ILLINOIS TOLLWAY

Illinois easily transitions from concrete bridge pioneer to state-of-the-art designs

by Paul Kovacs, Illinois Tollway

The Illinois Tollway pioneered the use of prestressed concrete bridge beams during construction of the state's original tollway system in the late 1950s. Concrete bridge beams—both standard and unique designs—continue to be preferred for the tollway's bridge structures. Across its 286-mile system of four interstates in Northern Illinois, the Illinois Tollway favors the durability and constructability of concrete bridges, as well as the engineering advances in the construction techniques for concrete bridges.

In 2007, the Illinois Tollway completed the 12.5-mile expansion of the Veterans Memorial Tollway (I-355) featuring the Des Plaines River Valley Bridge described in the Spring 2008 issue of *ASPIRE*™. This bridge spans 1.3 miles over the Des Plaines River, the Illinois and Michigan Canal, the Sanitary and Ship Canal, several railroad lines, and forest preserve land. This was the first bridge in the state of Illinois to use post-tensioned, precast, prestressed concrete bulb-tee girders.

In 2009, reconstruction of the Reagan Memorial Tollway (I-88) twin bridges over the Fox River was completed. Structural arch members of the twin bridges support a prestressed concrete beam superstructure to reflect the design of the original bridges built in 1958. See *ASPIRE* Summer 2009 for more details.

Today, the Illinois Tollway continues to lead the way with innovative concrete bridge designs as part of its 15-year, $12 billion capital program, Move Illinois: The Illinois Tollway Driving the Future. Move Illinois will:

- address the remaining needs of the existing tollway system,
- rebuild and widen the Jane Addams Memorial Tollway (I-90) as a state-of-the-art, twenty-first century corridor,
- construct a new interchange to connect the Tri-State Tollway (I-294) to I-57,
- build a new, all-electronic Elgin-O'Hare Western Access, and
- fund planning studies for the Illinois Route 53/120 project and the Illiana (Illinois-Indiana) Expressway.

Move Illinois will include the reconstruction of more than 70 mainline and crossroad bridges as part of the I-90 Rebuilding and Widening Project. The Elgin-O'Hare Western Access Project will provide more than 80 new and improved bridge structures. Shallow depth beams are being used on the Illinois Tollway for the first time, and U-shaped girders are being considered for accelerated construction of longer spans.

In addition, as part of Move Illinois, the Illinois Tollway is extending the expected service life of major bridges out to 100 years.

Traffic on the Des Plaines River Valley Bridge on the Veterans Memorial Tollway (I-355). Photo: Illinois Tollway.

Reconstruction of the Fox River Bridge on the Reagan Memorial Tollway (I-88) was completed in 2009. Photo: Henry G. Russell Inc.

This has prompted the Illinois Tollway to design several of the mainline bridges along the I-90 corridor with stainless steel reinforcement in the concrete bridge decks. This is expected to provide a long-term cost benefit.

Another long-term cost benefit is the incorporation of integral abutments in bridge designs. This design feature minimizes the bridge joints, which have shown to be the weakest link in the tollway's bridge performance chain.

The Illinois Tollway is also adopting the use of a performance-based deck concrete specification to reduce shrinkage cracking that often appears in bridge decks. The Illinois Tollway's approach is not to specify how the mixture proportions are to be developed, but to specify the end-result requirements for the plastic and hardened concrete.

Allowing concrete producers to evaluate the various tools available to reduce deck shrinkage will enable them to choose the approach that coincides with the construction contractors' activities. Options selected by local concrete producers to achieve the specification requirements have included shrinkage-reducing admixtures and lightweight fines to provide internal curing.

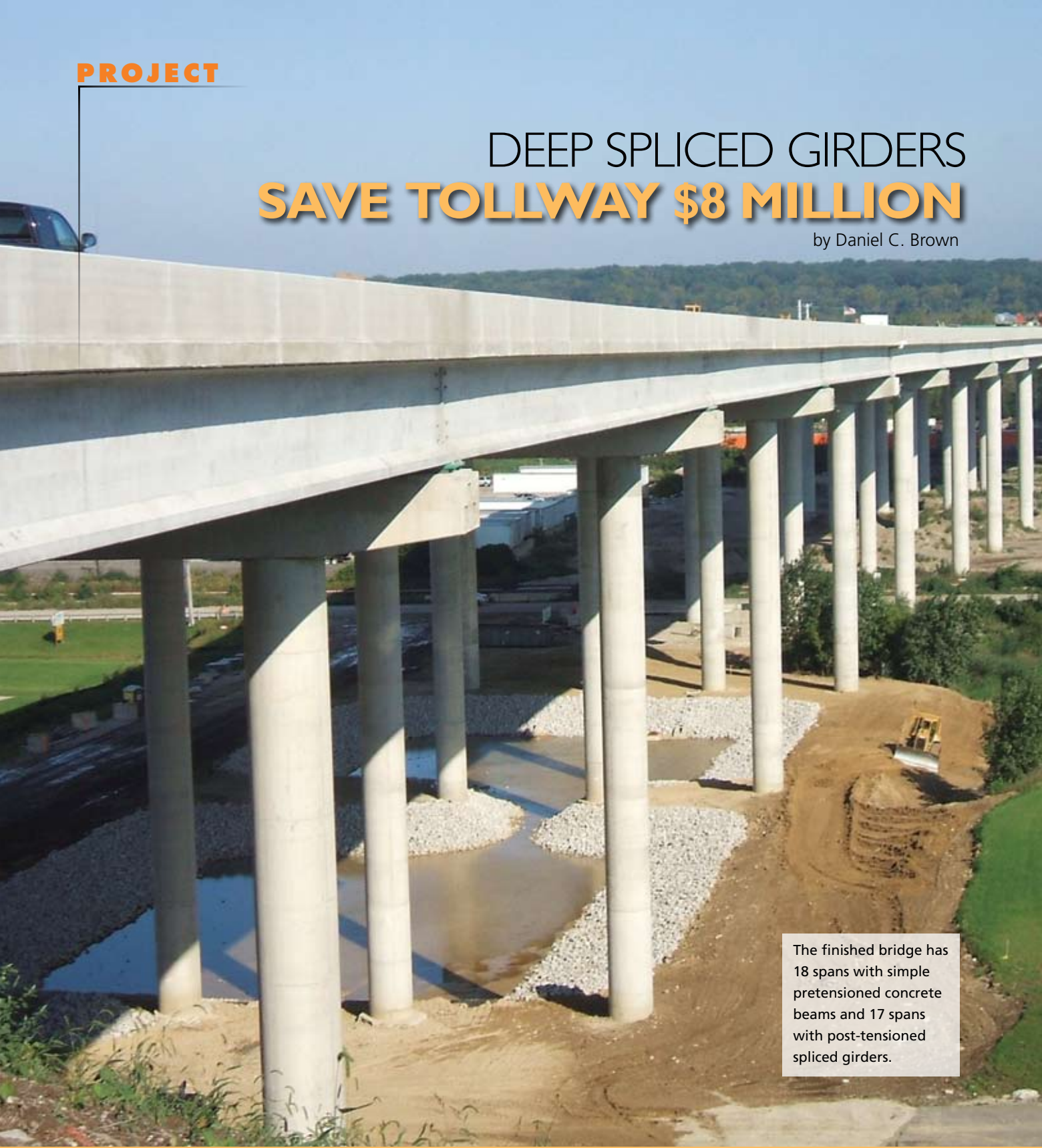
From its pioneering roots to the incorporation of state-of-the-art technology, the Illinois Tollway will continue to incorporate concrete bridges into its roadway infrastructure.

Paul Kovacs is chief engineer for the Illinois Tollway in Naperville, Ill.

PROJECT

DEEP SPLICED GIRDERS SAVE TOLLWAY $8 MILLION

by Daniel C. Brown



The finished bridge has 18 spans with simple pretensioned concrete beams and 17 spans with post-tensioned spliced girders.

profile

DES PLAINES RIVER VALLEY BRIDGE ON I-355 / LEMONT, ILLINOIS

ENGINEER: Janssen & Spaans Engineering Inc., Indianapolis, Ind.

DESIGN QUALITY ENGINEER: Bowman, Barrett & Associates, Chicago, Ill.

PRIME CONTRACTOR: Walsh Construction Group, Chicago, Ill.

PRECASTER: Prestress Engineering Corp., Prairie Grove, Ill., a PCI-Certified Producer

SECONDARY GIRDER PRECASTER: Prestress Services, Decatur, Ind., a PCI-Certified Producer

Offering a performance specification created benefits to entire construction team

The 1.3-mile-long Des Plaines River Valley Bridge has 34 piers and 35 spans, which range up to 270 ft long. All photos: Illinoise State Toll Highway Authority.

Bridges like this one don't come along very often. The 1.3-mile-long Des Plaines River Valley (DPRV) Bridge on I-355 near the Chicago suburb of Lemont, Illinois, is the state's first to use post-tensioned, precast, prestressed concrete spliced bulb-tee girders. Its success means that it also won't be the last.

Opened last November, the DPRV Bridge combines the use of post-tensioned spliced bulb-tee concrete girders and pretensioned concrete bulb-tee girders. The post-tensioned spliced girder span lengths range from 216 to 270 ft, while the pretensioned concrete girders have span lengths ranging from 114 to 170 ft.

Chicago-based Walsh Construction joined forces with Janssen & Spaans Engineering Inc. of Indianapolis, Indiana, to submit a $125-million, design-build proposal for the post-tensioned, spliced-girder design. The design represented the highest-priced bridge in Tollway history—but it still was the low bidder.

The winning proposal and the segmental concrete box-girder bridge alternate were both lower than the $175 million bid for a steel plate-girder structure.

Creating a performance specification cut costs, created flexibility, and saved 6 to 8 months.

Officials at the Illinois State Toll Highway Authority (Tollway) had originally designed the bridge in two other configurations: a steel plate-girder bridge and a segmental concrete box-girder structure. "Shortly before the project was advertised for bids, there was a lot of fluctuation in material prices, especially steel," says Paul Kovacs, Chief Engineer for the Tollway. "To address the fluctuations, the Tollway decided to include a performance-based bid specification that would allow contractors to propose their own design."

"Not only did the performance specification allow us to mitigate the price fluctuations and save money, it gave the contractor the flexibility to build what he was comfortable with, and saved us 6 to 8 months in design," says Colin Makin, the Tollway's Deputy Program Manager for Bridges.

Indeed, the Walsh-Janssen team was awarded the contract in December 2005, before design was complete. By

MULTI-SPAN PRECAST, PRESTRESSED CONCRETE I-BEAMS AND POST-TENSIONED SPLICED GIRDERS / ILLINOIS STATE TOLL HIGHWAY AUTHORITY, OWNER

POST-TENSIONING CONTRACTOR: Dywidag Systems International (DSI), Bolingbrook, Ill.

BRIDGE DESCRIPTION: A 1.3-mile-long bridge with 252 girders 90 in. deep; 300 girders 102 in. deep; 60 girders 120 in. deep

BRIDGE CONSTRUCTION COST: $125 million

Each side of the bridge has six beam lines.

Two cranes prepare to place a drop-in segment. A strong-back is located at the right-hand end of the beam being lifted.

the following March, the contractor had begun drilling foundation caissons. Meanwhile, Janssen & Spaans finished superstructure design. The DPRV Bridge spans over two canals, several railroad lines, two local roads, the Des Plaines River, and forest preserve land.

The spliced girder design minimized the impact on the wetlands.

The bridge has a total of 34 piers and 35 spans. The bridge features 18 pretensioned concrete spans and 17 post-tensioned spans. The tallest pier cap is 82 ft above grade, with the bridge deck rising to 90 ft at the highest point.

The simple spans at the DPRV Bridge are made continuous with closure pours over their pier caps. "Over the piers, there's about a 1-ft-wide gap between the ends of the bulb-tee girders," says Brian Slagle, Vice President at Janssen & Spaans. "Reinforcing steel protrudes from the ends of the beams into the gap. And when you cast the deck and make the closure you lock the beams in at that point, establishing continuity. There are no joints at the piers."

A typical simple-span prestressed concrete girder is a 90-in.-deep bulb tee, with a top flange width of 4 ft 11 in., a web width of 6 in., and a bottom flange width of 24 in. The typical post-tensioned bulb-tee girder is 102 in. deep with a top flange width of 5 ft 1 in. and a bottom flange width of 26 in.

"We haunched the girders on the 270-ft-long spans," Slagle explains. "We

Formwork for pier columns shown during concrete placement.

made the typical girder 102 in. deep, but it's haunched to 120 in. over the piers, where you get maximum negative moment." Typically, each haunched girder was made in 120-ft lengths, but one was 138 ft long.

Falsework Supports Beams

For the post-tensioned spans, Walsh used falsework to support one end of the beams during erection, so that the beam rested on both a pier and the falsework. Two beams would extend toward each other, leaving space between for a drop-in segment with a length varying between 124 and 150 ft. The drop-in segment was lifted with a crane at each end. A temporary strong-back was clamped to each end of the drop-in segment to provide an overhang that rested on the adjoining beam end. "The strong-backs supported the beam in place, after which we could release the cranes," said Slagle.

Once the girder was released from the crane, the contractor connected the post-tensioning ducts between the beam ends. Formwork then was placed, and the closure pour was made. "There's a nominal 1-ft gap at the splice," said Slagle. "We coupled the ductwork, set all the reinforcement and formwork, and then made the closure placements across all six beam lines at once. That way, the closure acted as a monolithic diaphragm."

Once the concrete in the closure reached 5000 psi compressive strength, the post-tensioning contractor installed the strand and tensioned it with hydraulic jacks. Each girder had four ducts for

The $6.3-billion Plan

The DPRV Bridge is the largest of 18 construction contracts let by the Tollway for the I-355 South Extension. The 12.5-mile South Extension connects I-55 on the north end with I-80 on the south. Together, the South Extension and the rest of the I-355 Tollway have been named Veterans Memorial Tollway.

The I-355 South Extension is part of the Tollway's long-term $6.3-billion congestion-relief plan called Open Roads for a Faster Future. In late 2004, the Tollway's Board of Directors approved the plan, which is scheduled to last through 2016. One of its programs is Open-Road Tolling, by which 20 mainline toll plazas are being converted to barrier-free design. In addition, most of the tollway system will be rebuilt or modernized, and nearly half of the system's 117 miles of existing roads will be widened or have lanes added.

"Most of the tollway system was constructed nearly 50 years ago and has reached its design life," explains Lis Henderson. The growth of the northern Illinois region also has brought on the need for improvements.

The Tollway already has committed $3.6 billion worth of improvements to contract, including $2.8 billion in construction work. "We're trying to deliver as many of the benefits to the public as soon as we can."

Ongoing construction of the piers.

the post-tensioning strand, explains Slagle. "Generally speaking, the ducts are arranged to be high over the piers and low at mid-span—points where the beam is in tension."

Deck placement of unit 4 southbound bridge. Deck was cast in a specific sequence to avoid deck cracking over the piers.

New Forms Created

The $24-million contract for the precast, prestressed concrete girders produced the largest-ever contract for Prestress Engineering Corp. (PEC), which is Illinois' largest precast concrete bridge supplier. To handle the order, the precaster built two in-ground casting beds in 5 months, bought three beam forms, doubled its workforce to 200 people, and purchased eight 10-axle trailers.

"We had to purchase seven additional acres," says Terry Muntz, Vice President of Operations at PEC's Blackstone, Illinois, plant. "Half of the land went for storage of product and the other half was used to build the two casting beds." Each casting bed is 400 ft long by 20 ft wide by 10 ft deep.

The prairie winds blow strongly in Blackstone, so PEC built the beds in-ground to help keep the concrete warm during casting. The in-ground casting beds also permitted PEC to use shorter travel lifts. "This way we only had to lift the product the height of the beams before we could carry them," says Muntz. "If we had a 10-ft-high form and a 10-ft-deep beam, we'd need to lift the beams to a point 20 ft above ground."

Training the new employees was the biggest challenge, he adds. They also had to create a new safety plan to deal with the larger beams. The largest beams the company had previously cast were 72 in. deep, and the deepest beams at the DPRV Bridge were 120 in. deep.

Tollway officials take justifiable pride in their new bridge. "This bridge provides a great benefit to the driving public," said Lis Henderson, a spokesperson for the Tollway.

For more information on this or other projects, visit www.aspirebridge.org.

Minimal Environmental Impact

The spliced girder design allowed the Tollway to use spans long enough to minimize the bridge's impact on the wetlands through which it passes. The bridge and its construction had to meet environmental requirements set by the U.S. Army Corps of Engineers, the Illinois Department of Natural Resources, the Illinois EPA, and the U.S. Fish & Wildlife Service.

"This design allowed us to come in under the wetland acreages that we could impact on both a temporary and permanent basis," says Paul Kovacs, Chief Engineer for the Tollway. "We were able to affect only 8.77 acres during construction and only 3.87 acres permanently. We built 34 piers, and 16 of those are in wetland areas."

Protected Species

Believe it or not, a rare dragonfly helped influence the design of the DPRV Bridge. The area around the bridge serves as habitat for the Hine's Emerald Dragonfly, which was listed as an endangered species in 1995.

"The Hine's Emerald Dragonfly is one of the reasons the bridge was built as high as it is," says Kovacs. "We identified the dragonfly and studied its habitat. So we built the bridge 10 ft higher to keep cars out of the path of the dragonfly." At its highest point, the bridge is 90 ft above grade.

The area is also inhabited by the Blanding's Turtle, which needs to be protected. Colin Makin, the Tollway's Deputy Program Manager for Bridges, said the turtles have been found and fitted with electronic locators. If a Blanding's turtle roamed too close to the construction area, a group of environmentalists would pick up the turtle and relocate it.

DES PLAINES RIVER VALLEY BRIDGE ON I-355 / LEMONT, ILLINOIS

Photos: Illinois State Toll Highway Authority.

Photo: Illinois State Toll Highway Authority.

Photos: Illinois State Toll Highway Authority.

The 10-span bridge features five spans of precast concrete Illinois I-girders plus five spans of concrete arches.

ARCH OF TRIUMPH

by Brian Slagle, Janssen & Spaans Engineering Inc. and Michael Gould, James McHugh Construction Co.

Concrete design replicates existing arch bridge so well that officials also replace original

Illinois State Toll Highway Authority officials faced a key challenge in planning to widen and rebuild portions of the I-88 Reagan Memorial Tollway in North Aurora, Ill. The roadway's bridge over the Fox River featured the tollway's only arch bridge, and they hoped costs would prove economical enough that they could add a second bridge with a similar design alongside for the extra lanes. Ultimately, the selected concrete design proved so impressive that the Illinois Tollway decided to replace the existing bridge with a new one, too.

The project's goal was to increase capacity on the tollway in each direction to three lanes from two. The plan was to use the existing arch bridge, which opened in 1958, to carry three lanes of westbound traffic, while the new structure would carry three lanes of eastbound vehicles. To achieve this economically, the Illinois Tollway used a performance-based delivery system similar to the design-build format used in other states and requested two distinct bid alternatives from design-build firms.

One design bid alternate provided parameters for an arch bridge that would closely match the shape and construction of the existing arch bridge. The second design bid alternate was to focus on a simple concrete bridge consisting of typical beams and piers, with no elaborations. But that bid also had to include a $3-million noncompensable adjustment for selecting the simple bridge type.

McHugh/Janssen & Spaans investigated both alternatives and concluded that the arch structure could be designed and constructed within the $3-million premium allowed for the more aesthetically pleasing arch structure. They submitted this alternate in their bid package, which was selected as the best combination of aesthetics and economics. McHugh served as the team leader for the project.

Five Arch Spans

The new 1345-ft-long bridge comprises 10 spans. Five spans use cast-in-place columns and bent caps supporting 10

profile

FOX RIVER BRIDGE / NORTH AURORA, ILLINOIS

ENGINEER: Janssen & Spaans Engineering Inc., Chicago, Ill., and Bowman, Barrett & Associates Inc., Chicago, Ill.

GENERAL CONTRACTOR: James McHugh Construction Co., Chicago, Ill.

PRECASTER FOR GIRDERS: Prestress Engineering Corp., Prairie Grove, Ill., a PCI-certified producer

AWARDS: *Top 10 Bridges in North America,* Roads & Bridges *magazine*

Construction sequencing had to accommodate a very stringent set of geometric restraints.

lines of 42-in.- and 54-in.-deep precast, prestressed concrete Illinois I-girders. The other five use four lines of concrete arch ribs with a span length of 178 ft. Each arch supports two cast-in-place intermediate spandrels. Columns and bents are provided above each arch support. The bents in turn support 9 lines of 36-in.-deep precast, prestressed concrete I-girders. The bridge has nine intermediate piers including two in the river and one on an island in the middle of the river. Forty drilled caissons were used, with 28 in the river and 12 on land. Each caisson, 6 ft in diameter, was socketed into solid rock at depths up to 28 ft. The cast-in-place bridge deck has a thickness of 8 in.

Each precast concrete arch was fabricated in two pieces about 1½ miles from the site in a yard established by McHugh. The arches, which are conventionally reinforced were cast on their side and then lifted and rotated into a vertical position using a device constructed for the project. The pieces were delivered using special heavy-load semitrailers with 13 axles, rear steering, and 90-ft-long flatbeds.

Each precast arch section was cast with polystyrene at its center to reduce weight without compromising structural integrity. Even so, each arch section weighed approximately 92 tons and contained approximately 48 yd^3 of concrete with a specified compressive strength of 7000 psi.

McHugh began installing the arches from each end, eventually meeting in the center. Placement of the arched sections required a choreographed crane operation. To maintain river flow and leave the river channel open during construction, a crane-pick location plan was developed to accommodate the erection of the arches. A temporary bridge, capable of supporting more than 1 million lb, was built to give workers access to the island and to support tractors and trailers with the arch segments to the erection points.

Arch Geometry Was Critical

Constructing the arch sections required the project team to monitor each arch during every stage of erection to ensure the structure functioned properly at all times. Sequencing the construction had to accommodate a very stringent set of geometric restraints inherent in creating an arched design that acts as a true arch.

Designers ran two models, a two-dimensional analysis that took into account time-dependent properties of the concrete components, and a 3-D analysis to model the load distribution for the arches. These analyses ensured the construction team could sequence the construction process to optimize the arch design's inherent benefits during each stage by slightly manipulating the activities.

Precast concrete I-girders frame the approach spans and span between the spandrel bents. (top)

The concrete arches were fabricated in two pieces and supported on the substructure and falsework tower before closures were cast. (middle)

Precast concrete half-arch in transit to the construction site. (bottom)

10-SPAN PRECAST CONCRETE I-GIRDER BRIDGE INCLUDING FIVE PRECAST CONCRETE ARCH SPANS / ILLINOIS STATE TOLL HIGHWAY AUTHORITY, OWNER

BRIDGE DESCRIPTION: 1345-ft-long, 10-span bridge incorporating five 178-ft-long concrete arches, precast concrete Illinois I-girders, and a cast-in-place concrete deck

BRIDGE CONSTRUCTION COST: $44.5 million (including Route 31 ramps and overpass)

The new 1345-ft precast concrete arched bridge over the Fox River along I-88 in Illinois, designed to add lanes alongside an existing arched bridge, proved so successful that the project was extended to replace the original bridge, too.

As each arch half was delivered to the site, it was placed on temporary falsework, with one end supported on the substructure and the midspan end supported by a falsework tower. Cast-in-place closures at the arch crowns and thrust blocks were then added to establish continuity. The arch was released from its falsework support so it would begin to behave as an arch. After the arch deflected due to its self weight, it was shimmed tight to the falsework tower, near the center of the arch, to minimize the anticipated design moments during the stages of construction. This approach reduced the amount of structural reinforcing that was needed, saving money.

Anticipating arch deflection during the construction sequencing and establishing the necessary geometry for support elevations represented the biggest design challenge for the project. A key concern was supporting the superstructure from the intermediate spandrel supports, which also move up and down during construction. Designers had to anticipate future deflections of the arch and the movement of the supports over the arch to establish proper beam seat elevations.

Site Conditions Added Challenges

In addition to creating the unique geometry of the arched design, the project also faced key challenges due to the site. The Fox River is not navigable where the bridge crosses it, but it still is subject to strong currents and rapid water flows. During construction, McHugh's crews persevered through a 500-year flood event and two 100-year flood events. Under normal conditions, the river flows at approximately 500 to 700 ft^3/sec; during the construction period, it was measured at more than 15,000 ft^3/sec.

Even before these historic flows were reached, the team had to maintain the river's flow while ensuring it could easily transport materials, leading to the creation of the temporary bridge as well as additional temporary access structures. Environmental standards also had to be maintained, including ensuring that no construction materials or debris entered the waterway. All materials, the cranes' support bases, and other equipment had to be secured against the fast-moving and rising waters. The river's active recreational uses also meant that the team had to be cognizant of kayakers and canoers, especially those who were drawn to the river when its waters were most active.

Original Bridge Replaced

The challenges faced on this project made McHugh better prepared for understanding the changing dynamics of the Fox River during subsequent construction projects, which came in handy almost immediately. Upon seeing the quality and design of the new structure, Tollway officials decided to replace the existing arch bridge in lieu of the planned rehabilitation. This new westbound span now is scheduled for completion in summer 2010.

McHugh is acting as general contractor for the additional project, with Teng & Associates serving as engineer of record and Janssen & Spaans providing construction engineering. A key challenge for the second phase was demolishing the existing 1958 structure. To ensure balance and stability during demolition, the bridge deck's weight first was reduced as much as possible. Each arch barrel then was removed in sequence, carefully reducing each arch's width while maintaining its stability. The new bridge's design is virtually identical to the earlier structure in length and span configuration, speeding construction.

Both projects required considerable coordination among a number of public agencies and private interests, since the bridge spans areas with a variety of stakeholders. The team had to coordinate and communicate with officials from the tollway, the Village of North Aurora, City of Aurora, Burlington Northern Santa Fe Railroad, Illinois Commerce Commissions, Fox Valley Park District, Fox Metro Sanitary District, Army Corps of Engineers, and several utilities.

These two projects together expand the functionality of the crossing and extend the crossing's service life significantly. They also retain the distinctive look that the original bridge provided to this segment of the tollway, and it will continue to do so for many decades to come, even though its original inspiration has been replaced.

Brian Slagle is a vice president at Janssen & Spaans Engineering Inc. in Chicago, Ill., and Michael Gould is vice president of infrastructure at James McHugh Construction Co. in Chicago, Ill.

For more information on this or other projects, visit www.aspirebridge.org.

Two bids were requested, one based on a typical bridge design with a second using an arch design similar to the existing bridge.

Nine piers were built, including two that were located in the river and one on an island in the middle of the river. The existing bridge is in the background.

Constructing the arch sections required the project team to monitor and survey each arch during every stage of erection to ensure the structure functioned properly at all times.

FOX RIVER BRIDGE / NORTH AURORA, ILLINOIS

Construction crews persevered through a 500-year flood event and two 100-year flood events.