawha River Bridge spans a railroad track operated by Norfolk Southern, Dunbar Avenue, the Kanawha River back channel, Wilson Island, the Kanawha River main channel, Riverside Drive and MacCorkle Avenue. A 760-ft-long main span—the longest concrete-box-girder span in the U.S.—resulted from the need to locate the main piers outside the main channel of the Kanawha River in order to avoid interference with barge traffic. The eight-span structure has span lengths of 144.5, 247, 295, 295, 460, 760, 540 and 209.5 ft for a total length between centerlines of abutment bearings of 2,951 ft. The bridge has an S-curve alignment including two circular curves with 1,910-ft radii, spiral transitions and a tangent alignment at the river span.

The bridge cross section accommodates three travel lanes, one auxiliary lane and shoulders for a total roadway width of 64 ft. The cross section of the superstructure consists of a single cell box with inclined webs. The structural depth varies along the main span from 38 ft at the piers to 16 ft at mid-span. The bottom slab thickness is variable with a maximum thickness of 5 ft at the main span piers and a minimum of 9 in. at mid-span. The approach spans have a 16-ft constant depth.

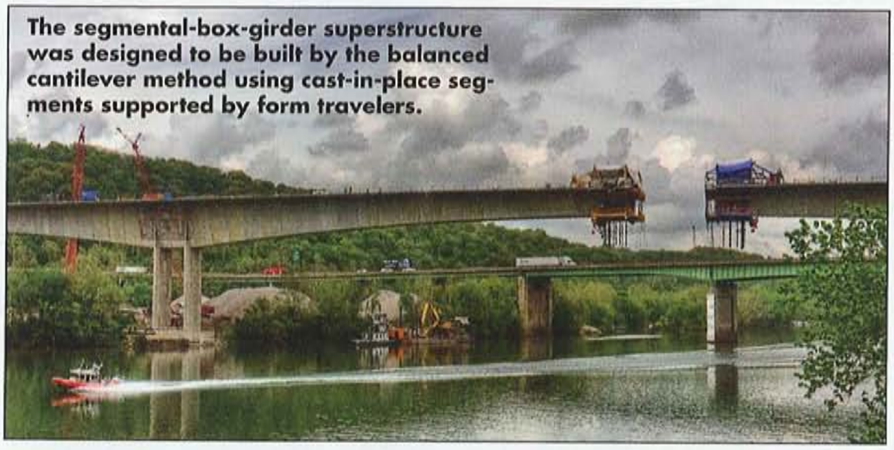
The top slab has constant dimensions for the full length of the bridge. Its thickness varies transversely from a minimum of 9 in. to a maximum of 2 ft at the intersection with the webs. The maximum 2 ft depth of the top slab is required to accommodate the cantilever tendons needed for the main span. The box-girder cross section has variable superelevation from plus to minus 8%. The specified concrete compressive strength was 6,500 psi at 28 days.

The concrete-box section is post-tensioned longitudinally, transversely and vertically. The longitudinal post-tensioning consists of two sets of tendons. The cantilever tendons, located in the top slab, are stressed during cantilever construction shortly after a new segment is added. The span tendons, located in the bottom slab, are used in the central part of the spans to provide continuity between adjacent cantilevers. Transverse post-tensioning is utilized in the top slab and in the diaphragms of pier tables. Vertical post-tensioning consisting of high-strength 1³/₈-in.-diam. bars is used in the webs.

The continuous box girder has expansion joints at the abutments only, in spite of the considerable 2,975-ft bridge length. The advantages of this design approach are to reduce maintenance, improve serviceability and simplify construction, as intermediate hinges are not needed. The superstructure is fixed at the main piers and is supported on unidirectional bearings at the approach piers and abutments. The bearings restrain the transverse displacements while allowing longitudinal displacements. Two high-capacity disk bearings are provided at each pier with vertical service capacities of up to 3,450 tons. A large modular expansion joint with a displacement capacity of 30 in. accommodates displacements caused by temperature, creep and shrinkage at the west abutment. The east abutment requires a joint with a 16-in. displacement capacity.

The segmental-box-girder superstructure was designed to be built by the balanced cantilever method using cast-in-place segments supported by form travelers with a total of 167 cast-in-place segments. Falsework was only required to cast the pier tables and the end segments near the abutments.

The main-span piers—piers 5 and 6—consist of twin concrete walls that frame into the superstructure. The twin-pier walls provide the necessary strength and stiffness during cantilever construction and, at the same time, are longitudinally flexible to accommodate superstructure deformations caused by creep, shrinkage and temperature changes. The approach piers—piers 1, 2, 3, 4 and 7—have a rectangular section with 45° chamfers.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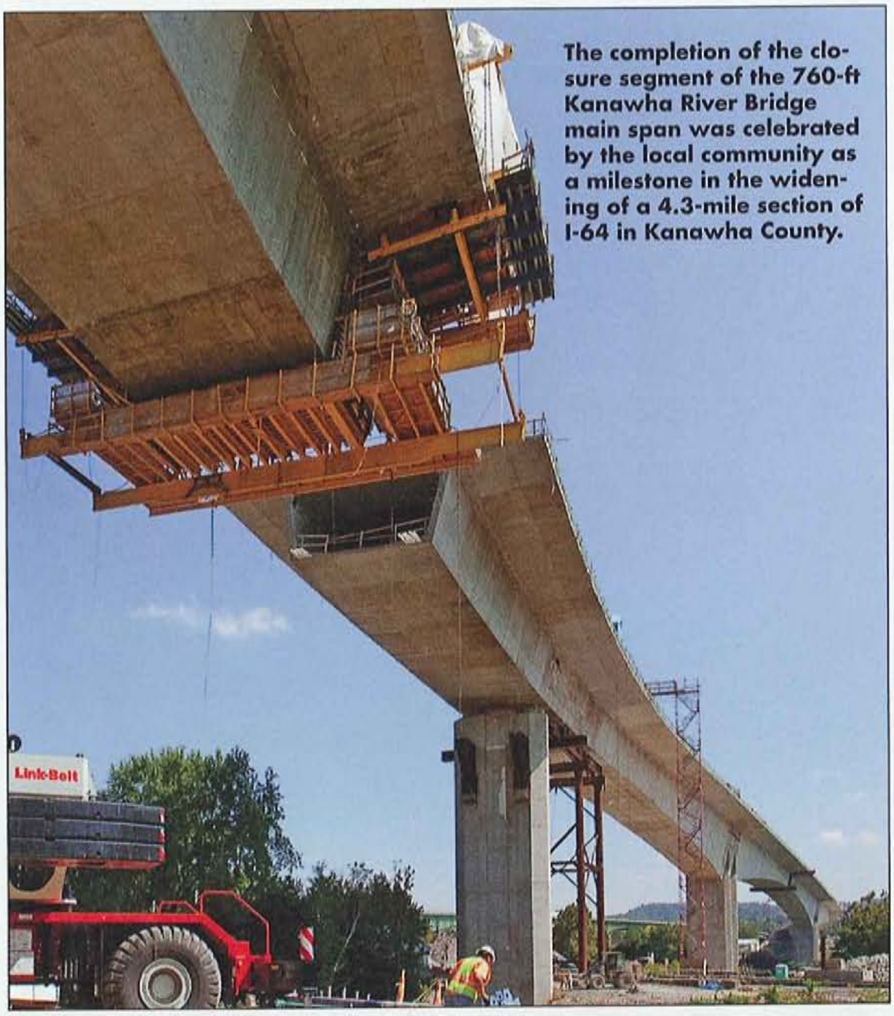
The foundations consist of reinforced-concrete footings and concrete drilled shafts socketed in the underlying hard sandstone. The average length of drilled shafts is about 60 ft. Two preconstruction drilled-shaft load tests, using the Osterberg method, were performed prior to final design. These tests verified the ultimate end-bearing and side-shear capacity.



The completion of the closure segment of the 760-ft Kanawha River Bridge main span was celebrated by the local community as a milestone in the widening of a 4.3-mile section of I-64 in Kanawha County.

The proposed segmental-box-girder bridge is a harmonious design with simple and consistent forms and the same basic cross section between abutments. The selected cross section, with long overhangs and inclined webs, results in a light appearance. The shadow created by the overhang reduces the perceived superstructure depth. The curved approach spans give a sense of openness and continuity with the graceful main span. The edges of the main-span piers embrace the webs of the superstructure, thus subdividing the box-girder depth. The piers have a modified rectangular section, with 45° chamfers, which reduce the perceived width of the columns in skewed views. A textured architectural treatment is used in the transverse faces of all piers and abutments. An applied concrete finish will be used on the surfaces of the substructure and superstructure elements.

With some modifications

The WVDOT used competitive bidding of the concrete bridge alternative versus a steel bridge alternative developed by another consultant to determine the most economical solution. The low-cost alternative was the concrete segmental design. The $83 million low bid from Brayman Construction Corp. for the concrete alternative saved the WVDOT $30 million compared to the low bid for the steel alternative. Excluding cost of tie-in roadway work and MSE walls, the bid price of the segmental-concrete-box girder bridge was $75 million, or an average cost of $379 per square foot. Ground breaking took place on May 23, 2007. During the construction phase T.Y. Lin International provided construction support services to the DOH. The DOH was responsible for construction inspection.

After the contract was awarded, the contractor presented a value-engineering proposal including the following modifications to the substructure:

- Some of the footings were raised above the water table so that they could be built in the dry, resulting in partially exposed footings. This modification eliminated the need for close-cell cofferdams and tremie seal concrete and allowed for the use of open-cell cofferdams;
- Use of 6-ft-diam. drilled shafts for pier foundations. The original design had 6-ft-diam. shafts for the approach piers and 7-ft-diam. shafts for the main piers; and
- Replace the hollow approach piers of the original design with solid piers.

The contractor also proposed two minor modifications to the superstructure as part of the shop drawings review process:

- Construction of four east pier 4 segments on falsework instead of using cantilever construction on form travelers; and
- Accommodate the superelevation by rotating the superstructure cross section as a rigid body.

The drilled shafts socketed in rock were built with special attention to bottom cleanliness because of the high end-bearing design capacity (400 tsf). The cleanliness of the rock socket was inspected with mini SID devices. Concrete was placed using the tremie method. Steel casings, used to support the excavation through soil, were extracted after completion of the concrete placement. The quality of concrete in the drilled shafts was verified by use of CSL testing.

The main-pier footings had 1,200 cu yd of concrete that was placed in 12 hours using two concrete pumps. The concrete in this mass-concrete pour was cooled with internal pipes using water from the Kanawha River. The temperature control for the piers was based on placement of low-temperature concrete in the summer time to reduce the maximum concrete temperature. Insulated forms were used to keep the temperature differentials within the allowable.

Superstructure construction began with the approach pier tables built on falsework with temporary supports. After the pier tables were completed the form travelers were erected for construction of cast-in-place segments using the balanced cantilever method of construction. Segment construction continued during the winter although some concrete pours made during winter months required external heat application. Post-tensioning operations were carried out after achieving a minimum concrete strength of 4,000 psi estimated with concrete maturity curves. This concrete strength was typically achieved in less than 48 hours. Post-tensioning strands were installed in the ducts with hydraulic strand pushers, and for the longer tendons by pulling preassembled (bundled by brazing) strands into ducts. The longest cantilever tendons at the main-pier cantilevers are 760 ft in length and had elongations during stressing of approximately 60 in.

The main-span closure segment was cast after connecting the adjacent cantilevers with strongback-steel girders designed to limit the relative displacements across the closure. Jacking of the main span prior to the final closure pour was required in order to compensate for superstructure displacements due to temperature changes and to concrete creep and shrinkage. The target displacement for jacking at an average 78° concrete temperature at the time of closure was 3⅞ in. This displacement was achieved with a total jacking force of 1,130 tons applied with four jacks.

The contractor is currently working on two approach-span cantilevers (piers 2 and 3). These spans are being constructed using the balanced cantilever method with form travelers and cast-in-place segments. Construction crews also are working on the east-end segment and the east abutment. Segmental bridge construction is expected to be completed before the end of 2009. Thereafter, the contractor will build the parapets, overlay and expansion joints. The contractor will then apply the bridge coating and complete the roadway. The contract completion date is October 2010. When construction is completed, this elegant and distinct design that blends into its surroundings and adheres to a limited budget will alleviate traffic congestion for commuters in the Charleston area. R&B

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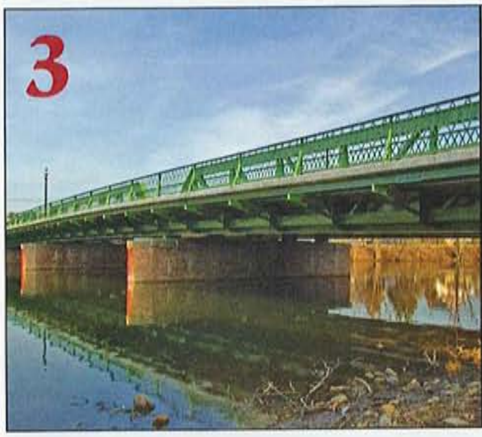
I-76 Allegheny River Bridge, Oakmont, Pa.

Cost: $189 million
Length: 2,350 feet
Designer: FIGG
Contractor: The Walsh Group
Owner: Pennsylvania Turnpike Commission

With the famed Oakmont Country Club serving as a backdrop, the I-76 Allegheny River Bridge is a monster drive for thousands of motorists each day. The span's 532-ft main span is the longest concrete-segmental span in Pennsylvania. The record length allowed the piers to be located where they would make the least amount of impact to ecological habitats and archeological areas.



Hillery St. Bridge, Passaic County, N.J.

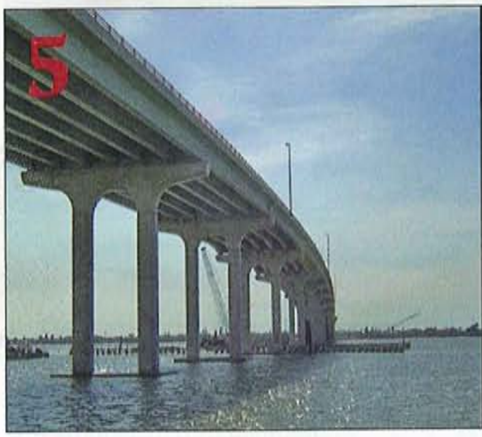
Cost: $11 million
Length: 400 feet
Designer: Parsons Brinckerhoff
Contractor: Rosangela Contracting Co. Inc.
Owner: Passaic County, N.J.

Meddling with a 110-year-old calls for a sensitive touch. The new Hillery Street Bridge carries some components of the original structure, which was built in 1898. The original bridge trusses were reused on three of the four spans. Significant beam camber was required, which caused the steel fabricator to account for the camber in the beam and deflection of the fascia beam to ensure an exact fit.

Cherry Valley Interchange, Cherry Valley, Ill.

Cost: $89 million
Length: over 11,000 feet
Designer: Hanson Professional Services Inc., Teng Associates Inc., McClure Engineering Associates Inc. and the Reinforced Earth Co.
Contractor: William Charles Construction Co., Rock Road Cos. Inc. and Civil Constructors Inc.
Owner: Illinois Tollway

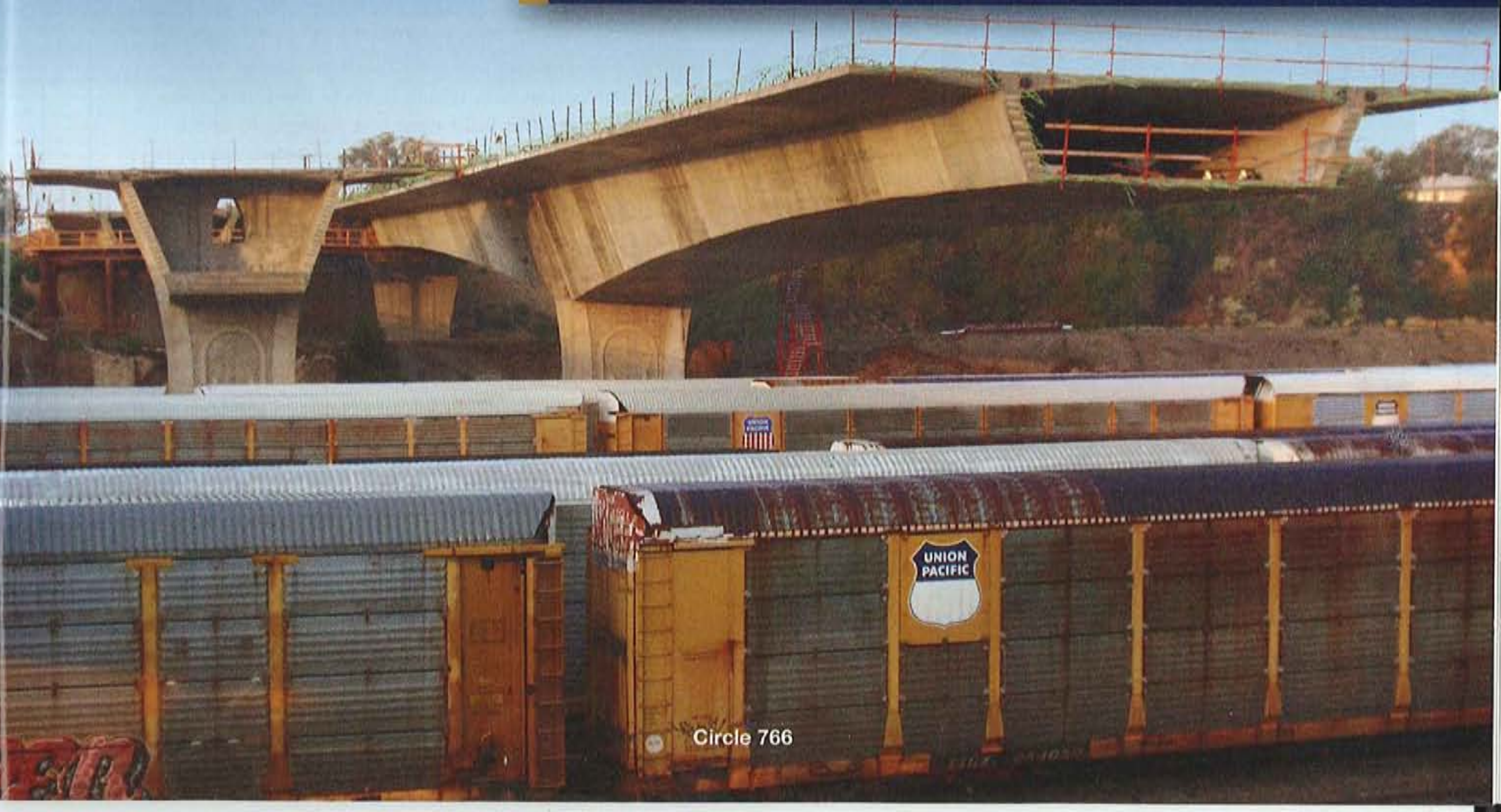
A tight loop brought everyone together in the wrong way. The prime trouble spot on the Cherry Valley Interchange needed to be revised, because it was causing daily congestion at a key spot for commerce on the move. The most significant improvement is the new two-lane flyover ramp bridge built over eastbound I-90 from northbound I-39 to westbound I-90.



Belleair Beach Causeway, Belleair Beach, Fla.

Cost: $72,219,244
Length: 3,350 feet
Designer: HDR Inc.
Contractor: Johnson Bros. Contractors Inc., Misener Marine Inc.
Owner: Pinellas County, Fla.

It is not often one reaches the level of NASA, but those involved in the Belleair Beach Causeway came close following a successful launch. This job involved the use of an incremental launching system for the construction of two 660-ft-long reinforced concrete post-tensioned flat slab portions of the 3,350-ft-long superstructure. Crews match-casted 37.5-ft sections of the superstructure and hydraulically launching the superstructure into position.



UNION PACIFIC

S.R. 46 over Lake Jesup, Seminole and Volusia counties, Fla.

Cost: $38 million
Length: 3,740 feet
Designer: Wilbur Smith Associates
Contractor: Johnson Bros. Misener Marine Design-Build
Owner: Florida DOT, District 5

When it comes to demolition, why stop at a deteriorating bridge? The S.R. 46 Bridge Replacement over Lake Jesup involves removing the existing bridge plus an existing causeway in an environmentally sensitive area. The removal also will eliminate the pollutant load currently draining from the roadway into Lake Jesup.

David Kreitzer Lake Hodges Bridge, San Diego

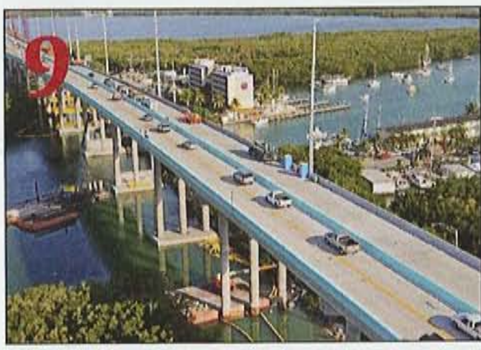
Cost: $8,686,541
Length: 1,000 feet
Designer: T.Y. Lin International
Contractor: Flatiron West
Owner: San Dieguito River Park Joint Powers Authority

Ribbons are meant to be pretty. The David Kreitzer Lake Hodges Bicycle Pedestrian Bridge is one of just a handful of stress-ribbon bridges in North America. The structure uses a 16-in.-thick concrete deck to span 330 feet between supports for a depth-to-span ratio of 1:248. The bridge is a cable-supported bridge with the bearing cables embedded within its concrete deck.

4th Street Bridge, Pueblo, Colo.

Cost: $27.6 million
Length: 1,137 feet
Designer: FIGG
Contractor: Flatiron Intermountain
Owner: Colorado Department of Transportation

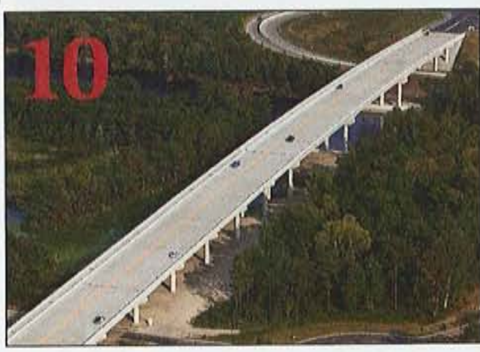
The new 4th Street Bridge will maintain a critical east-west link between residential neighborhoods and downtown. West of I-25, the 4th Street Bridge passes over the vast Pueblo Railroad Yard with 28 active railroad tracks and the Arkansas River. Twin, post-tensioned segmental box girders are being built from above in balanced cantilever to protect the river environment and keep rail and vehicular traffic moving during construction.



Jewfish Creek Bridge, Monroe County, Key Largo, Fla.

Cost: $147.8 million
Length: 7,500 feet
Designer: Jacobs Engineering Group
Contractor: Granite Construction
Owner: Florida DOT, District 6

No one wants to get under the skin of a crocodile. Crews working the Jewfish Creek Bridge construction site, which borders the Everglades National Park, built nine box culverts to allow crocodiles to pass under U.S. 1. Cranes set more than 450 beams at night to lessen disruption to traffic. The contractor also completed the bridge and opened the northbound lane to two-way traffic before hurricane season began in 2009.



Fantasy Harbour Bridge, Myrtle Beach, S.C.

Cost: $36 million
Length: 1,800 feet
Designer: STV/Ralph Whitehead Associates
Contractor: RR Dawson Bridge Co.
Owner: South Carolina Department of Transportation

At the time of design, the Fantasy Harbour Bridge was the longest spliced, post-tensioned concrete I-girder bridge in the U.S. behind a main span that was 330 ft long. Comprising 12 spans, the high-level bridge consists of a 76-ft-wide roadway and carries five lanes of traffic. A seismic analysis included a multimode spectral analysis and a push-over analysis.