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FALL 2017
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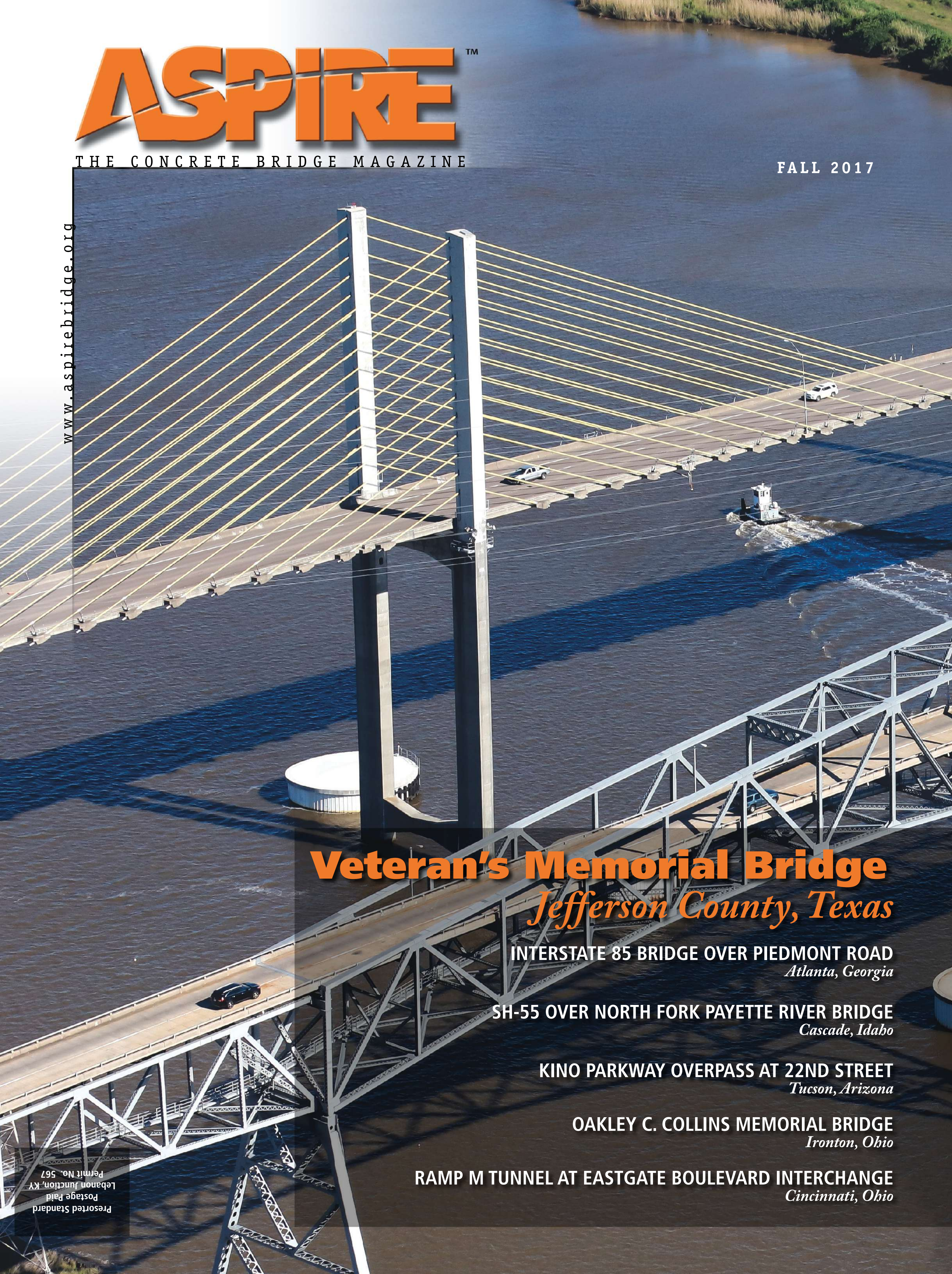

Veteran's Memorial Bridge
Jefferson County, Texas

Photo: Williams Brothers Construction.

Photo: City of Tucson

Photo: Brayman Construction Corporation

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Photo: Williams Brothers Construction.

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EDITORIAL

SUBSTITUTE MATERIALS


Photo: PCI.

William N. Nickas, *Editor-in-Chief*

In 1941, when the president of the United States launched the Lend-Lease program to transfer, sell, or lease war goods to U.S. allies, American management and labor were asked to increase production. Stories about the wartime shortages of aluminum, steel, and copper are well known, but did you know that shellac was also rationed? Only 30% of the shellac produced at 1941 levels could be consumed domestically in 1942. The remainder was reserved for the military, which needed it for phonograph records and radio transcription.

So, where did I run across this historical recap? After my mother passed away a little over a year ago, my brother and I started clearing out our parents' home, where we discovered her keepsakes. In a cabinet, we found a copy of the April 18, 1942, issue of *Business Week* addressed to her grandfather. This magazine gives insight into the war-machine build-up effort, and it also demonstrates how timeless some materials are in terms of resiliency. A theme in this particular publication concerning substitute materials is among the topics that continues to have relevance to today's construction industry.

In the magazine, the wood industry touts that, largely due to adhesives, plywood could be used to build planes. An advertisement proclaims that, "after a half century trend away from wood," the industry had overcome the challenges of rot, termites, and, to a great extent, fire through the use of modern wood preservatives. The ad highlights the use of creosote, chromatic zinc chloride, and other chemicals as "wolmanizing" (preservation) techniques. The same magazine discusses a "strange mineral" that works as an insulating material for mounting electrical apparatuses. The article expresses the potential, once the war is over, to expand the use of ebonized asbestos.

Other stories in the same issue cover labor and factory worker shortages. Steel was scarcer than gold, and portland cement was advertised to be a substitute material for the construction of badly needed war factories. Cement and glass had been featured previously in the magazine, but this issue includes a Portland Cement Association advertisement offering resources to improve and extend the use of concrete, a material that exemplified fire safety, great sturdiness, low maintenance, and thriftiness. I find it fascinating that, 75 years later, many of the same benefits of concrete are still being promoted today, and are increasingly linked to the concept of resiliency.

Time has a way of sorting out which structural materials are the most advantageous. While I am not sure that creosote and asbestos can be considered time-tested materials, concrete and steel can. We have reported in *ASPIRE*℠ [Spring 2017] on how many bridges have been built with concrete, steel, and, yes, wood, as reported by the Federal Highway Administration. Concrete has earned a commanding advantage.

Today, construction materials are not being rationed due to a war, but our industry is being closely scrutinized by sustainability experts. Structural materials need to perform under increasing demands related to more severe and frequent weather events. The American Society of Civil Engineers is attempting to assess this evolution of performance qualities through an assessment system by the U.S. Resiliency Council (USRC). The USRC system has three aspects: *safety*, *repair costs*, and *recovery time*. Among other things, resiliency reminds me to include all aspects of potential repair and recovery actions for the in-service bridge to create an accurate life-cycle cost analysis.

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The Veteran's Memorial Bridge over the Neches River opened in 1991 as the first cable-stayed segmental concrete bridge in the Texas and the state's first design-build project. Photo: Williams Brothers Construction.

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CONCRETE CALENDAR 2017–2019

For links to websites, email addresses, or telephone numbers for these events, go to www.aspirebridge.org and select the Events tab.

October 2–4, 2017
3rd International Symposium on Ultra-High Performance Fibre-Reinforced Concrete
Montpellier, France

October 4–6, 2017
2017 PTI Committee Days
CasaMagna Marriott Cancun Resort
Cancun, Mexico

October 4–7, 2017
PCI Committee Days and Membership Conference
Loews Chicago O'Hare Hotel
Rosemont, Ill.

October 15–19, 2017
ACI Fall 2017 Concrete Convention and Exposition
Disneyland Hotel
Anaheim, Calif.

October 24–25, 2017
ASBI 29th Annual Convention
New York Marriott Marquis on Times Square
New York, N.Y.

October 27–29, 2017
PTI Level 1 & 2 Unbonded PT Inspector Workshop
Baltimore, Md.

November 3–5, 2017
PTI Level 1 & 2 Unbonded PT Inspector Workshop
Orlando, Fla.

November 10–12, 2017
PTI Level 1 & 2 Unbonded PT Inspector Workshop
Houston, Tex.

November 15–17, 2017
PTI Level 1 & 2 Bonded PT Field Specialist Workshop
Austin, Tex.

November 18–19, 2017
PTI Level 1 Unbonded PT Field Installation Workshop
San Antonio, Tex.

December 7–8, 2017
2017 National Accelerated Bridge Construction Conference
Hyatt Regency Miami
Miami, Fla.

January 7–11, 2018
Transportation Research Board 97th Annual Meeting
Walter E. Washington Convention Center
Washington, D.C.

January 22–26, 2018
World of Concrete 2018
Las Vegas Convention Center
Las Vegas, Nev.

February 20–24, 2018
PCI Convention and National Bridge Conference
Colorado Convention Center
Denver, Colo.

March 21–23, 2018
2018 DBIA Design-Build in Transportation Conference
Oregon Convention Center
Portland, Ore.

March 25–29, 2018
ACI Spring 2018 Concrete Convention
Grand America & Little America Hotels
Salt Lake City, Utah

April 9, 2018
ASBI 2018 Grouting Certification Training
J.J. Pickle Research Center
Austin, Tex.

June 11–14, 2018
International Bridge Conference
Gaylord National Resort & Convention Center
National Harbor, Md.

June 25–28, 2018
AASHTO SCOBS Meeting
Sheraton Burlington
Burlington, Vt.

October 6–12, 2018
fib Congress 2018
Melbourne, Australia

June 2–5, 2019
2nd International Interactive Symposium on Ultra-High-Performance Concrete
Hilton Albany
Albany, N.Y.

Staying the Course

As Williams Brothers Construction prepares for a new generation of leadership, the company maintains its focus on competitive bidding on Texas Department of Transportation highways and bridges

by Craig A. Shutt

Williams Brothers built the Veteran's Memorial Bridge in Jefferson County, Tex. in 1991, which features a 640-ft main span of precast concrete segments supported by cables streaming from towers on either side of the river. All Photos: Williams Brothers Construction.

Doug Pitcock has seen many changes to the bridge industry since he helped found Williams Brothers Construction Co. in 1955. Now, at 89, he is turning over the reins to a new generation of leaders who will continue the company's skills in competitive bidding, ensuring constructability, and rolling with changes to build strong relationships.

Through the years, the Houston, Texas-based company has performed most of its work under the open, competitive-bid process, with 95% of that business commissioned by its principal client, the Texas Department of Transportation (TxDOT). It has completed more than 400 projects with a value of more than $12 billion, making it one of the largest highway contractors in the country and the largest in Texas.

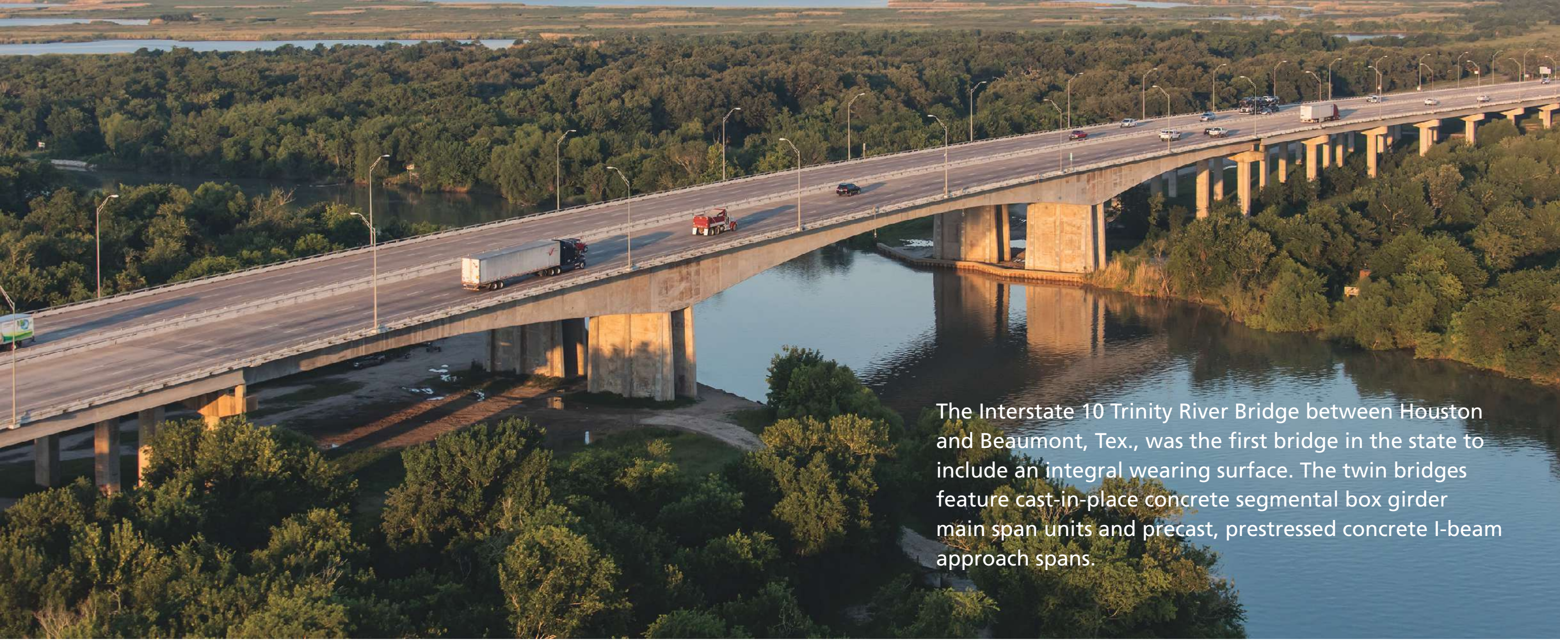
Along the way, it has constructed a number of challenging, complex concrete bridges, including

- the Veteran's Memorial Bridge over the Neches River, opened in 1991 as the first cable-stayed suspension, segmental concrete bridge in the state and Texas' first design-build project; and
- the Interstate 10 (I-10) Trinity River Bridge, twin structures using cast-in-place concrete segmental main spans and precast concrete beam approaches.

Foremost a Bridge Builder

"Williams Brothers is first and foremost a bridge builder," says Pitcock. "We have an unprecedented history of constructing many of Texas's exotic and complex bridge structures."

Although Williams Brothers made its name on hard-bid projects, its construction of the state's first design-build project indicates its ability to adapt to change. "Hard-bid projects



The Interstate 10 Trinity River Bridge between Houston and Beaumont, Tex., was the first bridge in the state to include an integral wearing surface. The twin bridges feature cast-in-place concrete segmental box girder main span units and precast, prestressed concrete I-beam approach spans.

'We have an unprecedented history of constructing many of Texas's exotic and complex bridge structures.'

are definitely giving way to design-build and even P3 [public-private partnership] methods," he says. "They change the ball game from the contractor working from the DOT's design to designers working for the contractor. That creates new relationships that lead to more efficient designs." However, the firm has steered clear of P3 projects. "We don't want to be involved in financing or those long-term contracts."

That first design-build project, which evolved to a contractor-proposed alternative, the Veteran's Memorial Bridge, was completed using 10-ft-long by 57-ft-wide precast concrete segments supported by cables streaming from towers on either side of the river. The towers for the 9440-ft-long structure reach 272 ft in height and hold 14 pairs of cables. The 640-ft-long center span, flanked by side spans of 280 and 140 ft, clears the river by 143 ft, 5 ft more than the minimum clearance required at the time.

When the company works on design-build projects, the team focuses on constructability issues and efficiency rather than value-engineering the design itself. "We don't involve ourselves in design issues, but we make suggestions that will enhance construction techniques and efficiency of construction."

Bridge Types Evolving

In recent years, its project types have changed noticeably, Pitcock says. "Owners needs haven't changed in what they want from us, but the types of projects that predominate our procurement have changed. We went through an era of building a lot of new bridges, especially over waterways, but that's slowed. Today, most of our work is elevated freeway interchanges, overpasses, and ramps. We jump at chances to bid on water crossings, but there are few new ones available."

Replacement of bridges also has been down, he adds. The ones that are replaced aren't done due to deterioration. "Most bridges are replaced to expand their capacity," he says. "We're a growing state with more vehicles all the time, and many bridges weren't designed to accommodate the amount of traffic they carry today."

About 95% of the bridge projects Williams Brothers builds today use concrete girders, he notes. "It's typically up to the designer, but we can bid concrete designs very efficiently." Many of the longer bridges use segmental concrete designs, which have led to signature designs.

"Segmental concepts were pioneered in the United States and brought to Texas by Figg & Muller Engineers, and they gained a lot of attention here," he says. "It was a popular concept. TxDOT was using steel for longer spans because there wasn't another choice."

Segmental designs provided the alternative they needed. "Segmental concrete options created a more economical and competitive design than structural steel. Concrete is more cost effective and faster to build than steel in almost all cases. That made it a top choice, and it's become the prevailing mindset with the DOT."

Segmental designs have added other benefits too, he says. "As the segmental designs have gotten longer and deeper, they've created more aesthetically pleasing designs, too. We now can produce prettier bridges than were possible in the past, and the designers are taking advantage of that."

One of their projects using a segmental design was the Quintana Beach Bridge in Freeport, Tex. The $10.7 million structure, completed in 2003, crosses the Gulf Intracoastal Waterway with a 350-ft main span using cast-in-place concrete segments constructed using the balanced-cantilever method. The single-cell box girder has a deck width of 51 ft and was cast using form travelers. The total segmental length was 740 ft (195, 350, and 195 ft, respectively, in three center spans), with the remaining portions of the 26-span bridge consisting of 142-ft-long AASHTO Type VI Modified prestressed concrete girders.

Deck Wearing Surfaces

The use of a highly durable wearing surface has become more popular in the state, especially on segmental bridges, Pitcock notes. "The wearing surface smooths out the joints and creates a more comfortable ride. Some designers

The second Texas bridge to feature an integral wearing surface, the Interstate Highway 10 Bridge over the Neches River in Orange County, Tex., features cast-in-place concrete segmental box-girder main-span units built using the balanced-cantilever method and precast, prestressed concrete I-beam approach spans to create a widened structure to handle higher traffic volume.

don't like to use it because it adds cost, but it is well worth it in the long run, in my opinion." An example of this type of wearing surface was for the Fred Hartman Bridge in Baytown, Tex., where the 8 in. of structural concrete deck was covered with a 4-in.-thick wearing surface that was specified by TxDOT for protection against an accident involving a burning petroleum truck.

Williams Brothers has been involved with several bridges using integral wearing surfaces, including the first in the state for the I-10 Trinity River Bridge between Houston and Beaumont, Tex. The project consists of twin 3636-ft-long bridges featuring a 990-ft three-span cast-in-place concrete segmental box girder main span unit, erected using the balanced-cantilever method, and a total of 2646 ft of precast, prestressed concrete I-beam approach spans.

These twin bridges feature 3 in. of clear cover to the top mat of reinforcing steel in the deck, providing a maximum of 1 in. available for grinding to obtain the final surface profile and grading. The segmental superstructure called for a design concrete compressive strength of 6 ksi at 28 days.

The second such integral wearing surface was used on the I-10 Bridge over the Neches River in Orange County, Tex. Ninety percent complete in 2017, the twin 3896-ft-long bridges feature TxDOT 70-in.-deep (Tx70) precast, prestressed concrete beams supported on reinforced concrete bents and precast, prestressed concrete piles on concrete footings for the approach spans. The main span for each bridge is a 680-ft-long cast-in-place concrete segmental box girder with a 320-ft-long main span that is flanked by two 180-ft-long back spans. The depth of the box-girder units varies between 18 ft at the piers and 7 ft at midspan. The same 4-in.-thick integral wearing surface was used for these bridges as for the Trinity River Bridge.

Williams Brothers competitively bids these projects with any type of girders desired, thanks in part to its in-house precast/prestressed plant, Valley Prestress, which casts components at four locations throughout the state. The company is one of the largest precast/prestressed concrete fabricators in the state. "We don't produce products for other contractors, but owning these facilities helps us keep costs down to provide any shape or size of precast concrete piece," Pitcock says. "It makes us more economical, because we're not factoring in a middleman's profit. TxDOT is one of the best in the U.S. in creating new designs as needed for special challenges, and we cast the girders that are called for."

'TxDOT is one of the best in the U.S. in creating new designs as needed for special challenges.'

In recent years, the impact of alkali-silica reaction (ASR) on fine and coarse aggregates has caused TxDOT to create prescriptive specifications to mitigate ASR, which complement specifications for high-performance concrete. The prescriptive approach provides mixture proportion options for contractors without the need for additional material testing.

On the Trinity Bridge project, Williams Brothers provided several concrete mixtures, with the majority featuring Class F fly ash contents of 25% and 30% for the total cementitious materials to comply with TxDOT's ASR-mitigation requirements. These mixtures produced concrete with compressive strengths greater than 9 ksi. The additional strength was not required by the design but was desired to keep the casting and stressing operations on schedule, TxDOT officials explained.

Construction Accelerates

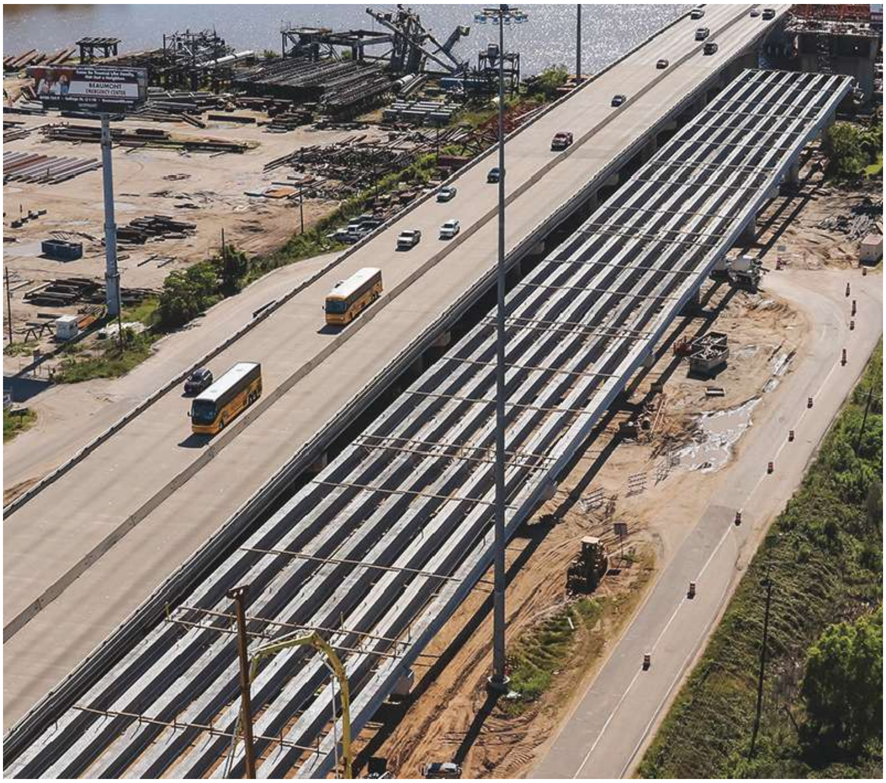
Williams Brothers also has focused attention on increasing the pace of construction activities, but it has been skeptical of techniques specified as accelerated bridge construction (ABC). "It depends on how ABC is defined as to whether we use it or not," Pitcock says. "We don't think that precasting concrete components off site meets the definition, but we complete projects as quickly as possible."

About 10 years ago, two overpasses on I-10 and Interstate 45 were demolished and replaced with new precast, prestressed concrete structures with conventional cast-in-place substructures and bridge decks in only 10 days using traditional construction methods. "I don't think it would be possible to replace them faster than that, no matter what techniques you use."

Compressed schedules have become a key factor in building bridges, he notes. "Owners want bridges built faster, and we have created processes that ensure that happens." The company works 24-hours-a-day, 7-days-a-week schedules on projects, especially on high-traffic sites. That ensures the projects are completed more quickly and reassures the traveling public. "We believe if travelers are being held up by lane closures, they should see people working to get the job done," he says. "The only thing worse than seeing a site with no one working is seeing one where people are standing around doing nothing. We make sure neither of those happens."

'Safety is less about holding meetings and more about conveying a mindset of being aware at all times.'

Safety isn't compromised with the focus on increased speed, he adds. "Accidents are a sign of inefficiency." The company holds daily safety meetings on projects and monthly meetings of all superintendents to review processes. "Safety is less about holding meetings and more about conveying a mindset of being aware at all times," he explains. "We're not unique in our systems, but we focus on them at all times."



The Interstate Highway 10 Bridge over the Neches River in Orange County, Tex., consists of twin 3896-ft-long bridges with approach spans constructed using Tx70 precast, prestressed concrete beams supported on reinforced concrete bents and precast, prestressed concrete piles on concrete footings.

A New Generation

Williams Brothers Construction Co. was founded in Houston, Tex., in 1955 by J.K. Williams, C.K. Williams, and Doug Pitcock, and thrived as the Interstate Highway Act was signed into law the next year. The Williams brothers were bought out in 1964 (J.K.) and 1984 (C.K.), leaving Pitcock the sole shareholder.

In 1998, the firm began to convert to an employee-owned corporation. The company now is transitioning to a management team of five executives as Pitcock cuts his workload. The company, with 2000 employees, had $536 million in revenues in 2016, making it no. 155 on *Engineering News-Record's* Top 400 Contractors list.

Safety procedures are aided by the company's founding membership in a captive group casualty insurance company, American Contractor Insurance Group, based in Dallas. "By self-insuring our employees, it ensures our focus remains on safety and reducing claims and instituting policies that reduce incidents throughout our business."

The company's self-performing policy ensures continuity as the industry changes, and Pitcock is doing his part to ensure that on-going success. "For me to be a success with this business requires people behind me who are ready to take over in a methodical, smooth transition," he says. To that end, he has a management team of "five superstars" that is comprised of President Bob Lanham and Vice Presidents Jesse Khangura, Randy Rogers, Seth Schulgen, and David Casteel.

Pitcock, however, has no intention of leaving the business behind. "I probably never will get out altogether, I wouldn't know what to do with myself," he says. "I'm just trying to keep my mouth shut more often these days."

Lateral Stability: Who Owns the Risk?

A 209-ft-long, 96-in.-deep Florida I-beam being transported from a precast concrete plant. Photo: Durastress.

by J.P. Binard, Precast Systems Engineering LLC, and Glenn Myers, Atkins

Prestressed concrete girders are widely used for construction of bridges in the United States, and have been used successfully since their introduction. The girders are generally designed for initial conditions at the transfer of the prestress force and for final conditions with the girder incorporated into the bridge.

One of the features of prestressed concrete girders is that they are fabricated in a manufacturing facility rather than at the project site. Therefore, they must be handled several times and transported prior to erection in their final locations in the bridge. Accidents or near-miss incidents have often been traced to assumptions that are made with a lack of complete control or complete information or awareness of interdependencies of variables regarding what is required to achieve the final positive outcome. In other words, the designer does not know the route or the equipment being used by the contractor and producer.

With newer types of girder sections and advances in materials, designers can now design girders that are significantly longer than those of the past. With the increased length comes an increased risk of lateral instability of the girder during handling or transportation, which can lead to damage or collapse of a girder. While such events are rare, those that have occurred are reminders that lateral stability of girders is an issue that needs to be considered by designers, contractors, and precast manufacturers.

The industry has recognized the need for improved methods for analysis of lateral stability of prestressed concrete girders at each stage of handling and transportation. When such an analysis is made, it is important that assumptions made by the designer in assessing the lateral stability of a girder and design modifications required to address lateral stability are clearly presented in the contract documents. This alerts the contractor and precast producer to potential issues, and allows them to assess their risks during the bidding process. Behavior of the girder during each of the following stages should be considered:

- transfer of prestress force,
- lifting the girder from the casting bed,
- transportation to the storage yard,
- support conditions in the storage yard,
- transportation to the project site,
- erection at the project site, and
- bracing requirements during the construction of the deck or post-tensioning operations.

Early work done by Mast[1,2] has now been extended and refined in the recently released publication from PCI: *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders*.[3] This comprehensive document has established the methods for analysis. This is a step forward in addressing the lateral stability of girders.

A major issue, however, remains to be answered, which is who owns the risk for each of the activities listed above: designer, contractor, owner, or precast producer? There is no consensus and the question remains controversial.

A common issue with many contracts is that there is no assignment of responsibility for stability analysis during each of these construction phases. With this lack of definition, many contractors elect to take responsibility for only the areas that are clearly within their scope of work and pass the remainder to the precast producer. The primary problem with this approach is related to technical competency, time, and transparency. The procurement procedure typically results in selection of the producer at a late stage in the project. If changes are made to the girder design to accommodate any of the construction phases, they can have significant schedule and coordination impacts.

PCI's *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders* offers guidance on how to address each step in the fabrication, delivery, and bridge completion cycle. The document assigns the role of responsible charge to a "stability engineer." This category of engineer is necessary because clear lines of responsibility have yet to be identified. The *AASHTO LRFD Bridge Design Specifications* are unclear: Section 5.5.4.3 states that stability shall be investigated; however, no responsible party is identified. The AASHTO Technical Committee T-10, Concrete Design, is currently considering how to address this matter and provide more explicit direction in the AASHTO LRFD specifications.

It is the opinion of the authors that designers must consider aspects of the construction process within the scope of their work and indicate on the contract plans their assumptions regarding lateral stability that they believe will provide a constructible solution. All modifications to the concepts presented by the designer in the plans are the responsibility of the contractor and producer. The stated assumptions for the transportation vehicle, maximum sweep, and route extreme characteristics will be an area that the designer will need agency and industry input. The result is less overall risk to the project, less uncertainty during the bidding process, and a collaborative platform where all parties are working under the same set of initial assumptions.

Handling in the Yard

A pivotal aspect of the design of precast, prestressed concrete girders is the concrete strength at time of transfer. Transfer strength requirements have economic implications relating to fabrication turnover time on a casting bed as well as design impacts pertaining to prestress losses, primarily due to creep and camber. The standard of care requires the designer to specify this strength. Techniques such as debonding (sheathing) strands, temporary top strands, and draping or harping (deflecting the position of the center of gravity of the strands downward), are used at transfer of prestress to control stresses. Minimizing the concrete strength at transfer is part of an economical design.

Immediately after the prestressing force is transferred to the girder, the product must be lifted and moved to allow the casting bed to be set up for the next casting. The support conditions assumed in design are altered during this handling as the girder is moved from the bed (end support) to hanging from lifting loops to sitting on dunnage (at locations that may vary from design bearing locations), while the concrete is still at this early strength. These changes in support conditions may influence the design strength required at transfer.

Lifting the girder or moving it from the bed to storage with travel lifts or by other means imparts a dynamic force, whereby the self-weight of the product is effectively decreased or increased. This dynamic force commonly makes the storage load case less critical, as long as the lift points are also the dunnage locations and the dunnage is placed on a level surface capable of providing adequate bearing resistance.

Stability during Lifting

Lifting the girder from the haul vehicle to erect it in the bridge typically does not control the design. The concrete strength at this time is higher and the prestress losses have reduced the effective prestress in the girder. Dynamic forces are also typically less than in the precast yard because a stationary crane is generally used.

The initial and final lifting stages described previously contain a lateral-stability component. Lift points may be considered a compromise of stress and stability in longer-span products. Equilibrium of the precast, prestressed concrete girder, as originally published by Mast and developed further in PCI's Recommended Practice, is a function of several items, including span length, overhang beyond lift points, stiffness of the product, and estimated sweep based on maximum tolerances in accordance with PCI's *Tolerance Manual for Precast and Prestressed Concrete Construction* (MNL-135). The concepts of equilibrium are then used to establish allowable lifting locations for stress conditions at both transfer and erection. Thus, at a minimum, initial design computations should address lifting as it pertains to lateral stability and stress for a functional design.

Stability in Transportation

Transportation is a more elusive matter. The equipment for hauling long-span bridge girders is specialized and varies by region and by hauler. Furthermore, terrain challenges vary from project to project. Both Mast and the PCI Recommended Practice provide a method of evaluation that can be considered for the safe and successful transportation of these components.

It is very likely that this set of minimum criteria will be altered by contractor or precast producer in the shop drawing and submittal phase. The original assumptions in the design phase can serve as a benchmark for the appropriate standard of care that the girder is transportable under a certain set of assumptions and a preferred hauling route. Publications and proprietary software provide the necessary guidance to establish the upper and lower bounds of acceptability for this condition.

Stability at the Project Site

After the girder has been handled and stored properly, and successfully shipped and erected at the project site, the remaining task is providing adequate bracing and checking the exterior girders for torsion from the deck overhang and paving equipment. Skews make this more complicated, but in general this step is already within the scope of work of the contractor to vet their on-site scheme for safe and successful completion of the bridge. Occasionally unique conditions may be analyzed by the designer in advance to provide a comprehensive overview of all limit states that may impact the original design.

Forms for deck paving and rail for paving equipment create eccentric loading on exterior girder. Photo: Atkins.

Conclusion

All parties are responsible for the safe execution of construction and the quality of a structure. It is often forgotten that design and construction are iterative processes during which we continually home in on the final, successful solution by a myriad of steps involving collaboration, communication, and execution. Lateral stability is no different and may be the most important parameter for future projects as our industry continues to evolve and adapt to greater challenges in construction.

To promote awareness of lateral-stability issues and communication among all parties, PCI is developing a spreadsheet tool for lateral-stability computations based on the *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders*.

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Supporting Engineers in Their Ethics Character Development

by Dr. Michelle Rambo-Roddenberry, Florida A&M – Florida State University

A licensed engineer is legally and ethically obliged to protect the public's health, safety, and welfare—not just to *protect*, but according to many codes of ethics to *hold paramount*. He or she must abide by the laws and rules that govern the practice of engineering in the state in which he or she is licensed. A state's laws and rules lay out the responsibilities of engineers, requiring them to meet specified minimum standards, follow certain procedures, and practice professionally and responsibly. When a licensed engineer violates those laws or rules, the honor of the engineering profession is compromised, along with the public's trust. More importantly, the public's health, safety, and welfare can be at risk, and therefore, the state's licensing board has the authority to take disciplinary action and impose penalties on the engineer.

From my experience serving on the licensing board of professional engineers in Florida, complaints are often filed against engineers by building officials after they review drawings submitted for permitting purposes. Some are filed by homeowners who, for example, are angry about an insurance claim and an engineer's report that is not in their favor. Sometimes a complaint is made by an engineer from a competing firm. (But anyone can make a complaint.) Common disciplinary cases include:

- Practicing outside one's area of competence
- "Plan stamping," where the engineer signs and seals drawings for which he or she did not have personal professional knowledge or did not author
- Missing details on design drawings
- Performing inadequate or non-code-conforming design calculations (or not doing them at all)
- Failing to report a felony criminal conviction (whether or not it is related to the practice of engineering)

Many engineering societies have codes of ethics. Although a licensed engineer is not legally bound to these ethics codes, many aspects of the laws and rules by which an engineer must abide are based on them. In addition to holding paramount the public's health, safety, and welfare, some codes of ethics include protection of the environment as a responsibility. This may include life-cycle design or disposal of a project or product at the end of its service life.

In recent decades, the subject of engineering ethics has earned its place as a broad professional concern rather than a philosophical issue or personal concern. This is evidenced by the establishment of several bodies to study and bring awareness to ethics-related issues, such as the National Institute for Engineering Ethics, the Murdough Center for Engineering Professionalism, the Center for Engineering Ethics and Society and their Online Ethics Center, codes of ethics established by most engineering societies, the National Society of Professional Engineers' (NSPE's) Board of Ethical Review, and NSPE's annual Milton F. Lunch Ethics Contest. In the past, ethics discussions were usually centered around major catastrophic failures or design flaws; lately, the discussions have expanded to include day-to-day dilemmas that involve the integrity of the profession.

Ethics is taught in engineering curricula for all disciplines. This can be attributed mostly to ethics criteria for engineering program accreditation. Programs can provide instruction on ethics in several ways, for example, by requiring an ethics course taught in a humanities department, by requiring a stand-alone engineering ethics course, or by teaching ethics throughout the curriculum. Case studies, such as those published by the NSPE's Board of Ethical Review, are excellent educational tools. Ring ceremonies for the Order of the Engineer also bring attention to ethical practice. (For more on the Order of the Engineer, see the sidebar.)

Teaching ethics to engineering students has its challenges, though. Throughout most of the curriculum, students are taught to solve problems where there is one clear, correct answer (in design courses, there may be multiple correct solutions). But some ethical dilemmas do not have a right or wrong answer, which can be uncomfortable to students and unchartered territory for faculty.

Some ethical dilemmas have multiple constraints that cannot all be addressed simultaneously. Other challenges to teaching ethics include an already tight curriculum and faculty who are committed to teaching courses in their area of expertise. Faculty are usually well-versed in responsible conduct of research and probably have access to training in this area. However, many have never practiced as an engineer and do not have firsthand knowledge of the day-to-day challenges of being in responsible charge of a design. They may not feel prepared or comfortable teaching ethical dilemmas because they are generally nontechnical in nature.

Team projects in school do not always effectively teach students about individual professional responsibility; teamwork sometimes sends the wrong message that it "just needs to get done in the end." It gets even more complicated in the office: an engineer completes only a part of design, while other engineers do the rest. Who is responsible for the design? Legally, the engineer who signs and seals the documents is responsible. A developing engineer might take too much comfort in this; he or she shouldn't assume that the Engineer of Record will be able to pick up all errors that the engineer interns or junior engineers make.

Engineering firms that have a culture of quality control—checking calculations and drawings to identify errors and deficiencies before they leave the office—understand this. However, this type of quality control is rarely taught or carried out in academic coursework and is even lacking in some engineering firms.

Developing engineers (recently graduated), who are not yet licensed, are impressionable and perhaps even vulnerable. They need nurturing by employers and mentors to help them develop professional character. New engineers might put too much trust in others, be afraid of looking dumb and therefore not ask questions when needed, or avoid challenging authority when something doesn't seem professionally or technically correct.

This is a call for senior engineers to help engineering trainees develop their ethics character.

They might not fully understand their responsibilities in design and how they fit with colleagues' work. They may struggle with meeting multiple constraints such as getting the job done on time, economy, reputation, or profitability. Or they might not know how to prioritize their obligations to society, clients, employer, supervisor, and profession. Developing engineers climb a steep learning curve with regard to technical matters. The same is true for ethical matters. This is a call for senior engineers to help engineering trainees develop their ethics character. They will remember your guidance for years to come and will carry on your legacy.

After becoming licensed, engineers should stay current with a state's laws and rules as well as ethics. Several licensing boards require continuing education courses in laws, rules, or ethics to be completed for licensure renewal. I hope that in the future more boards will require this.

The ethics conversation is not just about avoiding the next disaster; it's also about ordinary decisions that engineers make to serve society well and to preserve our profession's integrity and respect.

What about engineers who practice in exempt disciplines but never get licensed or who work for governmental agencies that do not require licensure? Professional societies should also continue to do their part to reach them.

All engineers are responsible for engineering ethics education: faculty, employers, mentors, supervisors, licensing boards, and engineering societies. It is good that many professional societies and organizations are rallying around the need for more ethics' education. They are providing faculty and practitioners with much-needed resources for this endeavor. However, there is still work that needs to be done to help recent graduates who are gaining their experience towards licensure.

The ethics conversation certainly needs to happen in the workplace—not just about the "no-brainer" dilemmas, but the subtle ones, too. Daily, mentors can identify situations where they made an ethical choice and use them to coach developing engineers. The ethics conversation is not just about avoiding the next disaster; it's also about ordinary decisions that engineers make to serve society well and to preserve our profession's integrity and respect.

EDITOR'S NOTE

NSPE's Code of Ethics can be read or downloaded from this webpage: https://www.nspe.org/resources/ethics/code-ethics.

The Order of the Engineer

The Order of the Engineer is a national organization whose purpose is to:

- Foster a spirit of pride and responsibility in the engineering profession
- Bridge the gap between training and experience
- Show the public a symbol (a ring) that identifies the engineer

During a ring ceremony, an initiate takes the "Obligation of the Engineer" oath and receives a stainless-steel ring to wear on the pinky finger of the working hand. When signing and sealing design plans, the engineer is reminded of his/her obligation when the ring makes a clanking sound against their seal embosser. The obligation contains parts of the ethics codes of major engineering societies. It is akin to the Hippocratic oath that doctors take at the beginning of their medical practice.

Eligibility includes licensed professional engineers, graduates from ABET-accredited programs, and senior students within one academic year of graduation. Engineers from all disciplines may be inducted. Individuals with other credentials can ask for approval from the Order's board. Induction is for life, but there are no membership meetings or dues to pay. Several societies and universities hold Order of the Engineer ceremonies for students and practicing engineers.

For more information, visit www.order-of-the-engineer.org.

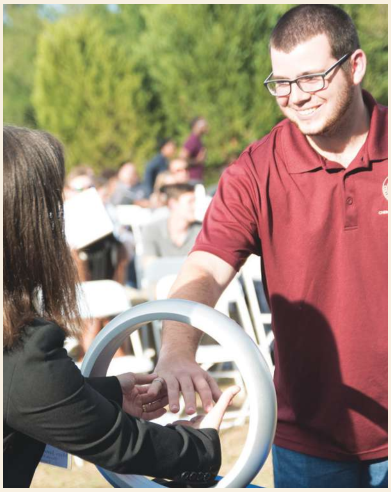


Photo: Kevin Hubbard

RAPID RISE FROM THE ASHES

GDOT's team rebuilds I-85 segment in 44 days using precast concrete bulb tees after devastating fire destroys three spans in both northbound and southbound directions

by Bill DuVall, Georgia Department of Transportation

I will long remember March 30, 2017. I was driving into town that evening with my son to have burgers when the radio announced there was an intense fire under the Interstate 85 (I-85) viaduct near Piedmont Road in Atlanta, Ga. I called the state bridge inspection engineer for an update, turned the car around, and headed to the office.

My son was so excited he didn't even mind going to my office. That worked well, as he could read and answer texts (he's good at it) and make calls for me as we went. I contacted my assistants, the construction office, management, and the Federal Highway Administration (FHWA). At 6 p.m., as we drove, we heard that a span had collapsed. I have experienced numerous incidents with bridges damaged by collision or fire, but none had ever brought down a span until that night.

Georgia State Patrol was first on the scene and closed I-85. Other first responders included Georgia Department of Transportation's (GDOT's) highway emergency response operators and local police and firefighters. Due to their coordinated and immediate response, no one was injured by the collapse. That left it to our team to determine the extent of the damage and the best and most expedient way to return the bridge to service immediately.

Evaluations found that three spans in each direction needed to be replaced as well as four bents, with round columns and inverted-tee bent caps. Demolition of the spans began immediately. All Photos: Georgia Department of Transportation.

243,000 Vehicles per Day

I-85 splits from Interstate 75 in downtown Atlanta, and heads north towards South Carolina. The viaduct crosses Piedmont Road in a section that carries 243,000 vehicles per day. Due to its key location and the extent of the damage, Governor Nathan Deal declared a state of emergency, which allowed FHWA to authorize emergency funding and allowed GDOT to negotiate the contract for repair. The governor also asked GDOT Commissioner Russell McMurry to fund incentives for early completion. Road-user costs were used to set the appropriate level of incentive.

McMurry immediately contacted C.W. Matthews (CWM) Contracting Co., which had responded quickly to a bridge fire on Interstate 285 in 2001. CWM's representatives were at the I-85 site that night placing light towers and evaluating the damage and reconstruction options.

The heat of the fire caused enough damage to the concrete and prestressing strands that the bridge collapsed. It also caused significant damage to the intermediate bents supporting that span and those spans directly north and south. The concrete bents experienced loss of concrete cover, buckling of column reinforcement, and significant cap damage. GDOT bridge inspectors later found extensive delamination and

profile

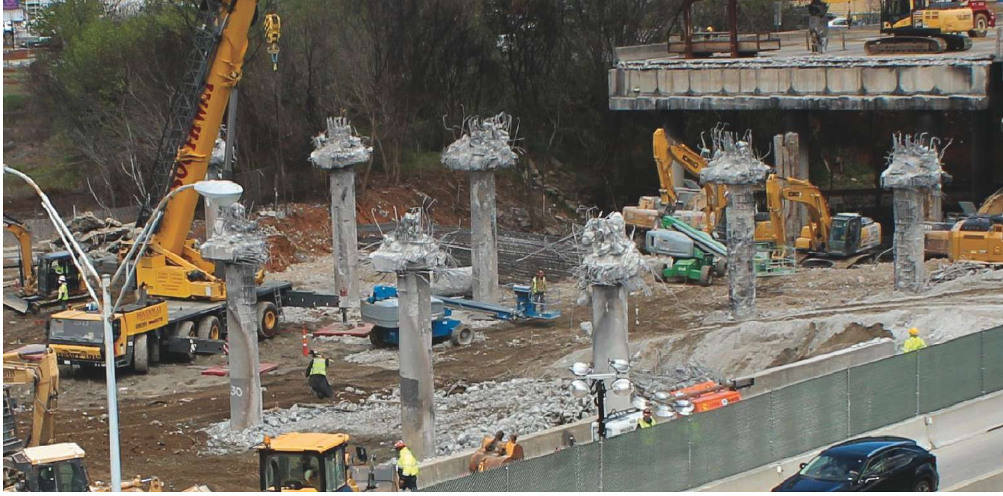
INTERSTATE 85 BRIDGE OVER PIEDMONT ROAD / ATLANTA, GEORGIA

ENGINEER: Georgia Department of Transportation, Atlanta, Ga.

PRIME CONTRACTOR: C. W. Matthews Contracting Co., Marietta, Ga.

DEMOLITION CONTRACTOR: D. H. Griffin Construction, Greensboro, N.C.

PRECASTER: Standard Concrete Products, Atlanta and Savannah, Ga.—a PCI-certified producer cracking of the bottom flanges of the inverted-tee bent caps. Ultimately, it was determined that three spans in each direction needed to be replaced: spans 29, 30, and 31 northbound (ranging from 76 to 92 ft) and spans 28, 29, and 30 southbound (ranging from 80 to 120 ft). Four bents also had to be replaced. They were similar in type, with round columns and inverted-tee bent caps, but the cap lengths varied due to the skew and number of beams supported.



The damaged portion of the bridge contained complex layouts, including a slight curve with the typical bent laid out radially, a 50-degree skew where the viaduct crossed Piedmont Road, and two trapezoidal spans

Similar to Design-Build

The project proceeded similarly to a design-build project, with GDOT working closely with CWM on issues related to the reconstruction. GDOT provided the contractor with initial structural details so they could immediately contact suppliers.

The GDOT team coordinated efforts through the Transportation Management Center and conducted progress updates every few hours. The first goal by department designers was to provide construction plans to the contractor and estimators by late Sunday so work could begin Monday morning. That goal was achieved through a tremendous team effort by the GDOT bridge engineering staff.

The reconstruction contract was designated for completion on June 15, 2017, with a $1.5-million incentive if completed by May 25 (before Memorial Day) and $2 million if completed by May 21. GDOT allowed $200,000 for every day prior to that, up to $3.1 million.

The existing spans were demolished in tight quarters, crushed, and cleared from the site. Crews used small pneumatic hammers to expose the concrete column cores and footings on all columns. The original columns were 3.5 or 4 ft in diameter and many of them could be salvaged, with new concrete placed around the cores. Existing pile footings were reused, and the contractor cleaned the adjacent bents and superstructure to expose their condition. Bridge inspectors worked throughout the demolition, identifying the damage and ensuring the remaining structure was sound.

As demolition transitioned to reconstruction, GDOT installed a webcam. In retrospect, it should have been installed at the beginning of the project so that citizens could watch the entire process. It's inexpensive and offers a great asset to share with the public. As an engineer, it was fascinating to watch CWM complete the project in record time.

The communications team also provided regular updates to the news media and social media websites. Interviews were conducted and placed on YouTube as well. Traffic information and construction updates were widely shared by partner agencies and officials. The GDOT communications team really came through, and the public appreciated the efforts to inform them along the way.

Beams on Critical Path

Early on it was evident that casting new beams would be on the critical path. The night of the fire, Standard Concrete Products (SCP), which had cast the original beams, was contacted. SCP found forms for the original AASHTO Type V prestressed concrete girders at various plants, but they were not available in sufficient numbers. So the 61 beams to be replaced were redesigned using 63-in.-deep bulb tees. Due to the varying span configurations, this required a huge effort.

The damaged portion of the bridge featured complex layouts, including a slight curve with the typical bent laid out radially and a 50-degree skew where the viaduct crossed Piedmont Road. In the six spans needing replacement, one (over Piedmont Road) had skewed bents at each end, two spans were trapezoidal, and three had radial bents.

The southbound span over Piedmont Road had 12 lines of girders, while the other two southbound spans each had 11 girder lines. The northbound bridge had nine lines of girders in each span. Six girder designs were created and detailed to replace the 61 girders. GDOT began checking shop drawings from the precaster on Sunday night and provided approved beam details to the contractor and fabricator before completion of the entire set of construction drawings at midnight on Sunday.

GEORGIA DEPARTMENT OF TRANSPORTATION, OWNER

OTHER MATERIAL SUPPLIERS: Live-feed webcam: OxBlue, Atlanta, Ga.; Steel diaphragms: Augusta Iron & Steel, Augusta, Ga.; Bearing pads: Highway Materials, Forest Park, Ga.; Metal deck forms: Topikal, Atlanta, Ga.

BRIDGE DESCRIPTION: Replacement of three spans both northbound and southbound (six in all) of the 4150-ft viaduct of Interstate 85 over Piedmont Road following fire

STRUCTURAL COMPONENTS: 61 prestressed, precast concrete bulb tees, 63 in. deep, ranging from 43 to 115 ft long; 4 concrete intermediate bents with inverted-tee caps; 5090 yd^2 of concrete bridge deck

BRIDGE CONSTRUCTION COST: $16.7 million (including $1.6 million for demolition and $3.1 million in incentives)

Many of the original columns, 3.5 or 4 ft in diameter, were salvaged, with new concrete placed around the cores. Existing pile footings also were reused.

Timeline

The timeline for the reconstruction of the viaduct on Interstate 85 in 44 days:

MARCH 30 (THURSDAY):	Fire event damages six spans. GDOT contacts C.W. Matthews and Standard Concrete Products about girder options.
APRIL 1:	Progress updates begin being shared every few hours through GDOT's Operations Center.
APRIL 2:	GDOT provides intermediate structural details to CWM so it can work with suppliers.
APRIL 3	(Monday): Plans for replacement prestressed concrete beams are sent to CWM and estimators at 12:01 a.m. Work begins to expose concrete cores on columns and footings.
APRIL 4:	Press conference announces timeline and plan. Governor asks GDOT Commission to incentivize project.
APRIL 6:	Columns at Bent 29 southbound are formed and placed. On-site webcam is installed and provides live feed.
APRIL 10:	Most columns are completed and caps are formed.
APRIL 17:	First prestressed concrete beams are set.
APRIL 25:	Final girder is placed on southbound span over Piedmont Road.
MAY 3:	All spans are placed and grinding begins on northbound bridge deck.
MAY 12:	Northbound lanes are opened.
MAY 13:	Southbound lanes are opened and the full incentive payment is achieved.

Two Plants Cast Beams

Forty-nine of the prestressed concrete beams were produced at SCP's Atlanta plant and 12 were produced across the state at their Savannah plant and trucked to the site. The contractor began work on the spans with the most conventional beams and then progressed to the trapezoidal spans. In some places, cranes had to reach 120 ft to set the beams. GDOT worked closely with the contractor to inspect the beams before they left the plant, and permitting restrictions were adjusted to create greater flexibility for deliveries.

SCP was able to manufacture the girders within days of receiving the plans. By April 18, two spans of girders were erected and crews were able to start cast-in-place deck construction.

Crews also had to work around overhead transmission lines in some locations. CWM coordinated directly with Georgia Power and did not interrupt service during the construction.

One of the most complicated portions of the project was the inverted-tee caps. There were concerns early on with trying to redesign the caps, but the original design was kept. The caps contain a tremendous amount of reinforcement with tight clearances. The design team worked closely with the field to make necessary adjustments and keep the project on schedule.

GDOT prefers to use concrete diaphragms in all of its bridge projects. However, steel diaphragms are allowed in certain situations. In this case steel diaphragms were provided in the design in order to accelerate construction.

GDOT required the contractor to wet-cure the decks for a minimum of three days using curing blankets and soaker hoses. Uncoated reinforcement also was used to save time, as the new deck would provide sufficient durability compared to the 30-year-old decks on subsequent spans. The new decks will be sealed in the near future to provide additional protection. In fact, the decks turned out better than expected and it is anticipated that due to the use of Type III cement the final concrete strength will be much higher than the 3.5-ksi requirement.

GDOT also used 24-hour accelerated-strength concrete to construct the substructure, with fiber additives to minimize cracking. The mixture design included Type III cement, but no. 89 stone was added due to the congestion of the reinforcement and to improve workability.

Incentives Realized

Work moved so smoothly and efficiently that CWM opened the northbound lanes on May 12 and the southbound lanes on May 13. That fast work generated the full $3.1 million in incentives and it was definitely worth it. In addition to finishing so quickly, no injuries were reported during construction. CWM did a great job with this project.

A formal report on the cause of the fire has not been completed; GDOT continues its support of and participation in an investigation of this event by the National Transportation Safety Board and appropriate local agencies. Armed with findings and recommendations, GDOT will develop additional practices to ensure the safety and integrity of its infrastructure.

That fast work generated the full $3.1 million in incentives and it was definitely worth it.

I am humbled by the work of the GDOT bridge office to return this critical bridge to service so rapidly. It required a huge team effort, and I was especially proud that so many of our junior engineers rose to the challenge. At this point, there is only one remaining task left on my list related to this event: I still owe my son a burger.

Bill DuVall is the state bridge engineer in the Office of Bridges and Structures with the Georgia Department of Transportation in Atlanta, Ga.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PROJECT

SH-55 Over North Fork Payette River Bridge

by Leonard Ruminski, Idaho Transportation Department

Completed bridge with concrete barriers and piers stained to match local stone. All Photos and Figures: Idaho Transportation Department.

The project is located in the small resort town of Cascade, Idaho, on a two-lane scenic highway that is also a vital north-south link within the state for both commercial and tourist traffic. Any prolonged traffic interruptions on this highway would have significant impacts as there is no practical detour available.

The existing 65-year-old, three-span steel girder bridge crossing a 20-ft-deep, 190-ft-wide river was classified as structurally and functionally deficient, and was originally scheduled to be replaced in 2017. However, due to excessive corrosion of exposed pier piles, the bridge could no longer support heavy truck loads, causing traffic restrictions along the route and impeding commercial traffic.

The Idaho Transportation Department (ITD) temporarily addressed the issue by encapsulating 50% of the corroded piles with epoxy-filled jackets, which allowed lessening of traffic restrictions. But to achieve full mobility as soon as possible, the bridge replacement completion had to be accelerated by two years and was set for October 2015.

To minimize impacts on the traveling public and local businesses, the new structure was to be erected by accelerated bridge construction methods with precast concrete elements that would allow rapid assembly in the field.

The bridge removal and replacement were to be performed in two stages while maintaining two-way traffic through the construction site at all times. This required a 10-ft shift in the permanent roadway alignment and construction of long, mechanically stabilized earth (MSE) retaining walls at each end of the new bridge, due to right-of-way limitations. MSE walls with precast concrete panel facing were also used instead of conventional wingwalls at each abutment.

The bridge layout is oriented on a north-south alignment. Access within the river was only available on the east side of the bridge, where a modular temporary work platform was erected along the existing bridge during stage 1 construction. This working bridge was used to remove the eastern part of the existing bridge and to construct stage 1 of the new bridge. On the west side of the bridge, the existing topography at abutment 1 and the wetland area at abutment 2 made access and construction of a working platform impossible. Low-hanging electrical power lines also ran parallel along the east side of the bridge, making crane operations difficult. Therefore, during stage 2 construction, the remaining part of the existing bridge was used to support equipment for installing piles and the precast concrete pier wall and to allow erection of the girders. Piles for the new bridge were installed through openings cut in the existing deck, so the new pile spacing was designed to fit between the existing bridge girders. Using the existing bridge as a work platform

profile

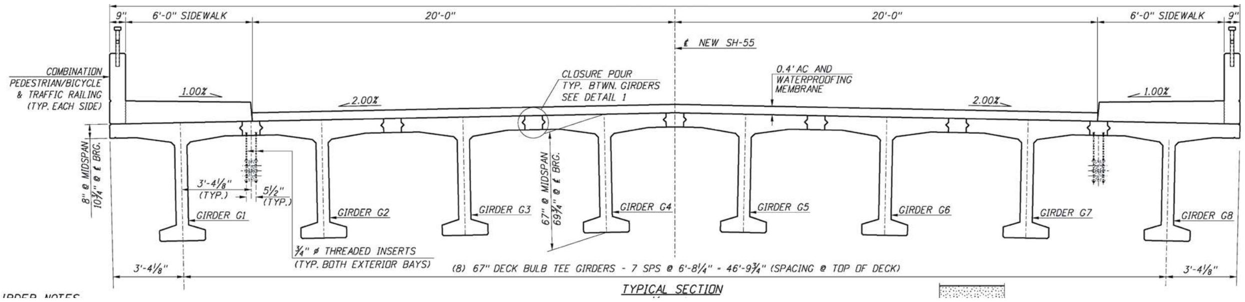
SH-55 OVER NORTH FORK PAYETTE RIVER BRIDGE / CASCADE, IDAHO

BRIDGE DESIGN ENGINEER: Idaho Transportation Department, Boise, Idaho

PRIME CONTRACTOR: RSCI, Boise, Idaho

PRECASTER: Hanson Structural Precast (now Forterra Structural Precast), Caldwell, Idaho—a PCI-certified producer

PILE FOUNDATION INSTALLATION AND PRECAST CONCRETE ERECTOR: Inland Crane, Boise, Idaho



Bridge cross section with closure-pour detail between deck bulb tees.

to support heavy equipment was questionable; however, with careful analysis, equipment placement restrictions, and the prior strengthening of the corroded piles, it was determined to be possible.

New pile installation was complicated by large cobbles and boulders that required predrilling and the use of temporary casings. Templates were used during pile driving at the pier and abutment locations to achieve the tight installation tolerances required for fitting the precast concrete substructure components to the piles.

Of particular interest was an innovative method of pier-wall installation within the deep river that eliminated the need for time-consuming and expensive cofferdams. The 30-in.-diameter steel shell piles were arranged in a single row and driven through water into the riverbed, cut off just above the water line, leveled, and filled with concrete. The pile penetration into the riverbed also had to be increased to account for 12 ft of potential scour. Fourteen-inch-diameter centering pipes were cast in the top of shell piles, and were used to align and secure the lower segment of the pier wall to the shell piles. Inverted U-shaped precast concrete lower pier-wall segments were positioned directly on top of the shell piles to completely hide them from view above the water, enhancing aesthetics. The hollow upper pier-wall segments were then erected and filled with high-early-strength concrete with fibers. Polypropylene fibers in the amount of 1.5 lb/yd^3 were added to the high-early-strength concrete to reduce shrinkage cracks of the fast-curing, highly cementitious material. Using hollow pier-wall segments kept their shipping weight below 30 tons, simplifying transportation, erection, and reducing cost. Precast concrete abutment pile caps with 30-in.-diameter corrugated metal pipe pile block-outs were erected on top of HP piles and the block-outs were filled with high-early-strength concrete with fibers.

Deck bulb-tee girders were erected and top flanges connections were made with 10-in.-wide closure pours. Top flange transverse reinforcement protruded 9 in. into the closure pours. Epoxy-coated upper bars were used for improved protection against corrosion, while the lower bars had end terminators. These devices provided adequate development and pull-out resistance. Closure pours were then filled with high-strength grout with fibers, resulting in a robust and durable moment-resisting connection. Since the ends of the deck girders were cast within the integral abutment and pier diaphragms, and no conventional deck placement was required, intermediate diaphragms between girders were not needed. This approach also simplified and accelerated construction.

High-early-strength concrete with fibers was used for the integral pier and abutment diaphragms, allowing removal of the formwork after 24 hours, considerably less than the form curing time required for conventional concrete. After the approach slab, sidewalk, and parapet placements, the entire riding surface was covered with a spray-applied waterproofing membrane and a double layer of asphalt. Finally, asphaltic-plug expansion joints were placed at the end of each approach slab.

Due to its location next to a recreational resort and within beautiful natural surroundings, the new structure had to be aesthetically pleasing and blend with the environment. This was achieved by texturizing and staining the exterior surface of the precast concrete pier-wall segments, MSE wall panels, and concrete parapets. Formliners were used on the exposed surface of the pier walls, MSE walls, and parapets to create a textured concrete surface and enhance aesthetics. Staining of the textured surface was then applied after casting with variable colors to match the natural colors of the rock rip-rap and surrounding rock formations.

Innovations and Accomplishments

All elements of the superstructure and substructure of the new bridge, except sidewalks and parapets, consisted of precast concrete components, allowing quick field assembly. This reduced inconvenience to the public, reduced economic and

IDAHO TRANSPORTATION DEPARTMENT, OWNER

BRIDGE DESCRIPTION: 250-ft-long, 53.5-ft-wide, two-span (124-ft each), precast, prestressed concrete deck bulb-tee girders supported by integral piers and integral abutments. The bridge carries two 12-ft-wide lanes of traffic with two 8-ft-wide shoulders and two 6-ft-wide sidewalks.

STRUCTURAL COMPONENTS: Eight 67-in.-deep deck bulb-tee girders per span, precast concrete abutment pile shell caps and precast concrete pier walls consisting of multiple segments approximately 6 ft high, 5 in. thick, and 26 in. wide. Cast-in-place closure pours between deck girders using high-strength grout with fibers; cast-in-place abutment and pier diaphragms using high-early-strength concrete with fibers

BRIDGE CONSTRUCTION COST: $4,100,000

AWARDS: 2016 PCI Design Awards: Best Bridge with Main Span from 76–149 feet, Honorable Mention in All-Precast Concrete Solution Category; Idaho Business Review 2016 Top Projects: Honorable Mention in Transportation Category

Stage 1 upper pier segment erected. Workers are placing temporary bearings for deck girders. Projecting vertical bars will be cut at deck girder locations.

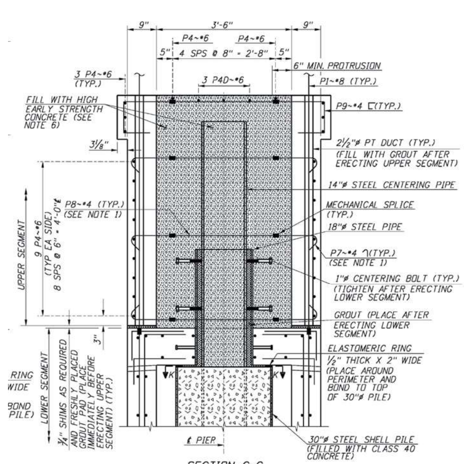
Stage 1 deck girder erection from existing bridge.

environmental impacts, improved safety during construction, and provided a high-quality, durable, low-maintenance, and aesthetically pleasing bridge structure.

The innovative method of pier construction eliminated the need for deep cofferdams and forms within the river, significantly reducing cost and construction time and providing the appearance of a solid wall while hiding steel shell piles. Using multiple hollow pier-wall segments reduced their shipping weight, making their transportation and erection easier and less expensive.

The 10-in.-wide closure pours between deck bulb-tee girders filled with high-strength, fast-curing fiber-reinforced grout, were less expensive than comparable ultra-high-performance-concrete-filled closure pours, but still provided a strong, effective, and durable connection.

Girder continuity over the pier was achieved by extending the top flange longitudinal reinforcement into the pier diaphragm and splicing it with the reinforcement of the girder in the adjacent span using mechanical couplers. Developing bottom flange strands into the pier diaphragm provided a positive-moment girder connection. The girders were framed at the pier and abutments by cast-in-place integral diaphragms using high-early-strength concrete with fibers. The use of integral abutment and pier diaphragms increased structural redundancy and eliminated exposed bearings and expansion joints, reducing



Cross section of pier wall showing the filled pier shell and pile cap details.

Deck surface after girder closure pours have been completed.

future maintenance requirements. They also improve seismic performance and bridge resilience against high water velocities during floods.

Using high-early-strength concrete with fibers instead of conventional concrete for cast-in-place concrete significantly reduced in-form curing time requirements and the formation of shrinkage cracks, which improves long-term performance. Its overall unit cost premium was negligible, considering the benefits and relatively low volume required for this project.

A variable top flange thickness (8 in. minimum) along the length of the deck bulb-tee girders was designed to mitigate the effects of upward girder camber and eliminate the requirement of variable asphalt thickness along the span, simplifying paving operations. A spray-applied waterproofing membrane on all deck surfaces covered with a double layer of asphalt ensures a well-protected, long-lasting deck and approach slabs, reducing future maintenance requirements.

Summary

The successful and timely completion of this challenging project was only possible with the use of precast concrete elements. Using simple and practical details with allowance for tolerances and field adjustment along with an innovative construction procedure enabled the contractor to assemble the bridge structure on schedule and within budget. The bridge structure was assembled within a four-month period compared with 10 to 12 months for a similar structure using conventional construction methods.

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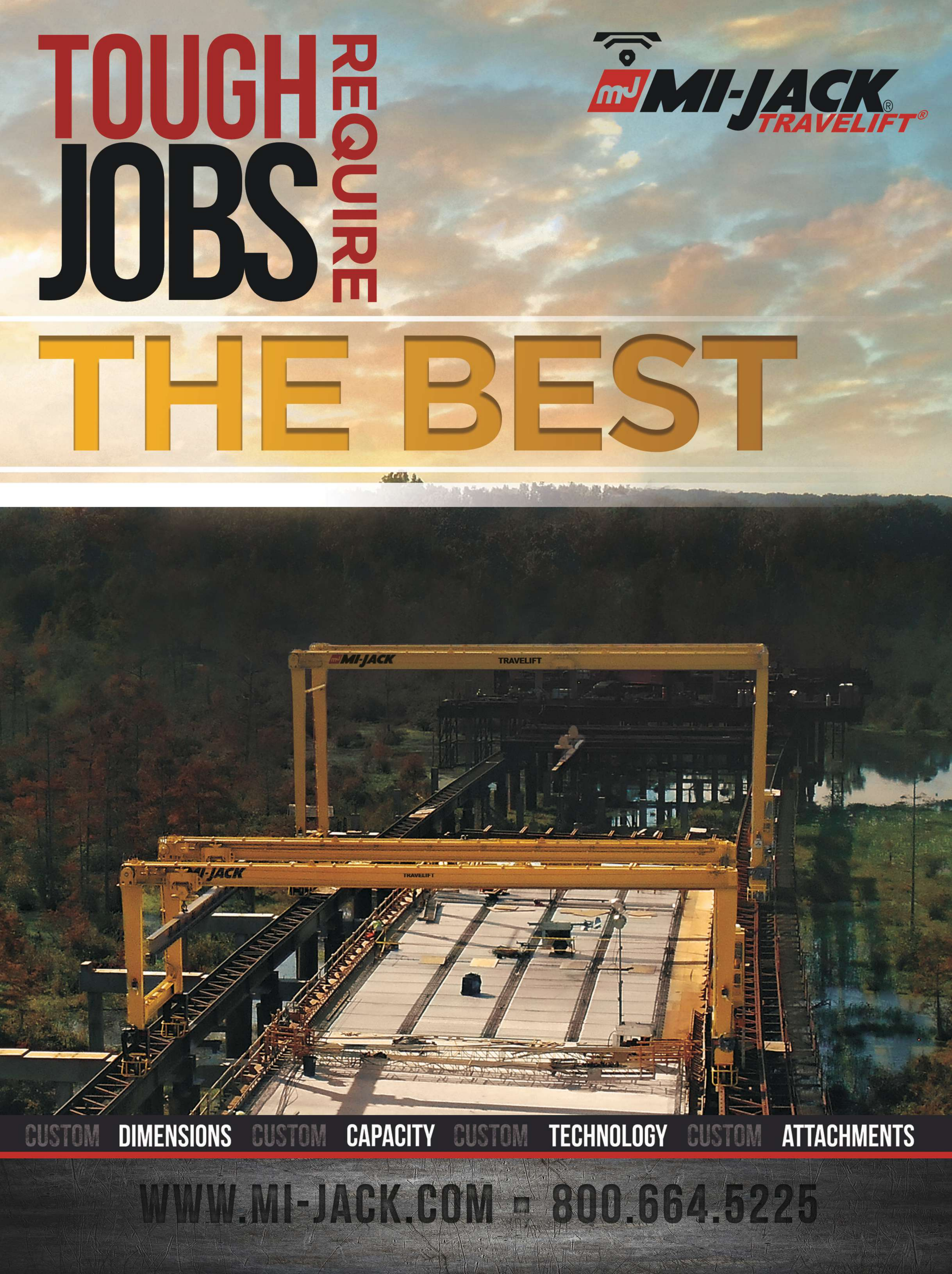
Leonard Ruminski is a technical engineer 2 with the Idaho Transportation Department Bridge Section in Boise, Idaho.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Aerial view of completed project showing tiered retaining walls with artistic and architectural enhancements. Photo: City of Tucson.

KINO PARKWAY OVERPASS AT 22ND STREET

by Jim Glock and Claudia Perchinelli, Structural Grace Inc.

The Kino Parkway Overpass at 22nd Street was a vision of the Tucson, Ariz., community for decades. It was not until the passage of the Regional Transportation Authority's plan and a half-cent sales tax funding mechanism in 2006 that this overpass design could move forward.

Kino Parkway Overpass at 22nd Street is a six-lane divided arterial roadway with a 20-ft-wide median island; it is planned to widen 22nd Street to a six-lane divided arterial as well. Prior to the construction of the interchange, the intersection of these two roadways was at grade and one of the more congested intersections within the city limits.

To accommodate future traffic volumes, Kino Parkway now crosses over 22nd Street. The two roadways connect through a single-point urban interchange (SPUI). The SPUI (at grade) includes dual left-turn lanes for traffic from both 22nd Street turning onto the Kino Parkway on-ramps and Kino Parkway off-ramps onto 22nd Street. It is the first grade-separated SPUI constructed by the city of Tucson.

As this interchange is located in a densely populated area within Tucson's core, a citizens' advisory committee (CAC) was formed to guide the city and consultant team in their approach to the visual aspects of the structure. Concern over the size and appearance of the interchange led to a variety of features that influenced the structure type. In particular, there was an interest to include many scale-reducing elements into the design. The design also needed to integrate aesthetic features into the structure, as opposed to "plop art"—surface treatments that lack meaning. In this vein, the theme of "structure from nature" was embraced, leading to cactus-rib-inspired fluted columns and art elements incorporated into the design. The project team relied on the unique collaboration of the bridge architect with the project.

Close-up of bridge with fluted piers and art elements along with architectural enhancements in hardscape and superstructure. Photo: City of Tucson.

profile

KINO PARKWAY OVERPASS AT 22ND STREET / TUCSON, ARIZONA

BRIDGE DESIGN ENGINEER: Structural Grace Inc., Tucson, Ariz.

PRIME CONTRACTOR: The Ashton Company, Tucson, Ariz.

PRECASTER: TPAC (A Division of Kiewit Western Co.), Phoenix, Ariz.—a PCI-certified producer

POST-TENSIONING CONTRACTOR/SUPPLIER: Consolidated Rebar, Phoenix, Ariz.; Dywidag Systems Inc. (DSI), Long Beach, Calif.

OTHER CONSULTANTS: AECOM, Tucson, Ariz.; PSOMAS, Tucson, Ariz.; McGann and Associates, Tucson, Ariz.; GLHN, Tucson, Ariz.; EDAW, Phoenix, Ariz.; Barbara Grygutis, Tucson, Ariz.

OTHER MATERIAL SUPPLIER: CAID Industries, Tucson, Ariz.

Construction of cast-in-place concrete box girder. Photo: Structural Grace Inc.

Erection of drop-in girder to complete main span. Note dapped end of girder. Photo: Structural Grace Inc.

The SPUI configuration prohibits a median in the intersection to accommodate the left-hand turn movements that are the basis of the SPUI function. The curb-to-curb width of 22nd Street varies from approximately 150 ft at the edge of the bridge to approximately 110 ft at the intersection with Kino Parkway. Safe sight distance requirements, along with other constraints, resulted in the minimum clear opening requirement of 175 ft.

Twenty-Second Street is a major arterial roadway that, prior to construction, carried over 35,000 vehicles per day on two travel lanes in each direction. This relatively high volume placed a premium on the maintenance of traffic during the construction.

In summary, the design had to include:

- A clear span length of 175 ft to accommodate the geometry of the SPUI and safe sight distances
- A typical section with an open median in the overpass
- Aesthetic design criteria established by the CAC
- Minimal structure depth
- A construction sequence that allowed a maximum number of lanes to remain open on 22nd Street

The culmination of these criteria and collaboration of the bridge architect and project artist with bridge designers resulted in the twin 344-ft three-span structures that carry the Kino Parkway Overpass at 22nd Street. Each of the twin bridges is 42 ft 8 in. wide with two lanes each to accommodate projected traffic volumes. These unique structures are a combination of cast-in-place (CIP) post-tensioned box girders and drop-in precast, prestressed concrete box girders of both standard and custom shapes. The CIP post-tensioned box girders, built on soffit fill and ranging from a depth of 9 ft 6 in. at piers to 4 ft 6 in. at abutments and cantilever end/hinge locations, make up the 80-ft back spans and 44-ft front cantilevers. The CIP box is comprised of an 8 in. top deck, a 6 in. bottom slab, and six webs that were each 1 ft thick. The total post-tensioning force for each 124 ft CIP box girder is 7910 kip, which is applied using 12 tendons with fifteen 0.6-in.-diameter strands per tendon. The design is based on a 28-day concrete compressive strength of 5.5 ksi, with a minimum strength of 3.5 ksi at time of stressing.

The design assumed the CIP portion of the bridge to be constructed on falsework, but the contractor opted

CITY OF TUCSON, OWNER

BRIDGE DESCRIPTION: Twin 344-ft three-span bridges combine cast-in-place, post-tensioned concrete box girders for back spans and cantilevers and drop-in precast, prestressed concrete box girders of standard and custom shapes for the portion of the center span directly over the 22nd Street travel lanes. Each bridge is 42 ft 8 in. wide and carries two lanes of traffic.

STRUCTURAL COMPONENTS: Flared, fluted cast-in-place concrete single-column piers, nominally 10 ft in diameter at top and 8 ft at bottom. Stub abutments behind retaining walls on cast-in-place concrete spread footings. Cast-in-place, post-tensioned concrete box girders comprised of an 80-ft back span and a 44-ft cantilever. Drop-in precast, prestressed concrete box girders are 91-ft-long with topping slab. The interior girders are 4 ft wide and the exterior girders are a trapezoidal shape.

BRIDGE CONSTRUCTION COST: \$2.8 million (not including retaining walls), \$96/ft^2

AWARDS: American Council of Engineering Companies, Arizona Chapter – 2015 Grand Award Winner; American Public Works Association, Southern Arizona Branch – 2016 Public Works Project of the Year; Structural Engineers Association of Arizona – 2016 Excellence in Structural Engineering Award of Merit to construct the CIP portions on soffit fill supported by jersey barriers. This required the abutment, piers and tier 2 walls to be buried within the temporary soffit fill.

The 4-ft-deep drop-in precast, prestressed concrete box girders are 91 ft long and fill in the center portion of the 179-ft-long center span directly over the 22nd Street lanes. The interior and exterior beams have dapped ends and are designed for a 28-day concrete strength of 6 ksi and 5 ksi minimum at time of transfer. The interior beams are standard 4-ft-wide beams with vertical webs. The exterior beams are custom shaped with a sloped exterior web to match the exterior web of the CIP box girder.

The use of precast, prestressed concrete box girders was paramount to the design so that 22nd Street traffic did not need to be detoured off its current alignment during construction. After the CIP portion of the bridge was complete and the soffit fill removed, 22nd Street traffic was shifted to the south under the CIP portion of the bridge. The precast, prestressed concrete girders were placed in 2 days—1 day for the southbound bridge and 1 day for the northbound bridge—with no 22nd Street traffic detours required.

The soil conditions at the site made it possible to utilize shallow foundations. A stub abutment founded on fill instead of a full-height abutment was made possible by using a tiered-wall system.

These complex and innovative three-span bridges that were built in multiple construction phases, were the culmination of approximately 10 years of planning and design with the city of Tucson and the project's CAC. The bridges met the primary design criteria of efficiency in cost, structural design, maintenance of traffic, material use, staging, and construction. Evidence of these efficiencies is the contractor's bid price, which was 25% less than the engineer's estimate, and the fact that no traffic detours were needed around the construction zone.

The CIP post-tensioned box back spans were designed to maximize span while minimizing concrete volumes. Precast concrete elements were used to avoid interrupting traffic and to limit direct labor for the CIP falsework, forming, and finishing. A longer bridge was designed to minimize fill and accommodate tiered retaining walls in front of the abutments, mitigating the appearance of a single, tall abutment wall. Spread-footing abutments were founded on fill behind these tiered retaining walls, avoiding the need for deep foundation types. Soffit fill was used in lieu of falsework for the CIP post-tensioned box construction, with stepped temporary retaining walls made from jersey barriers retaining the fill.

The structural design met the project's budget criterion: the engineer's estimate was \$3.9 million while the contractor's bid price was \$2.9 million, which equates to a very efficient \$96/ft^2. The structural design met the critical maintenance of traffic objective by maintaining traffic operations at 80% of their typical volume throughout. The project also met all of Tucson's and the CAC's contextual objectives.

The structural design addressed three key and unusual challenges for the project:

- "No falsework over travel lanes" was a key requirement from a traffic flow and safety perspective.
- "No substantial impact/detouring of traffic operations through the intersection" was essential during construction.
- The use of a SPUI meant that the Kino Parkway bridge had to span the entire intersection, 175 ft, to accommodate all turning movements.

These led to the creative structural design and construction methodologies described. This unique structural system combination and its construction phasing allowed 22nd Street to remain open to traffic during the construction of the bridge. In the end, the structural design met the challenging SPUI requirements for a large clear span and minimal structure depth over the traffic lanes, and also met the length of span requirements to minimize high, lengthy retaining walls.


Stressing a post-tensioning tendon in the cast-in-place box. Photo: Structural Grace Inc.

Throughout a five-year rigorous research and structure selection process, three different structure type alternatives were studied. To maximize efficiency in structural design the precast, prestressed concrete box was designed as a simply supported beam that connected the CIP post-tensioned box girders to complete the main span. This allowed for 22nd Street to be detoured under the new CIP post-tensioned box so that the precast, prestressed concrete box girders could be erected over the existing 22nd Street without detouring traffic off 22nd Street. The structural design of the bridge maximized the efficiency of CIP post-tensioned box cantilevers by using a phased construction program to account for staging of construction to build efficiency into the design.

The interchange was recently named after Mayor Robert Walkup, who served as mayor of Tucson from 1999 to 2011. Among his many achievements, he spearheaded the 2006 Regional Transportation Authority Plan that provided for \$2.1 billion of vital transportation and transit improvements, including this magnificent interchange.

Jim Glock is the Tucson office manager and Claudia Perchinelli is the bridge designer and president of Structural Grace Inc. in Tucson, Ariz.

AESTHETICS **COMMENTARY**

by Frederick Gottemoeller

A single-point urban interchange (SPUI) is an aesthetic challenge. The distance required to span the left-turn lanes is a stretch for girders; the girders are made very deep. Often, their depth is as much as 50% of the vertical clearance. The opening below the bridge frequently looks squashed. On the cost side, the greater structural depth raises the profile, lengthening the ramps. One alternative would be a three-span structure to reduce the structural depth over the lower roadway. However, that option results in side spans with nothing to put under them—a seeming "waste of space." Therefore, it is rarely tried.

The designers for the Kino Parkway Bridge Overpass at 22nd Street took a careful look at all of these factors and decided that the conventional wisdom for how best to span a SPUI might be wrong. It turns out that their three-span structure is both economical and attractive. During construction, "wasted" space under the side spans allowed for maintenance of traffic. Afterward, the space was used for terraced, curved retaining walls that soften the appearance of the interchange, reduce the height of the abutment wall, and create a place for landscaping.

However, the biggest payoff is in the thinner main span, which opens up for drivers on 22nd Street the views through the bridge to the urban core beyond and makes the bridge seem lighter and more graceful. In addition, there is always a visual benefit when the shape of the structure demonstrates how the bridge is working; in this case, the depth of the bridge is the greatest over the piers, where the moments are the highest. People, even non-engineers, have an intuitive sense of structure. Where their intuition tells them the forces are the highest, they expect the bridge to look the sturdiest. Seeing their intuition matched by the shape of the bridge is always satisfying. The addition of the fluted feature on the girder web above the piers reinforces that satisfaction by drawing attention to the region of force concentration.

The flutes on the piers and the various art features draw strong shadows in the Arizona sun, making them recognizable at a distance, while the repetition of the flutes on all parts of the project ties the whole ensemble together. That makes the bridge and the interchange a memorable place, which makes the urban core around them memorable as well.

PROJECT

Oakley C. Collins Memorial Bridge Design Development

by Dr. Steven L. Stroh, AECOM

The new Oakley C. Collins Memorial Bridge over the Ohio River between Ironton, Ohio, and Russell, Ky., replaces an aged bridge that opened in 1921. The original Ironton-Russell Bridge was a cantilever through truss bridge with a 725-ft main span. This bridge was at the end of its useful life and was rated both functionally and structurally obsolete. The bridge was restricted to vehicle widths of 7 ft 6 in. because of geometry restrictions, and was load-limited to 26 tons. Because of fatigue and fracture concerns, the bridge was continuously monitored.

In 2003, the Federal Highway Administration issued a record of decision (ROD) for a replacement bridge on a new alignment. A design was developed for a new single-tower two-span cable-stayed bridge with a steel edge girder structural system and a 950-ft main span. This design was bid in 2006. The low bid was $109.8 million, whereas the state's budget estimate was $80 million. It was decided not to award the project and to implement a value-engineering process to try to get it within budget.

Value Engineering

The value-engineering process evaluated the current design and opportunities for optimization, assessed the project criteria driving the bridge type selection, and evaluated opportunities to refine the design solution within the requirements set by the ROD.

The value-engineering team concluded that it was not possible to refine the original design solution, a single-tower cable-stayed bridge, to achieve the budget goals. A more comprehensive redesign would be required to achieve project goals. This included redesign as a balanced three-span two-tower cable-stayed bridge (which required reassessment of U.S. Coast Guard requirements on tower placement), change to a concrete superstructure, a reduction in typical section to the minimum required by the ROD, and improving the bridge alignment to facilitate the three-span bridge arrangement. As an outcome of this evaluation, the project was advertised for redesign in 2008.

Reassessment of Navigation Requirements

The original two-span cable-stayed bridge concept was driven by a navigation requirement that the pier (or tower) on the Ohio River bank could be no more than 50 ft from the bank. Because of the curving alignment as the bridge reaches the Ohio shore, a tangent alignment in the side span was precluded, which led to the decision for a two-span arrangement to keep the cable-stayed portion of the bridge out of a horizontal curve. As part of the value-engineering assessment, it was determined that with a slight realignment and, if the tower could be moved 100 ft off the Ohio-side bank, a tangent alignment for the side span for a three-span cable-stayed bridge could be accommodated.

The U.S. Coast Guard was open to this reassessment and suggested navigation simulations to determine the acceptability of the tower location. Independent simulations were performed over a two-day period with three licensed river pilots piloting a 15-barge tow under a simulated bridge under a variety of navigation conditions. These included day and night, upstream and downstream, loaded and unloaded, and various river stage, flow, and wind conditions. The control simulations were run with the existing bridge; the new bridge was then inserted in the simulation with the tower at various distances from the Ohio-side bank and with varying skew angles for the tower. All simulations were run in the presence of U.S. Coast Guard personnel.

The results of the simulation with the tower located 100 ft from the Ohio bank were favorable. Additional simulations were run with the tower 150 ft from the Ohio-side bank, which were also found to be acceptable from a river navigation viewpoint. As a result of the simulations, the U.S. Coast Guard approved the

profile

OAKLEY C. COLLINS MEMORIAL BRIDGE / IRONTON, OHIO

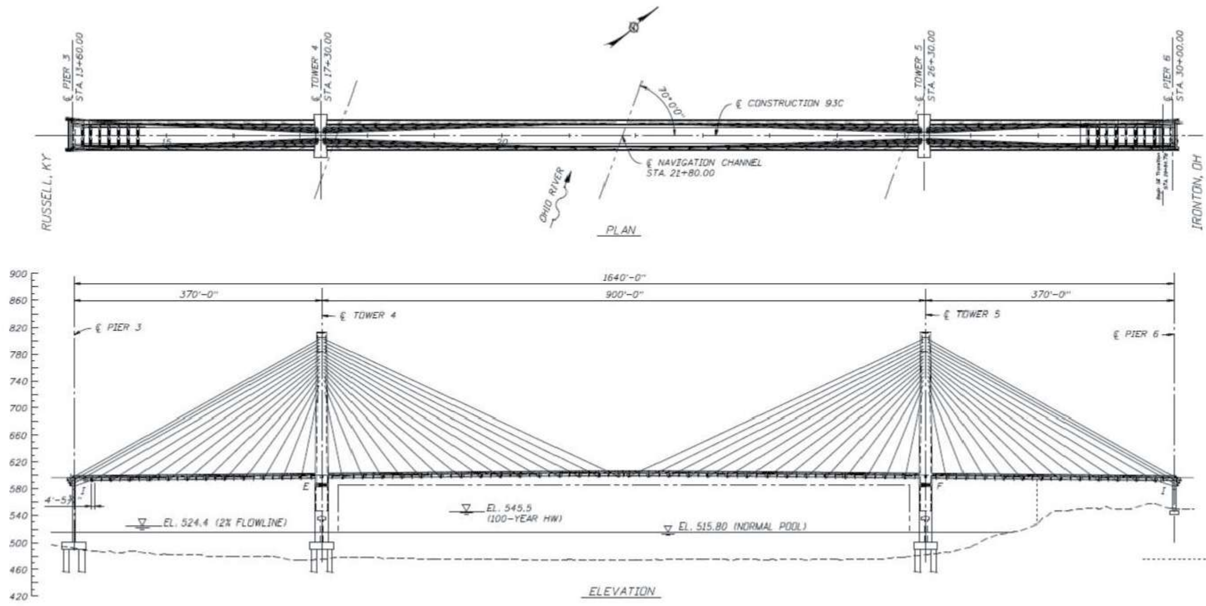
BRIDGE DESIGN ENGINEER: AECOM, Cincinnati, Ohio

NAVIGATION SIMULATIONS: Seaman's Church Institute, Paducah, Ky.

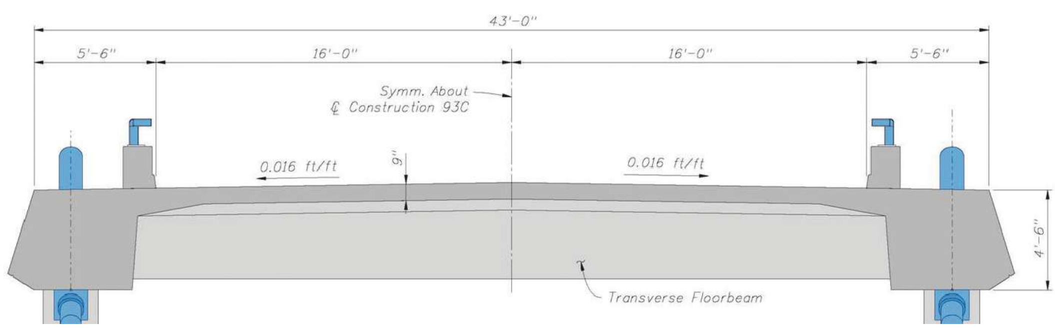
PRIME CONTRACTOR: Brayman Construction Corporation Heavy Civil & Geotechnical Contractors, Saxonburg, Pa.

CONTRACTOR CONSTRUCTION ENGINEER: Finley Engineering Group, Tallahassee, Fla.

CONSTRUCTION ENGINEERING AND INSPECTION: FIGG, Tallahassee, Fla.



Bridge plan and elevation. All Photos and Figures: AECOM.



Typical deck section, showing concrete edge girders, transverse floor beams, and deck.

location of the Ohio-side tower 150 ft off the Ohio bank, allowing two towers to be constructed perpendicular to the bridge alignment (20-degree skew to the river).

Project Design Details

The final configuration for the bridge is a symmetrical three-span cable-stayed bridge with a 900-ft main span and 370-ft side spans. The bridge is entirely on a tangent alignment. The design methodology is that the superstructure is restrained laterally and longitudinally at the Kentucky-side tower, restrained laterally but free to translate longitudinally at the Ohio-side tower, and constructed integrally at the two anchor piers. Expansion joints are provided at the two anchor-pier locations.

The superstructure typical cross section is a cast-in-place concrete edge girder/floor beam arrangement. With the modest traffic demands at this site, only a two-lane roadway is required. The 32-ft-wide deck cross section provides two opposing 12-ft-wide traffic lanes and two 4-ft-wide shoulders. The superstructure was designed as a conventionally reinforced concrete member.

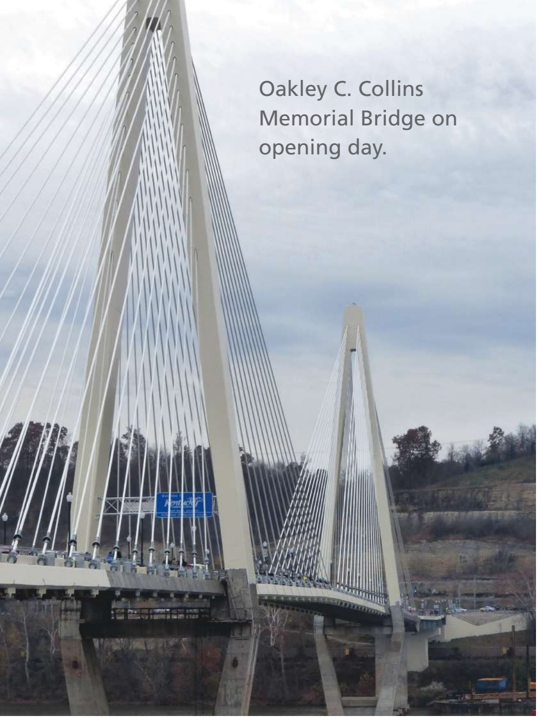
Two planes of stay cables are anchored at the edges of the concrete deck. The stay cables are arranged in a semi-fan pattern and are individually anchored at the girder and tower. The stays are spaced at 29 ft 3 in. in the main span and 28 ft 3 in. in the side spans, with three closely spaced backstay cables at the anchor piers. The cables range from fourteen to thirty-five 0.6-in.-diameter Grade 270 low-relaxation strands each.

OHIO DEPARTMENT OF TRANSPORTATION, OWNER

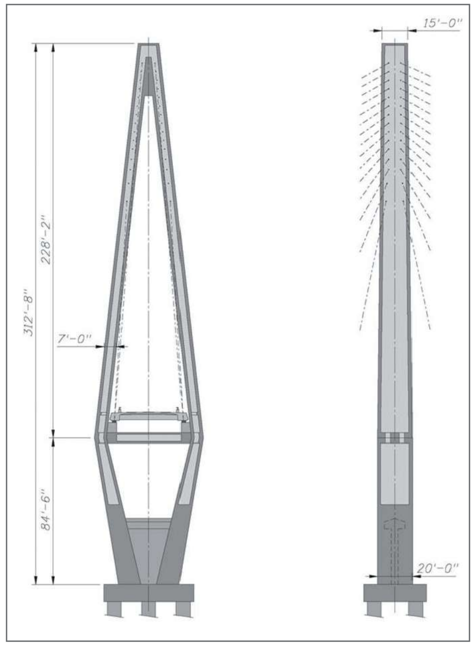
BRIDGE DESCRIPTION: Three-span concrete cable-stayed bridge with a 900-ft main span

STRUCTURAL COMPONENTS: 8.5-ft-diameter drilled shafts for foundations; cast-in-place concrete piers and towers. Superstructure is a concrete edge girder/floor beam arrangement with precast concrete components, including selected floor beams and stay-cable anchorages.

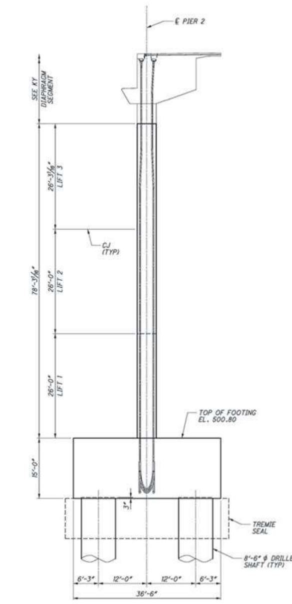
BRIDGE CONSTRUCTION COST: (low bid) $81.2 million



Oakley C. Collins Memorial Bridge on opening day.



Tower elevations.



Anchor-pier elevation.

The strands are individually greased and sheathed in a high-density polyethylene (HDPE) encasement, then are bundled together in an outer HDPE sheath. The outer sheath has a helical rib to help mitigate any wind/rain-induced cable vibrations. The design specified additional damping to be provided for each stay cable, and provided damping, power dissipation, force, displacement, and velocity parameters for each cable.

The 312-ft-tall towers are hollow, conventionally reinforced rectangular members forming a diamond shape. The cast-in-place tie element below the deck is post-tensioned with eight tendons, each consisting of nineteen 0.5-in.-diameter Grade 270 strands. The stays are anchored in fabricated steel box assemblies that constitute the inner form for the upper regions of the tower. The towers are founded on six 8-ft 6-in.-diameter drilled shafts with 8-ft-diameter rock sockets. Tower footings are submerged below the draft of barges at normal pool elevation and were constructed in cofferdam foundation forms with a bottom form and seal.

The anchor piers are integral with the cable-stayed superstructure and are slender members that flex in response to displacement demands. The anchor piers are vertically post-tensioned with U-shaped tendons that extend into the foundations. There are eight tendons, each consisting of twenty-seven 0.6-in.-diameter strands in each anchor pier providing the hold-down restraint of the superstructure. The hold-down restraint is provided by the mass of the anchor-pier assembly.

Aesthetics

The aesthetics of the Oakley C. Collins Memorial Bridge were developed following the functional requirements of the bridge, but also focused on providing good proportioning and detail. The bridge is a very tall and narrow structure, which provides certain elegance to the design. This is emphasized by providing clean, simple shapes. The towers are the dominant feature of the design and have a slender diamond shape. A transverse taper in the tower leg cross section is provided below deck level. Above deck level, the tower legs taper in the longitudinal direction, providing good visual balance for the tall tower legs. The superstructure leading-edge detail provides a slope break at middepth to provide a shadow line and accentuate the slenderness of the deck. The choice of a steel railing barrier also contributes to a slender superstructure profile. The final choice of internal stay dampers reinforces the clean lines of the structure, avoiding the clutter of external stay-anchor details.

Durability

The durability design of the Oakley C. Collins Memorial Bridge was developed based on a holistic approach to the practical decisions on material choice and detailing. Concrete was selected for the superstructure, in part due to its projected low future maintenance needs. Epoxy-coated reinforcing steel was used throughout the structure and an initial deck overlay was provided. Mass concrete was controlled to a maximum placement temperature of 180°F, and no greater than 35°F differential between the exterior surface and the core.

Construction

The Oakley C. Collins Memorial Bridge was successfully bid in January 2012. The engineer's estimate for the redesigned bridge was \$84.6 million and the low bid was \$81.2 million. The project was awarded with a notice to proceed on February 3, 2012. The contractor took advantage of flexibilities built into the design and contract documents to tailor the means and methods of construction, including some design revisions, to optimize construction.

The Oakley C. Collins Memorial Bridge was opened to traffic on November 23, 2016.

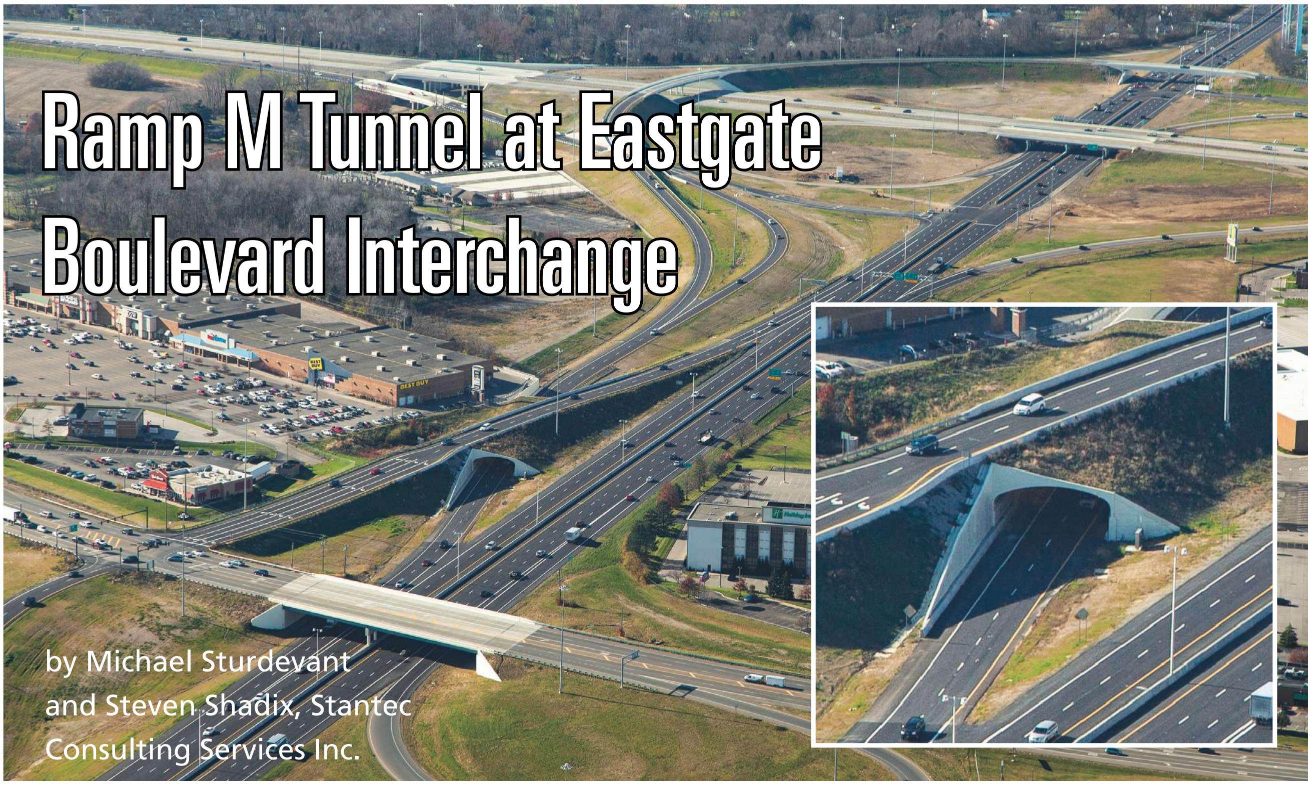
Dr. Steven L. Stroh was the lead design engineer for the Oakley C. Collins Memorial Bridge and is the national practice lead for long-span and complex bridges for AECOM in Tampa, Fla.

EDITOR'S NOTE

Details of the means and methods of construction of this project, including a discussion of the innovative precast stay anchorages that were designed by the contractor's construction engineer to help expedite construction, are covered in an article on p. 38 of this issue.

Ramp M Tunnel at Eastgate Boulevard Interchange

by Michael Sturdevant and Steven Shadix, Stantec Consulting Services Inc.



Aerial view of project site. Tunnel indicated near center of photo. Photo: ©1800topsite.com.

Over the past 35 years, many communities along the 85-mile Interstate 275 (I-275) beltway, which extends through Ohio, Indiana, and Kentucky, have experienced significant growth. Nowhere is this more apparent than on the eastern portion of the beltway, in the Eastgate commercial district of Union Township in Clermont County, Ohio.

The existing partial cloverleaf interchange of I-275 and State Route (SR) 32 servicing this area is the preferred route for residents from the east traveling to employment centers around Cincinnati. However, the area was plagued by severe traffic congestion during rush hour, resulting in numerous accidents. The situation was primarily caused by the weave of traffic on SR 32 between the exit and entrance ramps of the cloverleaf, as well as the weave of eastbound SR 32 traffic attempting to exit onto Eastgate Boulevard, just 0.5 mi east of the interchange.

The Ohio Department of Transportation determined a redesign of the interchange was required to reduce the congestion and number of accidents. After extensive study, the preferred solution for the redesign of the interchange involved eliminating two loops of the cloverleaf, adding a flyover ramp, revising two entrance ramps, and reworking the interchange at Eastgate Boulevard. The revised interchange layout with ramp braiding required seven new bridges, several with significant skews relative to the crossing roadway.

At one proposed bridge, carrying entrance ramp D to Eastgate Boulevard over the exit ramp M from I-275, the skew between the crossing roadways was approximately 70 degrees. While studying various layouts for different bridge types, engineers determined that the severe skew would significantly impact the span lengths, construction procedures, construction costs, and the durability of the bridge. An alternative to a bridge was needed. The design team proposed a tunnel consisting of a precast concrete three-sided culvert supported on cast-in-place concrete walls. Each section was 4 ft wide and weighed approximately 22.7 tons. This buried structure eliminated the skew issues, and reduced both the construction cost and maintenance cost over the life of the structure.

The resulting structure consists of a precast concrete arch or three-sided culvert, with a clear span width of 48 ft

profile

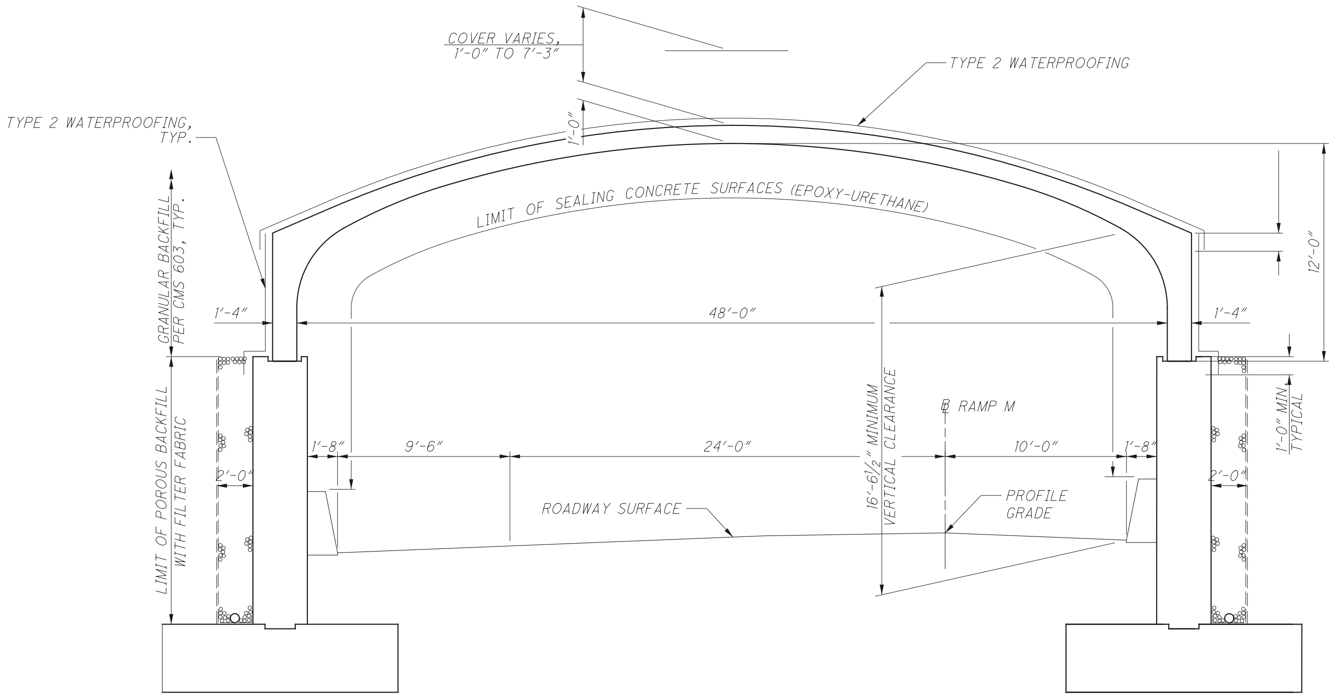
RAMP M TUNNEL AT EASTGATE BOULEVARD INTERCHANGE / CINCINNATI, OHIO

BRIDGE DESIGN ENGINEER: Stantec Consulting Services Inc., Cincinnati, Ohio

PRIME CONTRACTOR: John R. Jurgensen Company, Cincinnati, Ohio

PRECASTER: Contech, West Chester, Ohio

OTHER CONSULTANTS: Lighting design: AECOM (formerly URS Corporation), Akron, Ohio; Geotechnical: Gannett Fleming Inc., Columbus, Ohio



Typical section of tunnel. Figure: Stantec.

and a rise of 12 ft, that sits on cast-in-place concrete walls. The tunnel length was set to accommodate headwalls located just outside the concrete barrier along ramp M, resulting in a total length of 268 ft.

To provide sufficient clearance (16.5 ft minimum vertical) for traffic through the structure, the three-sided precast concrete structure sits on top of cast-in-place concrete walls that are approximately 19 ft high. A 3-in.-deep groove is formed into the top of the cast-in-place concrete walls, about 6 in. wider than the leg of the three-sided unit. The precast concrete section is set in the groove and grouted in place. There are no anchors or reinforcement attaching the precast concrete unit to the cast-in-place concrete walls, so it is a hinged connection. The walls are 3 ft thick to accommodate the base of the precast concrete section. The structure is supported on spread footings founded on bedrock. Approximately half the length of the structure is on a 5-degree 45-minute curved alignment to match the roadway passing through the structure; the remainder is on a tangent alignment. The roadway through the structure consists of two 12-ft lanes with 10- and 4-ft shoulders.

The tunnel was constructed by the open-excavation method. The sides of the excavation were laid back where possible, with only a short length of temporary sheet piles used where necessary to protect an adjacent parking lot. The end sections were supported temporarily during construction due to the weight of the headwalls along the outside edge of the section. The headwalls were detailed in the plans as cast-in-place concrete; however, the contractor elected to use precast concrete headwalls. The two headwalls varied greatly in height due to the extreme skew, ranging from 13 ft 3 in. to 1 ft 0 in. This made design and fabrication of the precast concrete headwalls more challenging.

Three of the wingwalls for the tunnel were designed using mechanically stabilized earth walls because a new embankment was being placed behind these walls. The walls varied in height from 3 ft to 33 ft. The fourth wingwall, which varied in height from 8 ft to over 20 ft, was designed using a soldier-pile wall with hardwood lagging to support an existing parking lot drive and building. To enhance the aesthetics of the structure, a concrete facade was added to the soldier piles when the excavation was completed.

OHIO DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: A 268-ft-long precast concrete three-sided arch culvert sections with 48-ft-long clear span and 12-ft-high rise on cast-in-place concrete walls

STRUCTURAL COMPONENTS: 69 precast concrete arch sections, 708 yd^3 of concrete in walls, 948 yd^3 of concrete in wall footings

BRIDGE CONSTRUCTION COST: $2.5 million on a 28-month construction schedule, which was completed in September 2015

East end of tunnel during construction. Note precast concrete headwall and temporary supports below precast concrete end section. Photo: Stantec.

View of completed tunnel looking east, with computer-controlled lighting system. Photo: Stantec.

Long-term durability of a structure is always a goal of the client and the designer. To improve durability, the Ohio Department of Transportation requires the use of epoxy-coated reinforcement in all precast concrete three-sided culverts, as well as in all cast-in-place concrete. To further enhance the durability of the structure, a rubberized asphalt peel-and-stick membrane was applied to the exterior surfaces on the top and sides of the precast concrete sections after they were placed. On the interior faces, an epoxy-urethane sealer was applied to both the precast and cast-in-place concrete surfaces to protect the concrete from deicing materials during the winter.

Due to the length of the structure, lighting was required to assist the driver while passing through the tunnel. A computer-controlled lighting system was installed inside the tunnel that adjusts the intensity of the lights throughout both day and night, providing safe passage for motorists.

Rehabilitating two interchanges immediately adjacent to one another in a large retail and office environment was challenging. The key was to design a transportation plan that provides safeguards to local business, while at the same time preserving the corridor's vitality and ensuring that it satisfies the safety and traffic flow concerns of motorists. The flow of traffic has significantly improved due to the new geometry and ramps, with the tunnel providing a unique entry point into the Eastgate commercial area.

Michael Sturdevant is structural engineering manager and Steven Shadix is an associate, both with Stantec Consulting Services Inc. in Cincinnati, Ohio.

New Light on an Old Practice

by Hugh Ronald, RS&H

Simple-span bridges are often combined with pile-bent construction. Together, they provide one of the most cost-effective solutions for the design of short- or medium-span structures. But often overlooked, or not considered, is the longitudinal stiffness afforded to pile bents when the superstructure is continuous over multiple piers or pile bents and a double row of bearings over each pier/bent is used. Though each span is typically designed for simple-span behavior, the bridge deck may be cast continuously across multiple bents to avoid frequent expansion joints[1] or because continuous-span behavior is desired for live loads. A continuous deck over a double row of bearings provides a quantifiable stiffness. And the mechanism by which the pile-bent stiffness is acquired is fairly straightforward.

Consider the action of a 100-kip braking force on the deck of a four-span unit. If the substructure consists of five pile bents, all about the same height and embedded in the same strata, you would expect all bents to attract the same longitudinal load, or about 20 kips per bent. But that does not occur if each interior bent is provided with a double row of bearings and a continuous deck above. Instead of articulating as free cantilevers with increasing lateral displacement, the pile-bent caps at the interior bents will remain essentially level—that is, not rotating—due to the resisting moment developed from the couple generated between the two rows of bearings. The vertical load developed on the trailing row of bearings will be greater than the vertical load on the leading row of bearings.

This stiffening results from reverse curvature of the piles in the interior pile bents with two rows of bearings. It yields significantly improved strength, reduced displacement, and redistribution of the braking force to the stiffened interior pile bents. Quantitatively, reverse curvature of a pile leads to an effective halving of its *KL*/*r* ratio and can mean the difference between a stable or unstable foundation, or permit use of slender plumb piles without battering.

The effect of the stiffening is illustrated by the two identical bridges with four equal spans that are shown in the figure below; the top bridge has a single row of bearings on each bent cap (case 1), while the bottom bridge has a double row of bearings on each bent cap (case 2). Longitudianl displacements and bent reactions for the two bridges when subjected to the same 100 kip longitudinal braking force are also shown. These results were obtained using software that employs an iterative *p-y* analysis of the soil-structure interaction (including nonlinear structural effects). The behavior demonstrated by the software is well documented.[1]

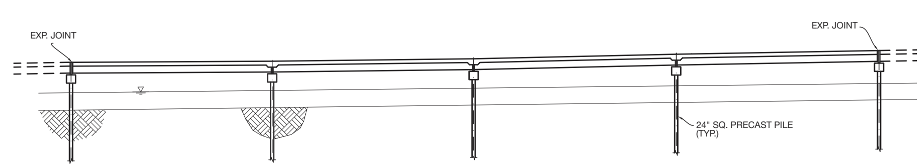
Significance

So what does this mean? It means one can often eliminate battered piles. Battering of piles will seldom achieve the same result as stiffening of the pile bent with a double row of bearings. But the torsion generated by restraint of rotation must be accommodated by proper detailing for pile-to-cap fixity. Analysis is necessary to quantify the magnitude of the torsion that must be resisted between cap and pile, and uplift at bearings must not be permitted.

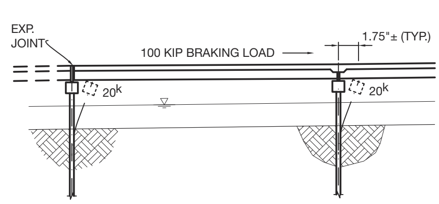
Reference

1. Podolny, W., and J. M. Muller. 1982. *Construction and Design of Prestressed Concrete Segmental Bridges*. New York, NY: John Wiley & Sons.

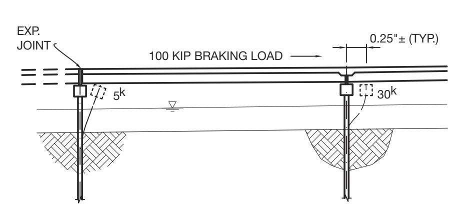
Hugh Ronald is a senior design-build engineer for RS&H in Orlando, Fla.



Example of a four-span continuous bridge.



Case 1
A single row of bearings on the centerline of each bent (or a double row of bearings without a continuous deck)



Case 2
A double row of bearings over the interior pile bents with a continuous deck

Comparison of stiffening behaviors of pile bents using single-row bearing versus double-row bearing. Figure: RS&H.

Precast Concrete Overhang Panels for Safer and Faster Bridge Deck Construction

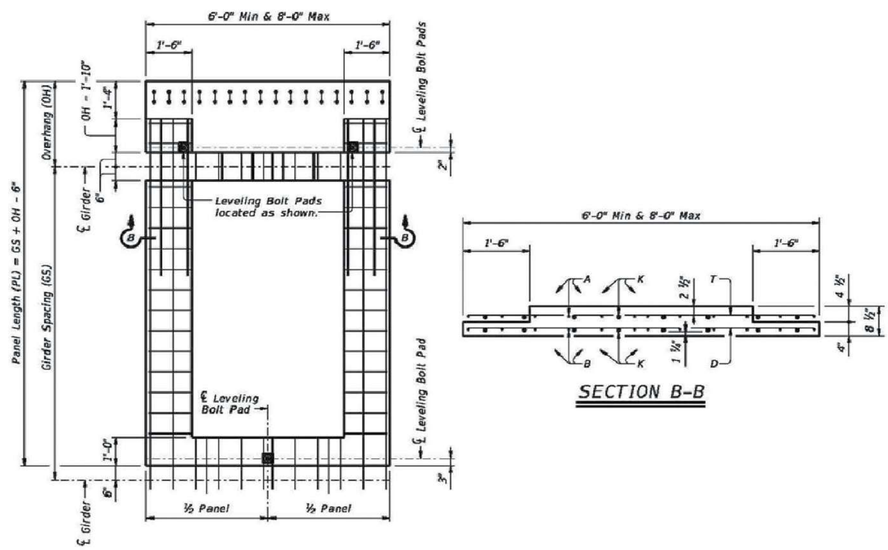
by Kevin Moyer, Texas Department of Transportation

The Texas Department of Transportation (TxDOT) constantly seeks innovative accelerated bridge construction methods that reduce the impact to the traveling public, improve safety in the work zone, and reduce costs. TxDOT began developing deck construction methods using precast, prestressed concrete panels (PCPs) in the 1960s, and these methods continued to evolve. In 2008, TxDOT sponsored a research project[1] to develop a precast, prestressed concrete overhang panel system for potential use in bridge construction.

This panel system was successfully implemented on the Farm-to-Market Road 1885 Bridge over Rock Creek in Parker County, Tex. The result was an improvement in safety due to the sturdy work platform provided by the panels, and elimination of the need for overhang brackets and formwork. TxDOT recently implemented the "second generation" of conventionally reinforced precast concrete overhang panels [PCP(O)s] on a bridge on Farm-to-Market Road 726 over Brushy Creek in Marion County, Tex.

The panel dimensions for the second generation of PCP(O)s vary from 6 to 8 ft in width (longitudinal direction of bridge) and 6½ to 13½ ft in length (transverse direction of bridge). The minimum width accommodates the development length of the reinforcement along the width of the panel. The maximum width keeps the panel within the transportation width limits so a permit is not required.

Two types of panels were designed: one for the interior of the span and one for the thickened slab at the ends of units. The full-depth panels (8½ in.) have conventional reinforcement and a full-depth gap over the exterior girder to integrate the PCP(O) with the girder after cast-in-place (CIP) concrete deck placement. The panels also have the ability to:



Plan view and typical section of a precast concrete overhang panel. All Photos and Figures: Texas Department of Transportation.

- be used with variable girder spacing,
- accommodate a sealed expansion joint,
- adjust their elevations with leveling bolts instead of the use of dense foam, and
- integrate with adjacent PCP(O)s and CIP concrete.

The main improvement of the second generation of PCP(O)s over the first generation is a full-depth gap that runs the entire width of the panel (along the girder), which eliminates the need for shear pockets and a separate grouting operation. Additionally, the partial-depth panel ledges allow for reinforcing steel that enables the adjacent PCP(O)s and the CIP deck concrete to work as a unit.

The ledges of the panels are 1 ft 6 in. wide and run the length of the panel, except for 1 ft 4 in. in the overhang region. The ledges that integrate the interior deck concrete are 1 ft wide and run the width of the panel. The main design challenge was designing the full-depth gap to handle stresses induced from lifting, transportation, CIP concrete deck placement, and stability during leveling. The panel was analyzed as a beam with different support conditions for each stage to determine the amount of reinforcing steel needed to stabilize the gap.

Another second-generation improvement is the leveling system, which consists of three leveling pads with coil bolts. Designed to support the panel during leveling, the leveling pad is a 4 × 4 × ¼-in. steel plate with a coil nut and 3-in. -diameter steel pipe welded to the plate. After the panel is leveled to the correct elevation, additional support needs to be provided by welding the gap reinforcing bars to the R-bars of the TxGirders or by placing a grout pad at the PCP(O) corners. The coil bolts may be left in place as long as the tops of the bolts are 2½ in. below the top of the deck. Unlike PCPs, PCP(O)s use an elastic polyurethane foam

Precast concrete overhang panel fabrication and completed panel.

Precast concrete overhang panel placement.

strip that is only used to contain the CIP concrete during deck placement.

The Brushy Creek Bridge project consists of two 90-ft spans, is 34 ft wide, has four girder lines, uses conventional PCPs between interior girders, and has no skew. The primary contractor was Longview Bridge and Road (LBR). The concrete for the panels was placed in two lifts which were approved by TxDOT as long as supplementary reinforcement was used to integrate the lifts. There were two challenges: the "notch" in the overhang region hindered the stripping of the forms, and the custom-made leveling pads were expensive components.

LBR erected most of the 24 east span PCP(O)s in approximately six hours, or approximately 15 minutes per PCP(O). With proper planning and equipment, all the panels, PCP(O)s and PCPs could have been placed in one day. LBR chose to support the panels after leveling with a grout pad.

The deck concrete placement took an average of four hours per span, due to concrete truck delays; this time could be reduced. LBR used both a longitudinal screed and transverse screed. The transverse screed was preferred for its ease of removal. The transverse screed spanned only the PCPs, not the entire bridge width. "Bridges" were made of 2 × 4 lumber to run the transverse screed over the PCP(O) ledges. Approximately 6 months after construction, the deck shows no signs of cracking at the cold joints where the deck concrete was placed against the PCP(O)s or at the panel joints.

The type of concrete used in the PCP(O)s and PCPs was TxDOT's Class H concrete (f'_c = 4 ksi) and the CIP deck concrete was Class S concrete (f'_c = 4 ksi). No special requirements were required to bond the CIP deck concrete and the PCPs and PCP(O)s, except for a roughened surface. The deck was ground approximately ½ in. to improve ride quality in the region of the PCP(O)s.

The use of PCP(O)s successfully decreased construction time on Brushy Creek Bridge by approximately three days by eliminating the need to erect and disassemble overhang brackets, and decreasing the time needed to place and finish the CIP concrete deck. PCP(O)s also made the work site a safer environment by decreasing the chance of workers falling while erecting and disassembling the overhang brackets. The panels provided a convenient work platform and convenient location to place a screed rail. Because the PCP(O)s were full- to partial-depth, they decreased the amount of CIP concrete used for the bridge deck as well as the amount of labor required to place and finish the deck.

Looking ahead, TxDOT will continue to use and improve on the second generation of precast concrete overhang panels, especially for projects requiring safer, faster bridge construction.

Reference

1. Trejo, D., M. Hite, J. Mander, T. Mander, M. Henley, R. Scott, T. Ley, and S. Patil. 2008. *Development of a Precast Bridge Deck Overhang System for the Rock Creek Bridge*. Report 0-6100-2, Texas Transportation Institute: College Station, TX.

Kevin Moyer is a transportation engineer in the bridge division of the Texas Department of Transportation in Austin, Tex.

Precast Concrete Innovations for a Cast-in-Place Cable-Stayed Bridge

by Craig Finley, Finley Engineering Group Inc.

Ohio's Ironton-Russell Bridge replacement, renamed the Oakley C. Collins Memorial Bridge, opened to traffic in November 2016. As with many complex projects, the road leading to the bridge follows a much straighter path than the one blazed by the construction team to create this stunning cable-stayed bridge crossing the Ohio River.

Starting with pre-bid engineering, the construction team worked together to identify the most challenging, time-consuming, and risky aspects of the project. Developing solutions to these issues led to a change in the construction scheme that required casting the back spans on falsework to eliminate the use of two form travelers. The modifications allowed the main span to be cast-in-place using a segmental, unidirectional cantilever method. To accomplish this, several innovative precast concrete solutions were developed to realize the new construction sequence. This included incorporating the contractor's strengths, equipment, and technology with the pioneering application of traditional precast concrete, as well as custom-designed adaptations to conventional construction means and methods.

Precast Concrete Innovations

This project benefited from the strengths of precasting by incorporating the following details at key areas to enhance the constructability of a traditional cast-in-place cable-stayed bridge design:

- precast concrete transverse beams
- precast concrete cable stay anchorage blocks
- precast concrete footing coffercell forms

Precast Concrete Transverse Beams

Revising the construction sequence to cast the back span on falsework had huge advantages to the project schedule and construction access. It allowed the back-span superstructure to be cast well in advance of the unidirectional cantilever construction for the main span. A large side benefit was creating access to the pylon from the deck level to simplify construction of the pylons early in the schedule. The use of precast concrete transverse beams provided the same benefits realized on routine bridge construction for the casting of the back-span superstructure deck. In addition, by providing a clear span between edge girders, a greatly simplified falsework system could be used that only required support at the edge girders.

Constructing the back spans on falsework simplified construction, reduced construction time, increased project safety, and reduced the amount and size of the equipment required for the pylon and main span construction on the

Precast concrete coffercells being lowered into place. Photo: Brayman Construction Corporation.

Precast concrete anchor block being lowered into place. Blocks are tied down to the traveler using threaded bars and then surveyed to ensure correct position. The cable-stay installation can then begin. Photo: Finley Engineering Group.

project. The falsework was also designed as a modular system, allowing it to be used for both the Kentucky and Ohio approaches.

Precast Concrete Stay Anchorage Blocks

Placement of cable stay anchorages, blockouts, guide pipes, etc., along with the congested reinforcement for the anchorage zone is typically a time-consuming challenge in segmental cable-stayed bridges that controls the speed of segment production. The design of an innovative precast concrete stay anchor block system was developed to address this issue and dramatically simplify stay cable anchorage placement. This is the first use of a precast concrete stay anchor block system in the United States. With this system, the entire stay cable assembly is cast into a full-depth precast concrete block with the edge girder cross section. This allows rapid installation of the precast concrete block set within the form traveler to the as-cast data, with four elevation geometry control points to align the stay cable anchorage. Following this, only the typical segment reinforcement is required to be placed before the segment is cast. During this project, segments could be cast within six days of casting the previous segment. This system also simplifies the form traveler because the stay cables are anchored directly to the precast concrete blocks, eliminating the need for complex temporary anchorage/transfer mechanisms.

This is the first use of a precast concrete stay anchor block system in the United States.

Precast Concrete Footing Coffercell Forms

Construction of submerged footings for the pylons within the Ohio River was a challenging task. The use of a precast concrete coffercell was one of the innovations that minimized complications, increased safety, and reduced construction time.

Precast concrete floor beams and stay-in-place deck forms saved $250,000 through value engineering change proposals. Photo: Brayman Construction Corporation.

Precast concrete coffercells were used for footings at piers 3 and 4, eliminating the need for construction of temporary cofferdams and thereby effecting schedule and cost savings. The precast concrete footing coffercells were developed to be integrated into the drilled-shaft foundation as a lost form, reducing its footprint, footing form costs, and the construction schedule, as well as minimizing excavation and its impact on the environment. These precast concrete coffercells, along with a steel sheet pile follower, were lowered onto the completed drilled shafts with a temporary hanger system attached to the drilled shaft casings. This allowed rapid installation and placement of a seal pour within the precast concrete coffercell, followed by dewatering and footing construction.

This project serves as an example of how precast concrete, together with a combination of materials and construction techniques, can provide the optimum solution for the construction of a cast-in-place concrete segmental cable-stayed bridge. Design innovations, technology, and new applications of existing materials and products will continue to play a larger role as local, state, and federal agencies look to repair, replace, and construct our nation's infrastructure at lower costs and within shorter time schedules.

Craig Finley is managing principal at Finley Engineering Group Inc. in Tallahassee, Fla.

Design innovation – precast concrete anchor blocks. Photo: Brayman Construction Corporation.

Lowering of the precast concrete coffercells. Photo: Brayman Construction Corporation.

A PROFESSOR'S PERSPECTIVE

CONTINUING EDUCATION FOR THE BRIDGE ENGINEER

by Dr. Michelle Rambo-Roddenberry, Florida A&M – Florida State University

For a professional engineer, *continuing education* refers to activities and courses taken after the university degree has been earned. Whether because of internal motivation or because they are mandatory to maintain one's employment or license, these activities should expand an engineer's skills and knowledge. Keeping one's engineering knowledge current and relevant is especially important for protecting the public's health, safety, and welfare.

Keeping one's engineering knowledge current and relevant is especially important for protecting the public's health, safety, and welfare.

Most often, engineers engage in continuing education activities or courses because it is necessary in order to maintain their professional license(s). Licensure is regulated at the state level, so each licensing jurisdiction (state board) has its own continuing education requirements. This is mandated either in the state's laws (as determined by the state legislature) or in the administrative rules (where the board is given authority by the legislature to establish its own rules). Most jurisdictions have continuing education requirements for maintaining a professional engineer's license. In August 2015, of the 56 U.S. engineering boards, 31 required 15 professional development hours (PDHs) per year, 8 required 12 PDHs, 6 required 1 to 11 PDHs, and 11 required none.

Because of ongoing efforts to promote licensure mobility and uniformity of laws and rules among states, many boards are in the process of adjusting their rules to match the continuing professional competency (CPC) standard recommended by the National Council of Examiners for Engineering and Surveying (NCEES). The NCEES CPC standard requires a licensee to obtain 15 PDHs per calendar year, of which at least one PDH must be earned from a course or activity that focuses on engineering ethics, improving a licensee's business practice/operations, or advancing professional skills/practices as applicable to the practice of engineering. NCEES's *Model Rules* (which provides licensure boards with guidelines for engineering and surveying licensing laws and ethics) Section 240.30 provides a list of qualifying CPC activities and credits, including college courses, webinars, seminars, authoring papers, and patents. (For more on NCEES, see the sidebar on the next page.)

Engineers who hold licenses in multiple jurisdictions are tasked with keeping track of hours earned for different states and license-renewal periods. In recent years, the NCEES Committee on Education helped develop a CPC tracking system to streamline this process. Launched in June 2016, the system enables a licensee to track and report PDHs for any state in which he/she holds a license. A licensee can log courses, upload documentation such as certificates of completion, list course descriptions and learning objectives, and compare with the NCEES CPC standard. The licensee can track PDHs and see a side-by-side comparison with CPC requirements for each jurisdiction in which a license is held.

NCEES CPC tracking is a free service to licensees; an engineer just needs to visit NCEES's website and create a MyNCEES account. Several jurisdictions now require their licensees to enter their CPC activities in the system. Also, the system enables a licensee to electronically send a CPC report to a board if required for renewal or audit.

When considering courses/activities to engage in, an engineer should look carefully for signs of quality.

When considering courses/activities to engage in, an engineer should look carefully for signs of quality. The educational content of the activities should not just promote or market a particular company's products or services. Consider using the NCEES Committee on Education's list of attributes of quality CPC courses and activities, which should:

- Have a clear purpose with stated and relevant learning objectives
- Be current, technically accurate, and effectively designed
- Be reviewed periodically and updated as necessary, as well as show a development or revision date
- Preferably provide an opportunity for engagement between the learner and presenter or facilitator, or assess the learning outcomes during the course or at the end of the course
- Be earned at a rate of no more than eight PDHs in a 24-hour period
- Be developed by individuals qualified in the subject matter
- Be delivered by individuals qualified in the subject matter

Many engineering societies and organizations offer quality continuing education programs, and technical institutes are no exception. Also, technical sessions are held at meetings and conferences such as the PCI Convention and National Bridge Conference, the ASBI Convention, and the PTI Convention; many of the sessions are allowed for continuing education credits and are indicated as such in the conference program. Attendance at these sessions may also be tracked and registered with a Registered Continuing Education Provider.

PCI's eLearning Center is the first education management system dedicated to the precast concrete and precast concrete structures industries. All courses offered through this system satisfy the continuing education requirements for engineers in all 50 states. PCI is currently creating web-based modules on bridge analysis and design through a partnership with the American Association of State Highway and Transportation Officials and funding by the Federal Highway Administration. It is recognized that a bridge engineer's knowledge is gained almost entirely on the job, with the possible exception of a bridge engineering course or two taken at the college level.

To help engineers with zero to five years of bridge design experience, these modules will provide in-depth explanation on loads, load distribution, manufacturing methods, materials, prestress losses, extending spans, load rating, full-depth precast concrete deck panel design, bridge geometry, and more. The modules will be released in the coming months, after a thorough review process. Many subject-matter experts have contributed hundreds of hours towards developing the modules' content, and PCI's Technical Activities Council is reviewing the modules for technical accuracy. Look for an article in a future issue of *ASPIRE*SM for more details.

NCEES

National Council of Examiners for Engineering and Surveying (NCEES) is the nonprofit organization that develops, administers, and scores the examinations used for engineering and surveying licensure in the United States. Comprised of 70 member boards (representatives of state, U.S. territory, and international engineering licensing boards), NCEES also helps to improve licensure mobility, to make it easier for engineers to obtain and maintain licenses in multiple states. At NCEES meetings and through committees, the boards work together to establish national *Model Laws*, *Model Rules* and licensing standards that boards can use in their own jurisdictions.

For more information, see http://ncees.org.

CONCRETE CONNECTIONS

Concrete Connections is an annotated list of websites where information is available about concrete bridges. Links and other information are provided at www.aspirebridge.org.

IN THIS ISSUE

https://www.tucsonaz.gov/tdot/22nd-street-kino-parkway-tucson-boulevard
This is a link to a comprehensive website for the Kino Parkway and 22nd Street Overpass project, with the history of the design process, environmental reports, and summaries of meetings of the Citizens' Advisory Committee and Technical Advisory Committee. The interchange was featured in a Project article on page 22.

http://bridgestunnels.com/bridges/ohio-river/ironton-russell-bridge
This is a link to photos of construction activities and history of the Oakley C. Collins Memorial Bridge, which is featured in Project and Construction Bridge Technology articles on pages 26 and 38, respectively.

https://www.union-township.oh.us/phocadownload/Resources/map-eastgate%20area%20improvement%206-2014.pdf
This is a link to a plan view showing the complexity of the Eastgate Boulevard Interchange featured in a Project article on page 30.

http://onlinepubs.trb.org/onlinepubs/archive/NotesDocs/NCHRP12-71_FR.pdf
This is a link to NCHRP 12-71 *Design Specifications and Commentary for Horizontally Curved Concrete Box Girder Highway Bridges,* which formed the basis for the curved, precast concrete spliced U-girders featured in the article on page 44.

https://www.pci.org/PCI_Docs/Publications/PCI%20Journal/2008/November_and_December_2008/Curved%20precast%20pretensioned%20concrete%20I-girder%20bridges.pdf
This is a link accessing the *PCI Journal* article "Curved, Precast, Pretensioned Concrete I-girder Bridges," which also includes box and U-shapes. Curved, precast concrete spliced U-girders are discussed in an article on page 44.

http://www.cproadmap.org/publications/MAPbriefApril2017.pdf
This is a link to a Moving Advancements into Practice (MAP) brief announcing performance-based concrete mixtures, the subject of the Federal Highway Administration (FHWA) article on page 48.

https://bookstore.transportation.org/item_details.aspx?ID=3767
This is a link to purchase American Association of State Highway and Transportation Officials (AASHTO) PP 84-17 *Provisional Standard Practice for Developing Performance Engineered Concrete Pavement Mixtures*, the recently published specification featured in the FHWA article about performance specifications on page 48.

OTHER INFORMATION

http://www.virginiadot.org/vtrc/main/online_reports/pdf/17-r20.pdf
This is a link to a recently released Virginia Department of Transportation research report, *Development of Improved Connection Details for Adjacent Prestressed Member Bridges*. The report contains analytical and experimental results on longitudinal joints of precast concrete box beams and voided slabs. Alternate connections were shown to perform better than current designs.

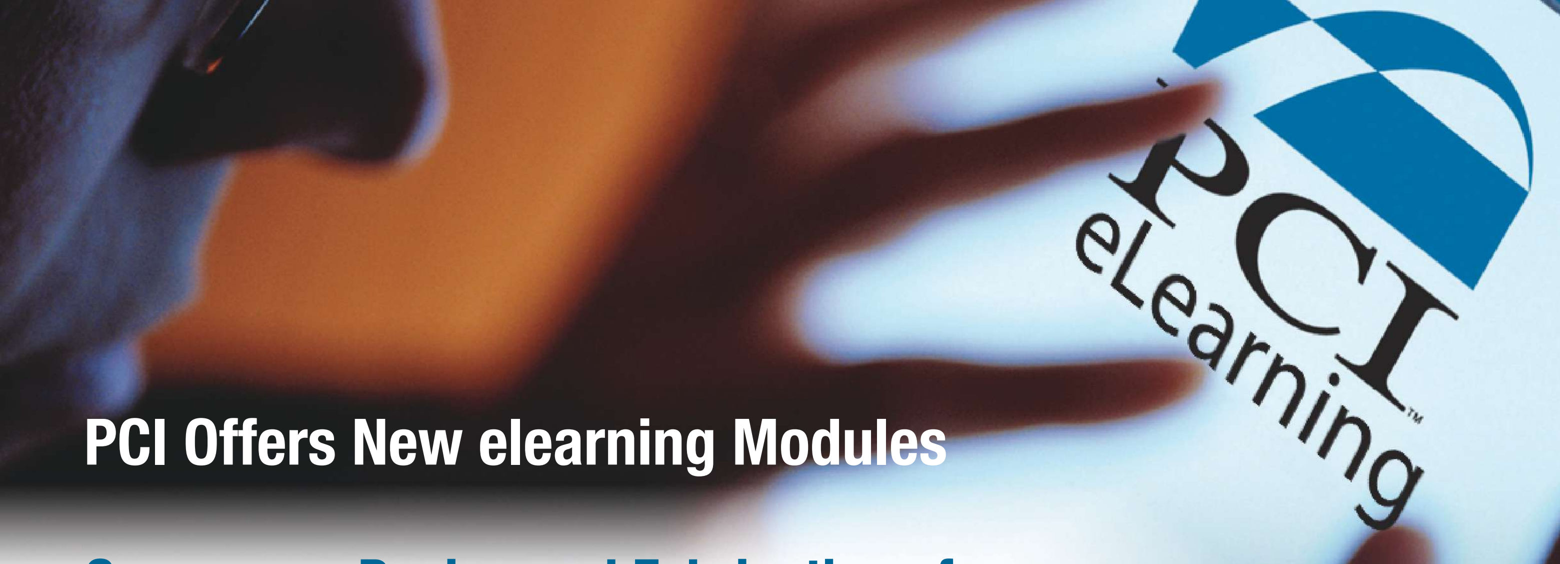
http://apps.trb.org/cmsfeed/trbnetprojectdisplay.asp?projectid=3171
This is a link to a report, that as a part of National Cooperative Highway Research Program (NCHRP) 12-91, proposes revisions to the current debonding provisions for pretensioning strand in the *AASHTO LRFD Bridge Design Specifications* and the *AASHTO LRFD Bridge Construction Specifications* as a result of a research study.

http://www.trb.org/Main/Blurbs/176394.aspx
This is a link to NCHRP Research Report 850: *Applying Risk Analysis, Value Engineering, and Other Innovative Solutions for Project Delivery*. The report investigates the state of the art in managing project development and delivery through application of value engineering for transportation projects. Tools and techniques are presented.

http://www.fdot.gov/research/Completed_Proj/Summary_SMO/FDOT-BDV31-977-35-rpt.pdf
This is a link to *Impedance-Based Detection of Corrosion in Post-Tensioned Cables: Phase 2 from Concept to Application,* a report released by the Florida Department of Transportation that quantifies corrosion rates and oxide film thicknesses for ASTM A416 steel in simulated pore solutions and grout. Also, indirect impedance is studied as a nondestructive method of detecting corrosion in post-tensioned tendons.

https://bookstore.transportation.org/item_details.aspx?ID=3734
This is a link to purchase the recently published AASHTO *Guide Design Specifications for Bridge Temporary Works, 2nd Edition.* The design specifications reflect the current state of the practice for the design and construction of falsework, formwork, and temporary retaining structures and include significant changes to the design loads for falsework.

https://bookstore.transportation.org/item_details.aspx?ID=3733
This is a link to purchase the AASHTO *Construction Handbook for Bridge Temporary Works, 2nd Edition,* developed for use by contractors and construction engineers. This handbook supplements the *Guide Design Specifications for Bridge Temporary Works*.



PCI Offers New elearning Modules

Courses on Design and Fabrication of Precast, Prestressed Concrete Bridge Beams

The PCI eLearning Center is offering a new set of courses that will help an experienced bridge designer become more proficient with advanced design methods for precast, prestressed concrete flexural members. There is no cost to enroll in and complete any of these new bridge courses. The courses are based on the content of the 1600-page PCI Bridge Design Manual, now available for free after registering with a valid email. While the courses are designed for an engineer with 5 or more years' experience, a less experienced engineer will find the content very helpful for understanding concepts and methodologies.

Where applicable, the material is presented as part of a "real world" design of a complete superstructure example so that the student can see how actual calculations are completed according to the AASHTO LRFD specifications.

All courses on the PCI eLearning Center are completely FREE.

PCI eLearning Series T100 Courses

Preliminary Precast, Prestressed Concrete Design (T110)

Preliminary design is the first step in designing an economical precast, prestressed concrete bridge. This first course in the series on design, presents the preliminary plan, superstructure, substructure, and foundation considerations, and member selection criteria with design aids and examples.

Materials and Manufacturing of Precast, Prestressed Concrete (T115)

This second course on design explores the constraints related to type, size, and method selection. Materials control strength and durability characteristics. The industries' manufacturing capabilities are important conditions on design assumptions. Plant handling and transportation constraints need to be considered in design. This course presents the important initial information required before beginning design, enabling designers to take advantage of the flexibility and economy of precast, prestressed concrete products while avoiding pitfalls that could make solutions less cost effective.

Design Loads and Load Distribution (T120)

This third course on bridge design teaches one of the fundamental tasks of collecting information on permanent and transient loads that may act on a bridge and how these forces are distributed to the structural components. It presents the load types and load distribution provisions of the LRFD Specifications related to superstructure systems.

This web-based training course was developed by the Precast/Prestressed Concrete Institute (PCI) for the Federal Highway Administration (FHWA) through a contract with the American Association of State Highway and Transportation Officials (AASHTO).

U.S. Department of Transportation
Federal Highway Administration

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U-Girder Standards Upgraded for External Post-Tensioning Tendons

New Go By sheets/concept drawings for curved, precast concrete spliced U-girders using bonded and unbonded post-tensioning for the next generation of structures

by Sam Fallaha, Florida Department of Transportation, and William N. Nickas, Precast/Prestressed Concrete Institute

Recent changes to Florida Department of Transportation's (FDOT's) post-tensioning policy that requires replaceable tendons have led to revisions of standard practices for post-tensioning bridge structures. With the growing popularity of curved, precast concrete spliced U-girders, engineers saw a need to update and upgrade the existing Precast/Prestressed Concrete Institute (PCI) Zone 6 U-girder designs to meet the new requirements. The result was a new set of concept drawings for spliced U-girders that use replaceable external tendons.

FDOT has taken a new look at the system that started in Colorado and was promulgated to the East coast by PCI. The latest concepts, which were approved by the Federal Highway Administration in July, were announced in FDOT *Structures Design Bulletin 17-08*, which can be found at www.fdot.gov/design/bulletins/SDB17-08.pdf. In an earlier memorandum, FDOT *Structures Design Bulletin 15-01*, FDOT instituted a policy that profiled tendons must be replaceable, so these tendons must be filled with flexible filler; however, flat tendons can still be filled with cementitious grout.

The revised PCI Zone 6 U-girder concept plans were developed as a joint effort between PCI and the Florida Prestressed Concrete Association (FPCA), the local PCI Chapter, to create standardized dimensions for curved, precast concrete spliced U-girders that allow access and replacement of external tendons during the service life of the structure. FPCA supported a team of consultants experienced with the system who developed the new concepts; their findings were presented to FDOT in 2016 for review. (For a list of those participating in the study, see the sidebar.)

In addition to meeting FDOT's requirements for replaceable tendons, the new concept drawings (listed below) were also intended to establish a set of standardized sections that could

Study Participants

The team participating in the FPCA-PCI study on wax-filled tendons for curved, spliced U-girders comprised:

Bob Anderson, AECOM (formerly URS), Tampa, Fla.

Roger Becker, PCI, Chicago, Ill.

John Corven, Corven Engineering, Tallahassee, Fla.

John Crigler, VStructural LLC, Baltimore, Md.

Kent Fuller, Dura-Stress Inc., Leesburg, Fla.

Trevor Kilpatrick, AECOM (formerly URS), Tampa, Fla.

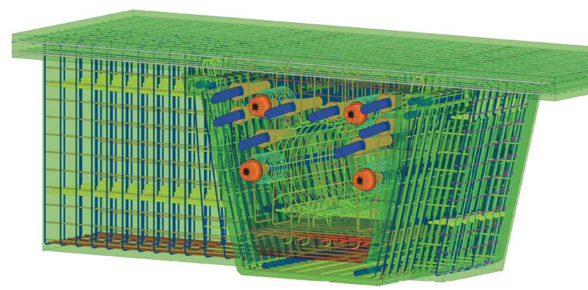
Mason H. Lampton, Standard Concrete Products, Columbus, Ga.

Tom Newton, Gate Precast, Jacksonville, Fla.

William N. Nickas, PCI, Chicago, Ill.

Richard Potts, Standard Concrete Products, Savannah, Ga.

Dr. Audi Sriboonlue, Dura-Stress Inc., Leesburg, Fla.



Example of reinforcement, tendon, and anchorage details for pier diaphragm. All Drawings: Precast/Prestressed Concrete Institute and Florida Department of Transportation.

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FDOT WU-1	GENERAL NOTES
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FDOT WU-4	TYPICAL EXPANSION PIER
FDOT WU-5	TYPICAL INTERIOR PIER WITH BEARINGS
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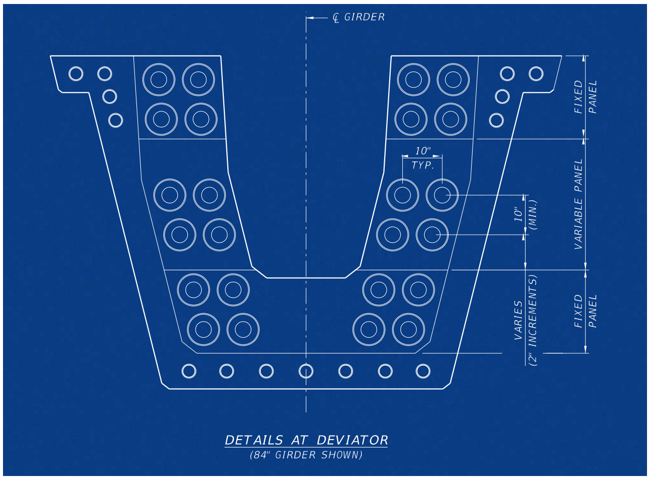
FDOT WU-21	EXAMPLE ERECTION PLAN DETAILS

Index of FDOT curved, precast concrete spliced U-girder drawings (Drawing WU-0).



U-girder post-tensioning details—Typical deviator locations (Drawing WU-14).

be produced cost-effectively. By using a uniform deviator design at a consistent spacing, the existing outer-formwork systems were preserved and could be used to satisfy the particular requirements of a project. With external tendons, the web thickness could be decreased, resulting in girder weights (including deviators) similar to those from the original PCI Zone 6 sections with internal tendons. The new concept drawings can be found at http://www.fdot.gov/structures/innovation/UBEAM.shtm.

The team, along with other industry experts, passionately discussed the changes in details, including the new system's reduced tendon eccentricities that have a significant impact on the efficiency of the structure. Once several projects have been specified and bid, contractors and designers can evaluate the costs of the increased post-tensioning quantities compared to thinner webs and simpler splice details (fewer ducts across the closure pours). It is anticipated that the cost of the new system with thinner webs, external tendons, and standardized deviators will be similar to the cost of the old system with internal grouted tendons.

U-Girder Advantages

Advantages identified by FDOT for the use of curved, precast concrete spliced U-girders include reduced fabrication times, faster construction, longer spans, and increased aesthetic appeal. Important considerations that need to be made before using this type of construction include shoring requirements, equipment selection for lifting heavy girder sections, field and erection engineering, and monitoring settlement and movement of temporary foundations during erection and post-tensioning operations. (For more on the development and early use of curved, spliced U-girders, see the Creative Concrete Construction article "Curved, Spliced, U-Girders Gain Momentum" in the Fall 2012 issue of *ASPIRE*℠.)

Design Criteria Update

Additional design criteria are included in FDOT's recent bulletin announcing the new precast concrete spliced U-girder concept drawings. A new limit state for the design of pretensioned/post-tensioned I-beams and U-girders is implemented, along with direction to use strain compatibility to determine section capacities. The purpose of the new limit state is to provide assurance that the structure has sufficient capacity in the event of failure of grouted tendons. The use of strain compatibility ensures accurate accounting of the controlling strains at any section and also accounts for the difference between unbonded steel, where the strains are constant over the length of the tendon, compared with bonded steel, where the strains vary along the length of the tendons. The use of strain compatibility assures accurate accounting of the controlling strains at any section. The additions to the FDOT *Structures Design Guidelines* are as follows:

- For pretensioned/post-tensioned I-beams and U-girders, in addition to the load combinations required by American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*,[1] satisfy the following limit state neglecting strand tendons that are grouted with cementitious material:

  $$1.25(D) + 1.75(LL) \leq 1.4(RN^*)$$

  where

  D = all applicable permanent load components of LRFD[1] Table 3.4.1-1

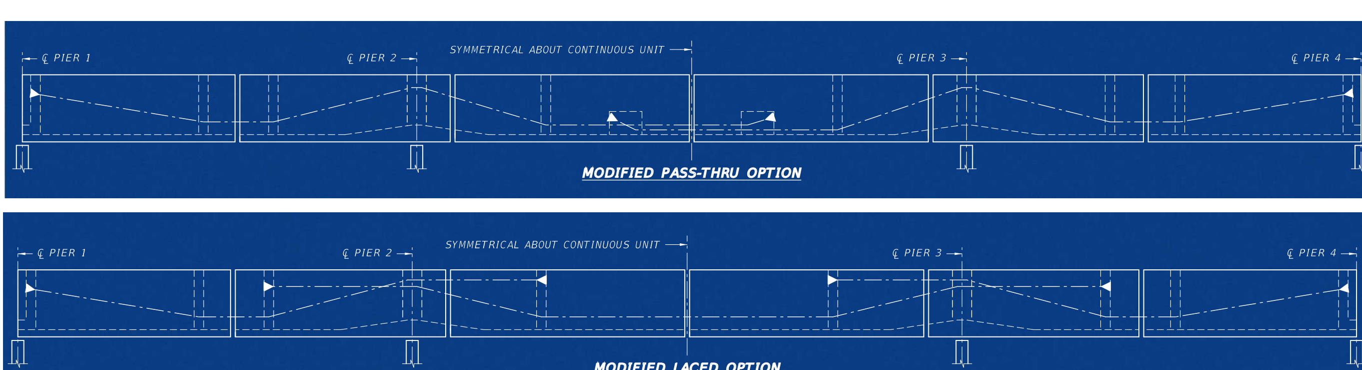
  LL = all applicable transient load components of LRFD[1] Table 3.4.1-1

  RN^* = nominal capacity (moment or shear) at any section using only the replaceable strand tendons with flexible filler, all permanent bar tendons, mild reinforcing steel, and pretensioning strands

- Use strain compatibility to determine section capacities using bonded and unbonded post-tensioning tendons, mild reinforcing steel, and pretensioning strands.

Benefits of Go By Sheets

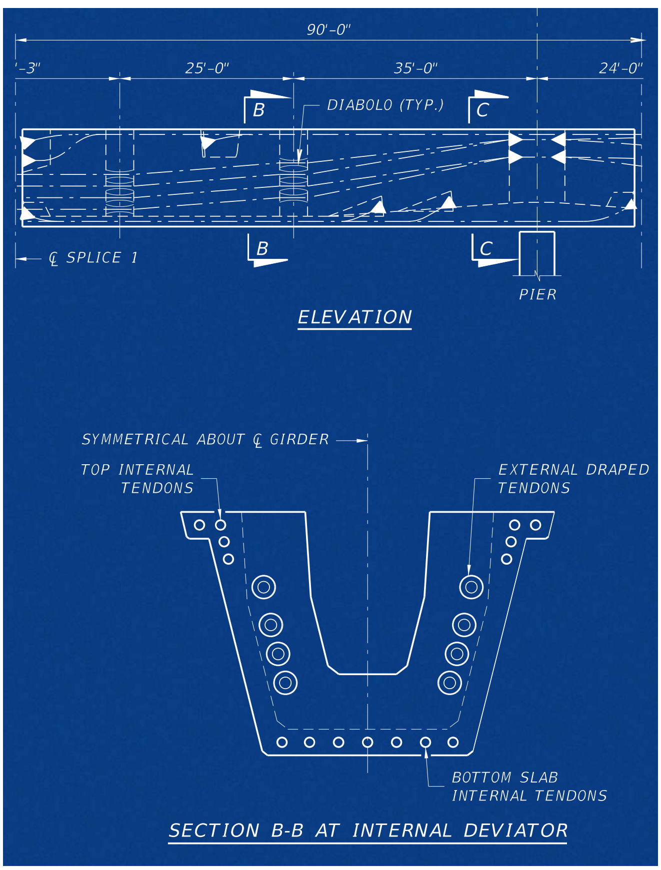
The concept drawings show standardized positions of external tendons in the diabolos (uniquely shaped voids designed



Two post-tensioning layout schematics (Drawing WU-11).

and formed into concrete deviator segments in a shape that accommodates the angle change of the tendon through the deviator. See "External Tendons with Diabolos—Making Something Out of Nothing," Fall 2015 *ASPIRE*), which offer significant cost savings in forming systems. When horizontal adjustments of tendon locations are needed in the midheight region, a variable-panel detail can be used. The absolute minimum centerline-to-centerline distance of the diabolos is 10 in. both vertically and horizontally for 19-strand tendons.

Drawing WU-11(excerpt shown on previous page) shows several options for tendon layouts. The pass-thru layout is typical of current construction, but with replaceable tendons, an end chamber would be required to allow access to the tendons for replacement. Eliminating end chambers at the supports by using laced and modified-laced tendons that are stressed at anchorages within the girders will avoid wide piers and costly substructure features. The drawing shows anchorage locations for both pass-thru and laced tendon layout.



Exerpt from post-tensioning layout 1—Pass-thru option (Drawing WU-12).

Replaceable external tendons and internal stranded post-tensioning tendons are used for analysis at the service limit state. All tendons in the U-beam will be counted on for the ultimate limit strength requirements, with bonded PT bars allowed at all limit states.

For states not implementing replaceable tendons with flexible filler, this standardized solution could be used with grouted external tendons, the conventional approach that the concrete segmental industry uses worldwide.

Summary

The additional design criteria in FDOT *Structures Design Bulletin 17-08* and the curved, precast concrete spliced U-girder concept drawings came about due to the focused and persistent efforts of industry, FPCA, and FDOT staff to create a collaborative solution that could meet the goals of each stakeholder. It is imperative that designers be provided successful concepts of the new generation of curved, precast concrete post-tensioned structures with replacable tendons and optimize them to meet the requirements of the owner.

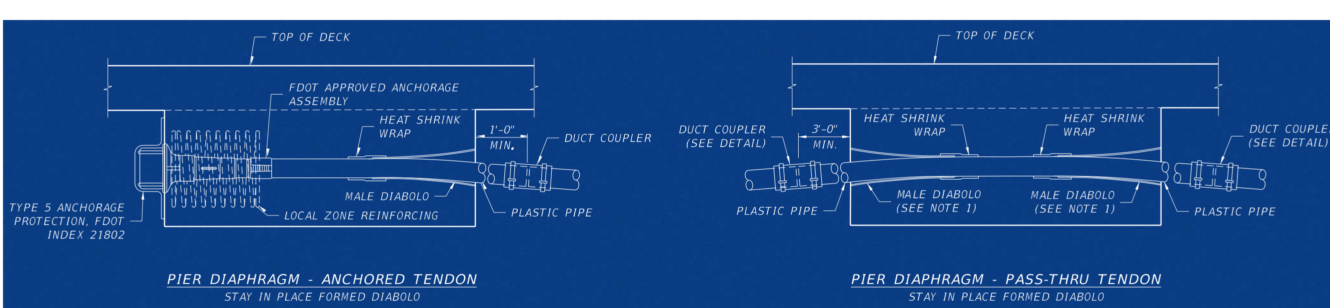
Reference

1. AASHTO (American Association of State Highway and Transportation Officials). 2015. *AASHTO LRFD Bridge Design Specifications*. 7th ed. Washington, DC: AASHTO.

Sam Fallaha is assistant state structures design engineer at the Florida Department of Transportation in Tallahassee, Fla. William N. Nickas is managing director of transportation systems at PCI in Chicago, Ill.

EDITOR'S NOTE

While the revisions to the PCI Zone 6 U-girder details discussed in this article were made to address FDOT's use of wax-filled external tendons, the concepts and details can also be used with grouted external tendons that have been successfully used around the world. The full set of drawings is available at www. aspirebridge.org or www. fdot.gov/design.



Typical diabolo details (Drawing WU-15).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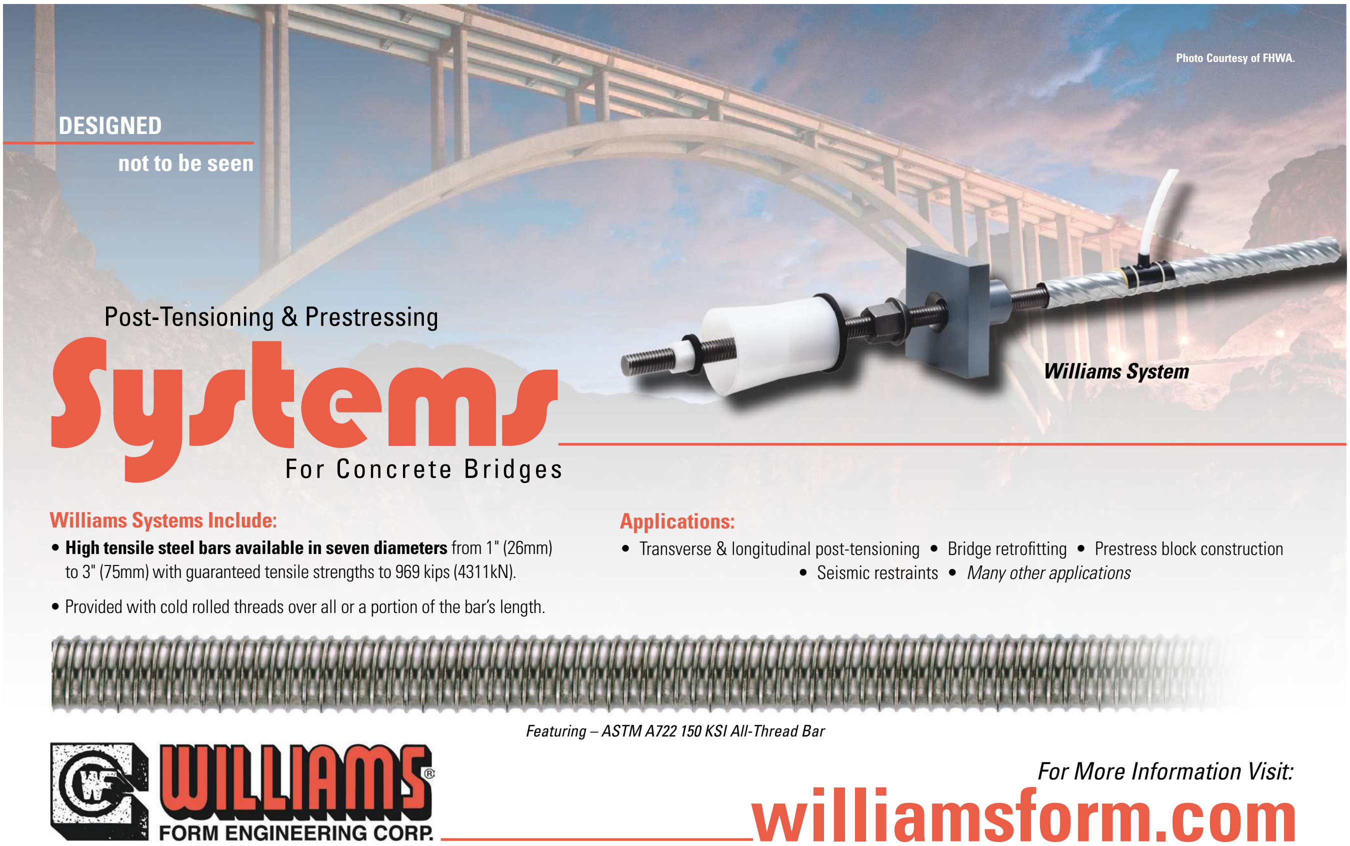
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Concrete Technology Advancements: New Tests and the Performance Engineered Mixture Specification

by Mike Praul and Gina Ahlstrom, Federal Highway Administration

For a number of years, the Federal-Aid Highway Program has been moving in a performance-based direction, seeking to link program- and project-level criteria with the results obtained. This was formalized in the MAP-21 (Moving Ahead for Progress in the 21st Century Act) legislation and has continued with the Fixing America's Surface Transportation Act. While this move toward performance criteria for the highway program has been on a programmatic level, concrete materials technology has moved in a similar direction. Recent developments in concrete technology have, for the first time, made it possible for highway concrete to be specified with a performance specification and for meaningful upgrades to take place with quality-control (QC) processes and programs.

PEM and What It's About

American Association of State Highway and Transportation Officials (AASHTO) recently published provisional specification PP 84-17, *Standard Practice for Developing Performance Engineered Concrete Pavement Mixtures*, known as the performance engineered mixture (PEM) specification. This specification is the result of a multiyear collaboration among the Federal Highway Administration (FHWA), state departments of transportation, researchers, and industry.

The underlying concept behind the PEM specification is to understand what makes concrete last and what failure mechanisms affect concrete durability. Then critical properties are specified and mixtures are designed to meet the required level of performance. Finally, testing is done on those critical properties, both as a QC function by the contractor during production and as an acceptance function by the agency.

The following six performance areas are identified as critical to durable in-service concrete:

- Strength
- Reducing unwanted cracking due to shrinkage
- Hardened cement paste freeze-thaw durability
- Transport properties (permeability)
- Aggregate stability
- Workability

In the AASHTO PP 84-17 specification, each of these properties has a table intended to guide the user in selecting the appropriate criteria to incorporate into a specification. Specifiers can choose which performance parameters they want to include into their specifications, with the understanding that not all owners may be willing to move to a complete performance specification right away. It is significant that while the title of the specification denotes applicability to concrete roadway paving, the concepts are nearly all directly applicable to structural concrete as well.

Durable Concrete Properties

The AASHTO PP 84-17 specification is flexible and can be tailored to the needs of the specifier. There are various performance and prescriptive options for many of the critical properties and tests. In addition, guidelines for each test are included, such as whether the test is used as a mixture qualification test, as an acceptance test, or both. Selected highlights for each property are as follow:

- Strength: In-service concrete rarely fails due to poor strength. This section of AASHTO PP 84-17 mirrors the common practice of specifying either compressive or flexural strength.
- Reducing unwanted cracking due to shrinkage: For specifiers who want to retain a prescriptive approach to shrinkage, the specification suggests a maximum volume of paste. The performance approach lists several options for assessing shrinkage, including a dual ring test that is being developed as an AASHTO standard test.
- Hardened cement paste freeze-thaw durability: Freeze-thaw durability is addressed with the prescriptive option of specifying a maximum water-cement ratio. The performance approach has several options, including using the super air meter (SAM) (AASHTO TP 118) in lieu of the traditional Type B pressure pot (AASHTO T 152). The SAM is a new test that offers the significant advantage of providing information

Compared to traditional test methods, the super air meter provides a better indication of concrete's ability to resist freeze-thaw damage. All Photos: Federal Highway Administration.

on the air-void system in the concrete, not just the total amount of air. The specification also includes guidance on the use of supplementary cementitious materials to address calcium oxychloride formation, a by-product of the use of modern deicing chemicals.

- Transport properties (permeability): For this property, specifying a maximum water-cement ratio is a prescriptive approach. Options for specifying performance include the rapid chloride permeability test (AASHTO T 277) or the surface resistivity test (AASHTO TP 95), either of which could be incorporated as part of the determination of the formation factor of the mixture. The formation factor is the subject of ongoing research by Dr. Jason Weiss at Oregon State University that links the electrical conductivity of the concrete mixture with its pore chemistry.
- Aggregate stability: The specification for this property includes standard methods for determining vulnerability to D-cracking (AASHTO T 161) and to alkali-silica reactivity (AASHTO PP 65).
- Workability: The slump test does little to inform specifiers about the durability or performance of a concrete mixture. It is merely an indication of workability, but does not consider how modern mixtures perform during consolidation. AASHTO PP 84-17 takes this into consideration by including the new box test and the V-Kelly test, which are better able to assess how the fresh concrete responds to vibration and are far better indicators of the workability of the concrete. The box test and V-Kelly are specifically for slip-formed concrete pavements. Similar concepts are being used to develop a test for structural concrete. This test, referred to as the float test, provides an indication of the finishability of structural flatwork concrete.

Quality Is Key

Performance specifications shift some risk and control to the contractor. With agencies retaining responsibility for maintaining the finished product, the traditional project oversight role needs to shift to one that is more appropriate in a performance-specification environment.

With a performance specification, the contractor's QC plan details much of how the concrete will be produced and placed, rather than relying on traditional method specifications. Agencies will need to take an increased role in approving the QC plan and overseeing its use on the project. In addition to the performance properties and associated selection tables, the PEM specification includes language regarding contractor QC testing and requires QC testing and control charts for both traditional and cutting-edge tests.

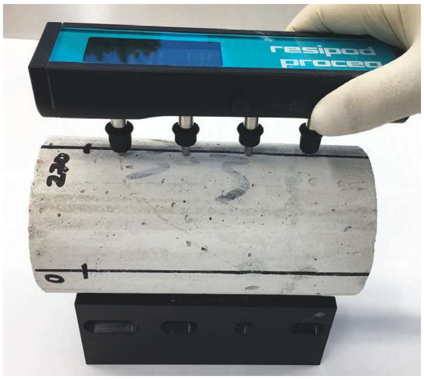
Implementation Underway

Implementation efforts are vital to moving agencies toward a performance specification for concrete. Training on new tests, user-friendly testing guides including suggested testing frequencies, and hands-on education are planned. FHWA's mobile concrete trailer has been using the tests included in AASHTO PP 84-17 for the past year and is planning to travel to state agency projects to pilot or shadow the usage of the specification. Good collaboration between public agencies and contractors is important for successful implementation of performance specifications. To meet this need, FHWA will work to include guidance for contractor quality-control processes under a performance specification.

Conclusion

Recent advancements in concrete technology have paved the way for the implementation of performance specifications. AASHTO PP 84-17, *Standard Practice for Developing Performance Engineered Concrete Pavement Mixtures*, when used in conjunction with other tools to optimize the materials in concrete mixtures, offers the ability to characterize concrete in ways that were not possible previously. It is also now possible to develop meaningful upgrades to contractor/supplier quality-control programs, which will ensure that more consistent concrete is produced. The FHWA remains committed to working with stakeholders to continually improve and advance PEM into widespread implementation. Ultimately, the FHWA is striving for a more durable, sustainable, and economic concrete, ensuring a longer service life benefitting taxpayers and the driving public.

The Federal Highway Administration's mobile concrete trailer assists states across the country with implementing new concrete technology.



The surface resistivity test is a quick and repeatable nondestructive test that provides an indication of the concrete's ability to resist chloride intrusion.

The box test evaluates how a concrete pavement mixture responds to vibration and provides a more accurate assessment of workability than the slump test.

EDITOR'S NOTE

For more information, click on the Resources tab at www.aspirebridge.org for links to two presentations on performance mixtures.

Psychology of Bridge Design

The segmental box-girder design of Ohio's Jeremiah Morrow Bridge provides lessons about the challenge of familiarity and how changes can impact drivers' perceptions

by Daniel P. Mendel, Ohio Department of Transportation

The new Jeremiah Morrow Bridge over the scenic Little Miami River in Warren County, Ohio, is the tallest bridge in Ohio and the first owned by the Ohio Department of Transportation (ODOT) with cast-in-place concrete segmental box girders. The twin structures and six-year construction plan created opportunities to improve from one structure to the next, but ODOT learned that care must be taken in applying those efficiencies. ODOT also learned about some intangible aspects of driver psychology.

Construction began in March 2010 and was finished in July 2016, with completion of paving, grading, and demolition of the original bridge, although it only opened to traffic in December 2016. The first structure (southbound) represented ODOT's introduction to segmental design using the balanced-cantilever method, which was required at 239 ft above the valley floor. The six-span twin bridges have three 440-ft-long main spans, one 416-ft-long interior span, and side spans of 229 and 270 ft. A variable-depth, single-cell box-girder cross section with cantilevered deck overhangs provides a 52-ft-wide roadway with a 42-in.-tall concrete barrier.

Experience from the first bridge was applied to the second one, but new challenges were created by assuming the learning curve had plateaued. The long schedule and use of new personnel on the second bridge, coupled with the desire to improve by using what had been learned, led to some issues that required adjustment.

Efficiencies Added

A number of efficiencies were introduced for the second bridge, leading the team to believe it understood the process completely. As a result, diligence on evaluations that were double- and triple-checked on the first bridge were reduced in some cases. As an example, vibration activities of fresh concrete were lessened to save time, creating some honeycombs and the need to patch portions, negating the time saved upfront.

One benefit of the design ODOT had not anticipated has come through feedback from drivers. The original steel truss bridges had load limits and were narrow, with an aging, lower parapet, creating some anxiety for travelers, especially due to the height of the bridge above the river below. The new design features a barrier wall that is 6 in. taller (42 in. instead of 36 in.) and wider lanes with a 6-ft-wide shoulder on one side and a 10-ft-wide shoulder on the other. The design eliminated the fear factor, drivers report, which had not been part of the considerations.

Jeremiah Morrow Bridge, with cast-in-place concrete segmental box girders, is the tallest bridge in Ohio. All Photos: Ohio Department of Transportation

The Jeremiah Morrow Bridge was an exciting project because it gave new insights into the segmental design concept and expanded ODOT's capabilities for meeting new challenges. The next project using the segmental design will be as exciting, but it will be constructed with the knowledge of new efficiencies and where shortcuts can or can't be taken to speed construction.

Daniel P. Mendel is construction administrator with District 8 of the Ohio Department of Transportation in Lebanon, Ohio.

EDITOR'S NOTE

Following the completion of the first of the dual bridges, the Jeremiah Morrow Bridge was featured in the Winter 2014 issue of ASPIRE℠.

Accelerated Construction of Railroad Bridges

by Kevin Eisenbeis, Burns & McDonnell

Precast concrete subcaps, caps, and double-cell box beams at Barstow, Ill. Replacement took place during a 16-hour track closure. Photo: BNSF Railway.

Accelerated bridge construction (ABC) practices have been used in the rail industry for many years. Most railroads are privately owned and revenue generation depends on efficient train operations. Design procedures and innovative construction techniques that minimize disruption to rail traffic have been developed, implemented, and refined to ensure rapid replacement of railroad bridges.

Besides reducing impacts to revenue generation, the rail industry faces other unique challenges that make ABC a necessity. The rail network is clearly defined and limited to specific track locations. Detours can add rail traffic to already-congested routes and may involve using a competitor's track, where access may not be a priority. Amtrak passenger trains also share many routes throughout the country. Speed restrictions or track outages can affect the entire rail system. In addition, many railroad bridges are located in remote locations where access by conventional roadway is not available. In many instances, the terrain is also unsuitable or right-of-way is not available for a temporary bypass.

Railroad bridge construction typically takes place under live rail traffic conditions, within track windows (defined times between scheduled trains) or during track closures (defined shutdowns), or a combination thereof. Techniques to accomplish construction rapidly during track windows or short closures include using precast concrete elements, building substructures below existing bridges prior to superstructure removal, staged construction change-outs, simplified connections between elements, lateral slide-ins, float-out/float-ins, and others.

Barstow, Ill.: 16-Hour Closure

An example of typical rail system bridge replacement using precast concrete elements and ABC techniques occurred in Barstow, Ill.

The single-track bridge replacement used a unique system of precast concrete subcaps and full-width pier caps to accomplish the bridge replacement during a 16-hour track closure. Piling was driven at new pier locations outside the limits of the existing bridge. Small precast concrete subcaps were attached by welding piles to embedded plates. Once all subcaps were installed, the existing concrete bridge was removed, allowing rapid installation of new full-width caps to the subcaps, then subsequent setting of the precast concrete double-cell box beams.

ABC Push

Economic factors drive the use of ABC techniques in the rail industry. Revenue generation is paramount and disruption to rail traffic must be minimized. ABC techniques, including the use of precast concrete elements, provide a means to accomplish rapid replacement of railroad bridges and minimize disruption to rail traffic.

Kevin Eisenbeis is director of bridges for Burns & McDonnell in Kansas City, Mo.

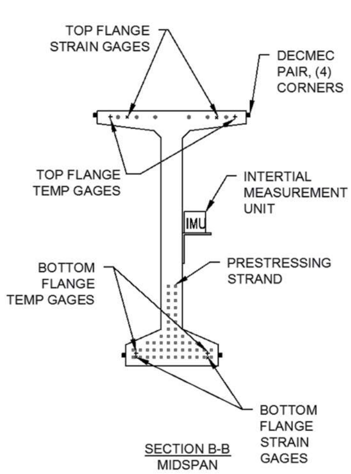
Active Monitoring of the Transport of Long-Span Precast Concrete Girders

by Richard E. Lindenberg and Jonathan C. McGormley, Wiss, Janney, Elstner Associates Inc.

The recently released PCI *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders* serves as a reminder of a particularly challenging problem for long-span bridge girder designers. What design forces should girders be required to resist prior to their installation and incorporation into the permanent structure? A particular issue lacking definition from available research is the behavior of girders during transportation. Very little real-world data have been gathered on this issue and yet there are reports of instances where girders were damaged during transport outside of lifting or accidents.

Research

In 2011, the Louisiana Department of Transportation and Development (LaDOTD) awarded Wiss, Janney, Elstner Associates Inc. (WJE) a research study to examine the transportation of precast concrete long-span girders to the jobsite. As a part of this research, WJE instrumented two 130-ft-long precast, prestressed concrete girders. One girder was an American Association of State Highway and Transportation Officials (AASHTO) Type IV and the other was a 72-in.-deep bulb tee (BT72). Monitoring occurred from moving the girders from storage to the truck through transport to the site and lifting from the truck. The girders traveled similar routes that exceeded seven hours in transit across Mississippi and Louisiana, and included a variety of roadway geometries commonly identified as possible contributing factors to girder damage during shipping (such as non-horizontal grades, railroad crossings, superelevation, bridge expansion joints, and the like). Supplementing the research were material testing and analytical modeling to better understand girder behavior.



Typical cross section showing instrumentation. See figure at right for instrumented cross-section locations along girder. All Photos and Figures: Wiss, Janney, Elstner Associates Inc.

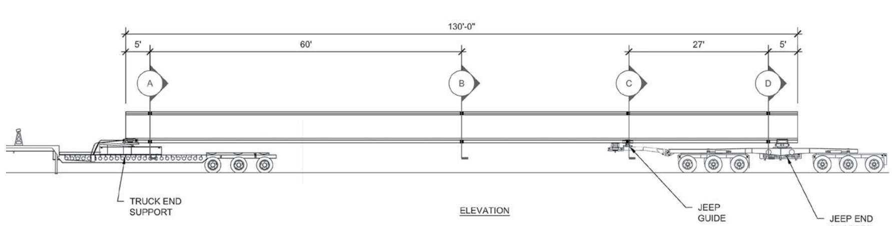
The girders were instrumented with a variety of dynamic strain, temperature, and inertial sensors (comprising three-dimensional rotation displacement sensors with rate of rotation, along with translational triaxial acceleration sensors) to measure the behavior of each girder during transport. Additionally, geolocation of the girders was recorded to correlate significant events of the transport to measured readings.

Both girders were supported in similar fashion, with a three-axle tractor pulling a fifth-wheel three-axle trailer supporting the front end of the girder that was positioned on a rotating bunk and a Hydra Steer six-axle rear jeep supporting the back end of the girder. The rear jeep provided considerable maneuverability, permitting the single driver/operator to efficiently steer the girder through a variety of maneuvers. The rear jeep was capable of operating in different steering configurations based on the navigation circumstances required. A single driver both drove and operated the rear jeep steering during transport of both girders.

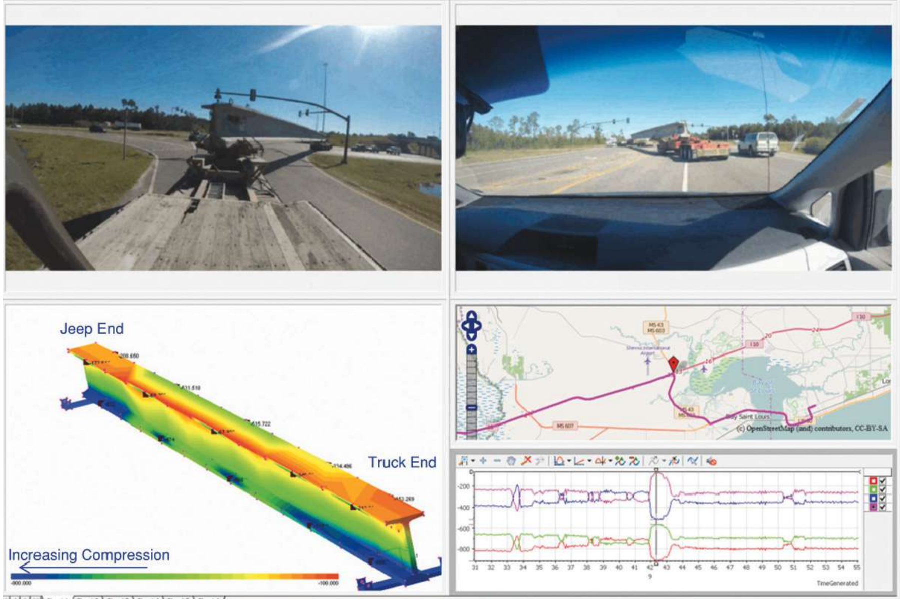
Data Collected

Both girders traveled from Pass Christian, Miss., through Louisiana on Interstate 10 into Baton Rouge, La. From there, the transports deviated with one girder traveling to Alexandria, La., and the other to Lake Charles, La. For each girder, over 40 channels of instrumentation were collected at 100 Hz to record individual events along the route. Time-lapse video correlated with geolocation data allowed the research team to review events along the shipping route. The data were fused to correlate time lapse, geolocation, traditional time versus strain response, and sensor-mapped imagery.

A significant challenge of this research was to efficiently investigate many hours of collected data. The fused data was not intended to accurately identify critical stresses and girder position, but



Location of instrumented cross sections along girder.



Data fusion of traditional strain plots, with synchronized time-lapse video, geolocation map, and interpolated three-dimensional sensor mapping.

rather was used to assist the investigators with the rapid interrogation of girder response while simultaneously observing time-lapse video correlated to events of interest, for example, turns and railroad tracks. The strain gage placement permitted peak responses to be captured during transport

Notable Findings

WJE reviewed the data for maximum responses along with notable correlation between inertial and strain measurements. The data confirmed expectations that the Type IV girder had lower horizontal flexural bending responses than the BT72 to similar turning events, which is consistent with the differences in geometric section properties between the two girders. Typical highway transportation, including changes in superelevation, transport across railroad tracks, and riding over bridge expansion joints produced relatively minor strain activity in both girders.

The most notable finding was that measured strains exceeded predicted cracking strains in both girders. Low-speed maneuvers, such as tight turns, produced the greatest tensile strains in both test girders during transport. Based on a review of these events, these strains were principally due to the lateral force introduced by the jeep tongue.

Accordingly, in many cases the girders experienced the highest tensile strains at the location of the jeep tongue, and not at midspan of the girder. Therefore, the force input by the jeep tongue strongly influenced the girder bending response. This force is a consequence of the driver's operation of the jeep, with no direct feedback to the driver on the magnitude of that force. This exceedance occurred several times for both girders during transport. The largest strain responses from standard transport activity occurred during low-speed maneuvers (less than 10 mph) that relied on the engaged jeep tongue to turn the rear bunk, such as the turn onto the interstate ramp. Post-transport inspection found no visually observable cracks in either girder.

Girder turning onto an interstate ramp, an example of a significant event causing differential bending strain at the top flange of the girder.

Conclusion

This research provides insight into girder behavior during transport based on actual measured response. In particular, it highlights circumstances where truck-girder interactions due to driver maneuvers produced girder responses that had not been previously identified in research. Both girders experienced events during otherwise routine transport that exceeded predicted cracking strains. The location and magnitude of these jeep-tongue-induced strains are not typically considered by designers or precast producers for girder transportation. To better understand how cracking during transport can be minimized, research to quantify imposed forces on girders by drivers' actions during transport is recommended, including additional field testing of various transport trailer systems and full-scale lab testing using actuated support conditions derived from actual field-generated time-history responses.

The research was significantly complete by the time the PCI *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders* was made available to the public. The investigators have since reviewed the this recommended practice and have found that many of the same references used in the PCI document were included in their work. Moreover, the PCI *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders* suggests a wide array of loading conditions; however, loading of the girder through the transport jeep tongue via driver operation was not incuded. Given the findings of the LaDOTD research, it appears that this should be considered.

The complete research report (Report No. FHWA/LA.16/567 *Development of Guidelines for Transportation of Long Prestressed Concrete Girders*) is available online from the Louisiana Transportation Research Center at https://www.ltrc.lsu.edu/pdf/2016/FR_567.pdf

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The *AASHTO LRFD Bridge Design Specifications*: Moving Forward

by Dr. Oguzhan Bayrak, University of Texas at Austin

The annual meeting of the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Bridges and Structures (SCOBS—but soon to be the Committee on Bridges and Structures) took place in June 2017 in Spokane, Wash. During that meeting, the AASHTO Technical Committee T-10, Concrete Design, met to further its work towards improving Section 5 of the *AASHTO LRFD Bridge Design Specifications*.

This column in the Fall issue typically reports on changes related to concrete design that were approved by AASHTO SCOBS at their annual meeting. However, there were no concrete-related items on the ballot this year because of the major effort required to complete the reorganization of Section 5 that was approved in 2016. Therefore, this article focuses on the upcoming work of the T-10 committee on improving concrete bridge design provisions.

The eighth edition of the AASHTO LRFD specifications will soon be published (they were not published at the time of this writing). This edition contains the complete reorganization of Section 5 to streamline the design provisions that had been modified as new research was completed since the specifications were introduced in 1994. Moving forward, a new edition of the AASHTO LRFD specifications will be published every three years, and no interims will be published. The reduced frequency with which the design provisions will be revised and published will make it easier to keep track of the changes and to implement them in design software and training materials.

For its work in the near term, the T-10 committee decided to consider at least these five working agenda items:

- Shear design provisions for the design of precast concrete girders with ducts in their webs (such as spliced girders and segmental construction)
- Design provisions for welded-wire reinforcement
- Stability of precast concrete girders during storage, transportation, and erection
- Clear-cover requirements applicable to bridge sub- and superstructures
- New approaches to strand debonding limits and bottom flange confinement

These items will be worked on through the course of next year and, if the T-10 committee comes to an agreement, will be balloted during the next SCOBS annual meeting. In the new cycle, the items balloted in June 2018, if approved by the committee, will be published in June 2020 and no interim revisions will be published before this date. The adoption of the balloted/approved agenda items into the state design manuals prior to their publication by AASHTO is at the discretion of each state.

After the 2018 annual meeting, *ASPIRE*℠ will inform its readers of design provisions that have been approved in the AASHTO LRFD specifications.

Readers are encouraged to send in their questions or concerns to the *ASPIRE* team and we will provide the necessary clarifications in this corner, as appropriate. We hope you find this update useful. Stay well until the next issue.

EDITOR'S NOTE

For more information on the reorganization of Section 5, see the Winter 2017 issue of ASPIRE *for the LRFD article by Montgomery, Bhide, and Freeby.*

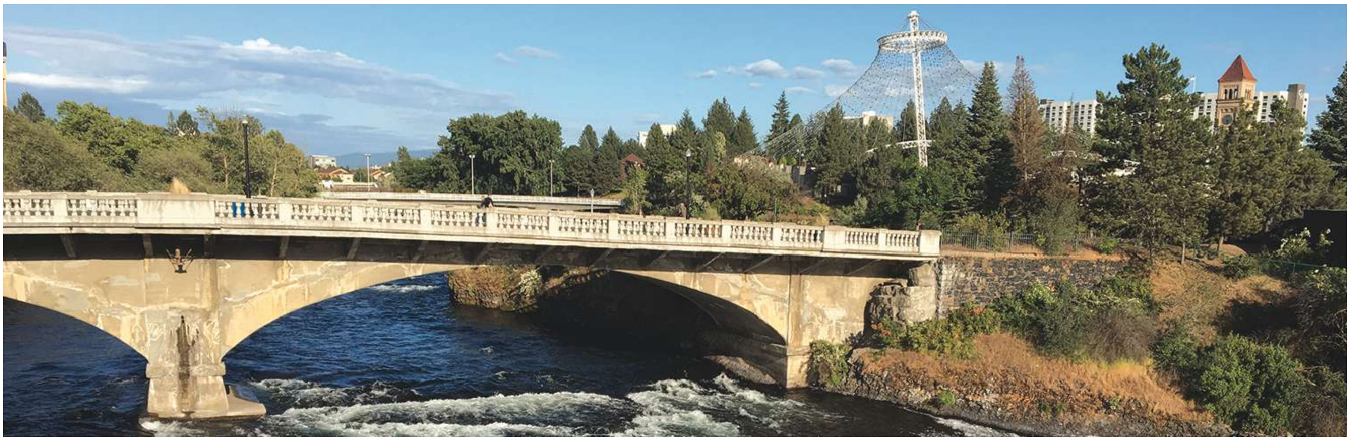

Photo of an old concrete arch bridge in Spokane, Wash., taken by the author in June 2017 while he was attending the American Association of State Highway and Transportation Officials Subcommittee on Bridges and Structures meeting. Photo: Oguzhan Bayrak.