

ASPIRE™

THE CONCRETE BRIDGE MAGAZINE

WINTER 2012

Edwin C. Moses Boulevard Bridge

Dayton, Ohio

INDIAN RIVER INLET BRIDGE
Bethany Beach, Delaware

MAYOR MIKE PETERS BRIDGE
Hartford, Connecticut

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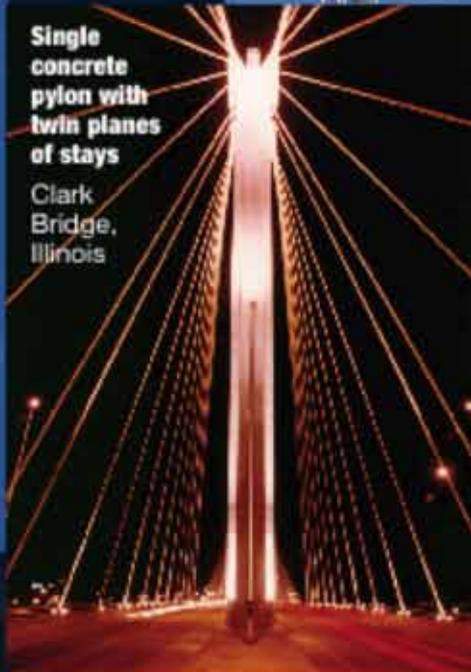
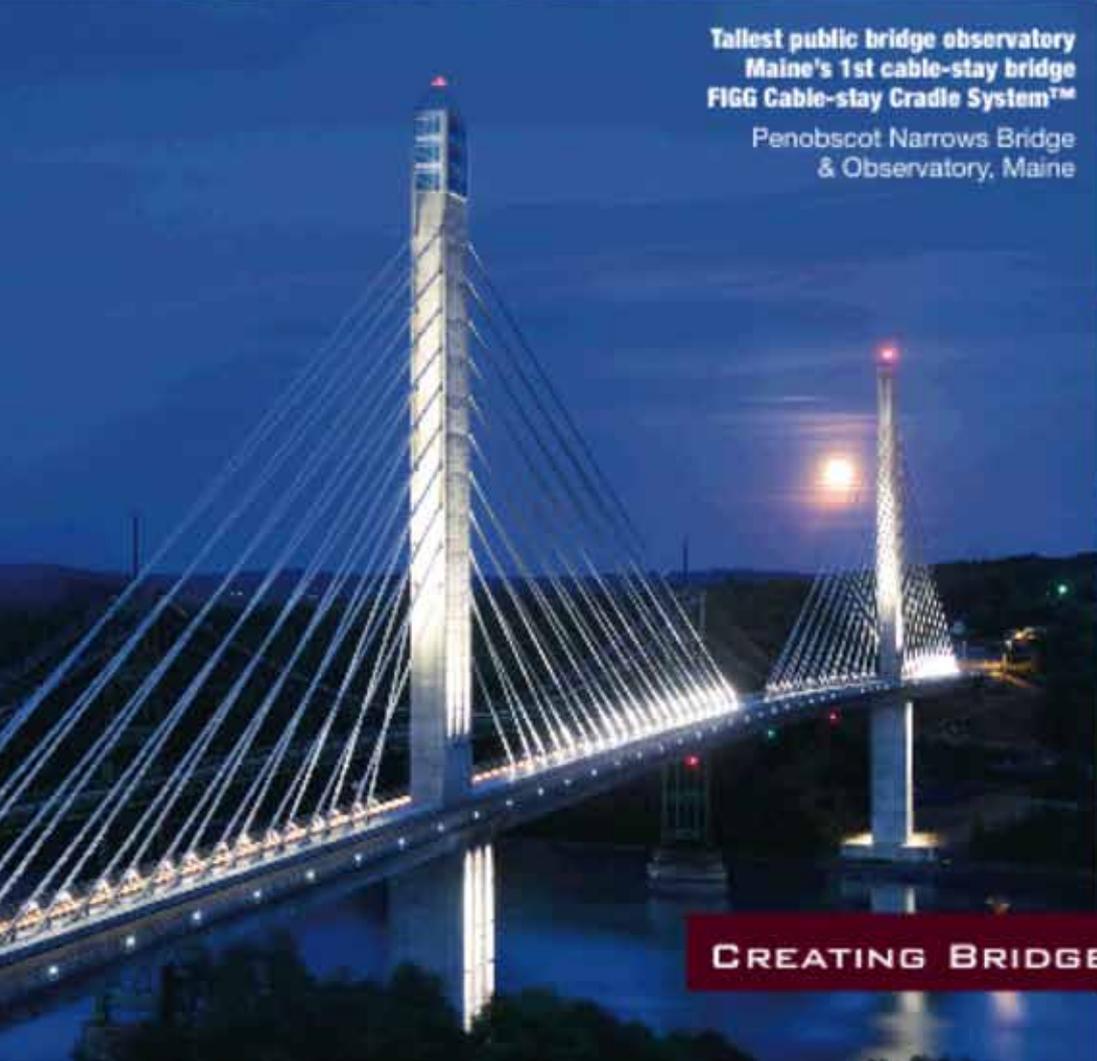
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Photo: RW Armstrong.



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Photo: King County, Wash.

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Variations on a Theme

John S. Dick, *Executive Editor*

Photo: Ted Lacey Photography.

Once again, you'll find a wealth of interesting reading on innovative bridge designs nationwide in this issue. Among the project reports are two major structures, two pedestrian bridges, and a short-span conventional bridge . . . but with a twist.

This issue reports on bridges in 14 states across the country including state-, county-, and city-owned structures. The projects are located coast to coast and border to border. It is always exciting to discover these projects located in every section of the country. Each presents unique challenges faced by the owners and designers.

All five projects took full advantage of the capabilities provided by concrete. Four combined precast with cast-in-place concrete; a trend that appears to be increasing. The two construction methods work well together, with each offering specific benefits that can be used together to create aesthetically pleasing, cost-effective, and quickly constructed bridges.

Rehabilitation of older bridges is growing in importance, as owners and engineers acknowledge the need to stretch scarce maintenance and construction dollars. Finding effective ways to save graceful and cherished landmarks has become a focus for everyone in the bridge community. Three beautiful arch bridges given new life are described in articles in the Concrete Bridge Preservation section that begins on page 47. Two of them also combine cast-in-place with precast concrete solutions.

With debate raging over funding of a new transportation bill, the Pennsylvania secretary of transportation, Barry Schoch, challenges the public to consider the cost of their wireless service and other

utilities and compare those to the cost and value of the transportation infrastructure. This issue's Perspective is on page 10. Oklahoma has risen to that challenge by committing additional funds to its infrastructure, with the intent to nearly wipe out all of its deficient bridges in an ambitious program starting this year. The report on their plans begins on page 40.

The wide range of topics continues with a look at how bridge lighting can be used as a triple asset to enhance aesthetics, safety, and security (see page 46).

What can be better than avoiding waste by finding a new use for old products? In Arizona, a "bridge" was built with discarded beams over the Central Arizona Project canal to house six giant pumps to withdraw water from the canal. This article is on page 34.

Congratulations to the design and construction firms responsible for all of the projects in this issue. We will continue to scour the country looking for innovative concrete applications of all kinds, and we expect we will find them as engineers and contractors continue to create new ways to push concrete's limits. If you have a project you would like considered for publication, please visit www.aspirebridge.org and select "Contact Us." We look forward to hearing from you.

Finally, many readers tell us how much they look forward to each new issue of *ASPIRE*.™ The most often heard comment is, "It's the only magazine I read cover-to-cover." If you like *ASPIRE*, take a moment to go to the website mentioned above and let us know. We'll select some responses and print them in the Reader Response section of the next issue.

Best wishes to all of our readers and sponsors as we embark on a new year of innovation and creativity.

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Cover

Edwin C. Moses Boulevard Bridge

Dayton, Ohio

Photo: RW Armstrong

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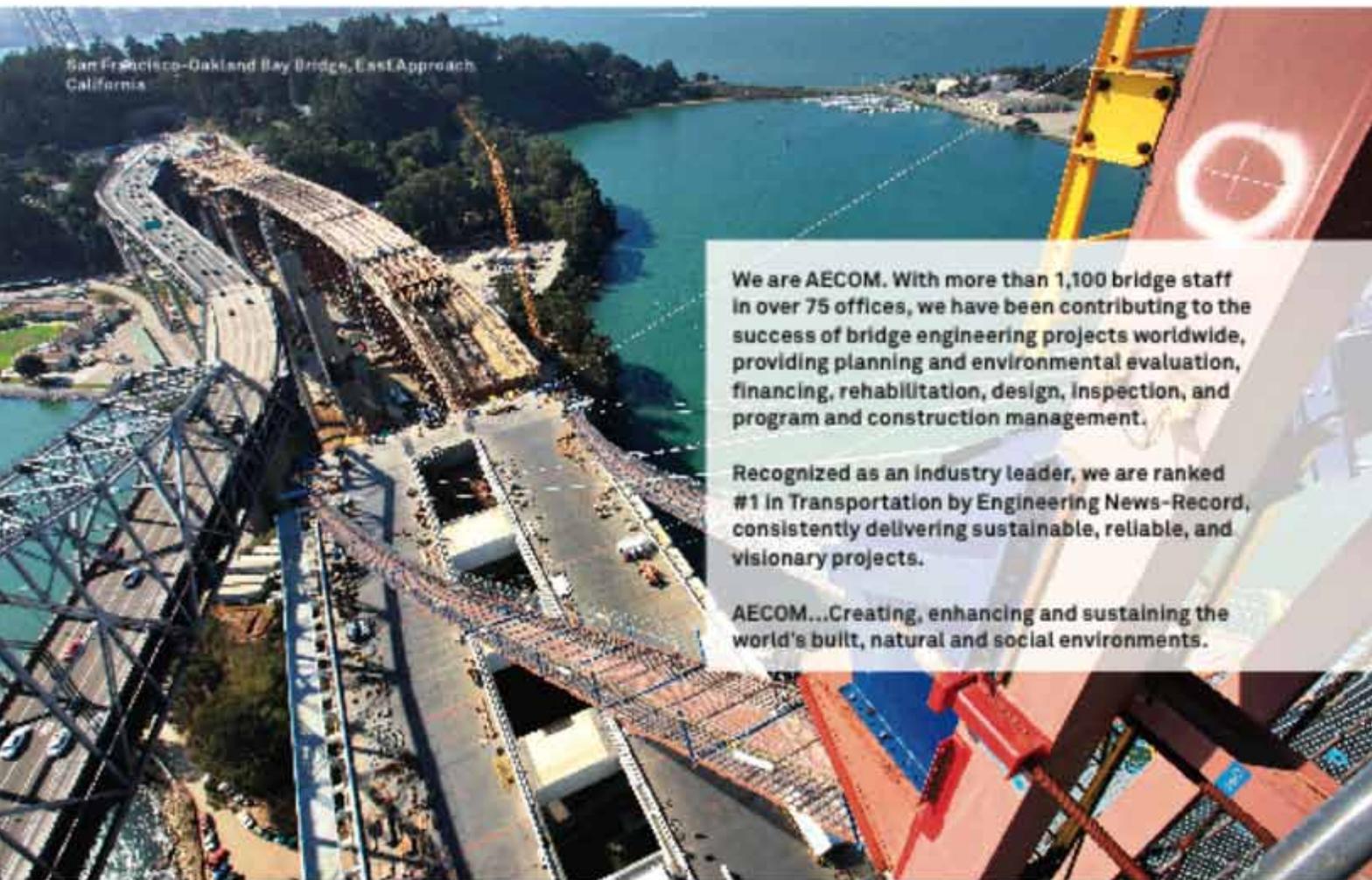


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Indian River Inlet Bridge
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THINKING MORE INNOVATIVELY



San Francisco-Oakland Bay Bridge, East Approach
California

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Frederick Gottemoeller is an engineer and architect, who specializes in the aesthetic aspects of bridges and highways. He is the author of *Bridgescape*, a reference book on aesthetics and was deputy administrator of the Maryland State Highway Administration.

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Dr. Henry G. Russell is an engineering consultant, who has been involved with the applications of concrete in bridges for over 35 years and has published many papers on the applications of high-performance concrete.

Photo:
Ted Lacey Photography.

CONCRETE CALENDAR 2012
For links to websites, email addresses, or telephone numbers for these events, go to www.aspirebridge.org and select "EVENTS."

January 22-26
91st Annual Meeting
Transportation Research Board
Marriott Wardman Park, Omni Shoreham, and Hilton Washington Washington, D.C.

January 23-25
PCI Quality Control & Assurance
Schools, Levels I and II
Las Vegas, Nev.

January 23-27
World of Concrete 2012
Las Vegas Convention Center
Las Vegas, Nev.

February 7-9
The Mid-Atlantic States Quality Assurance Workshop
Dover Hotel and Conference Center
Dover, Del.

February 16-18
4th International Conference on Grouting and Deep Mixing
Sponsored by the International Conference Organization for Grouting and the Deep Foundations Institute
Marriott New Orleans
New Orleans, La.

March 6
12th Annual Concrete Conference
Maryland Transportation Industry
Crowne Plaza Baltimore
Baltimore, Md.

March 18-22
ACI Spring Convention
Hyatt Regency Dallas
Dallas, Tex.

March 29-April 1
PCI Committee Days and Membership Conference
Wyndham Hotel
Chicago, Ill.

April 1-7
National Concrete Week

April 16-17
ASBI 2012 Grouting Certification Training
J.J. Pickle Research Campus
The Commons Center
Austin, Tex.

May 7-10
International Concrete Sustainability Conference
Renaissance Hotel
Seattle, Wash.

May 20-25
14th International Conference on Alkali-Aggregate Reactions in Concrete
Hyatt Regency Austin
Austin, Tex.

June 10-13
International Bridge Conference
David L. Lawrence Convention Center
Pittsburgh, Pa.

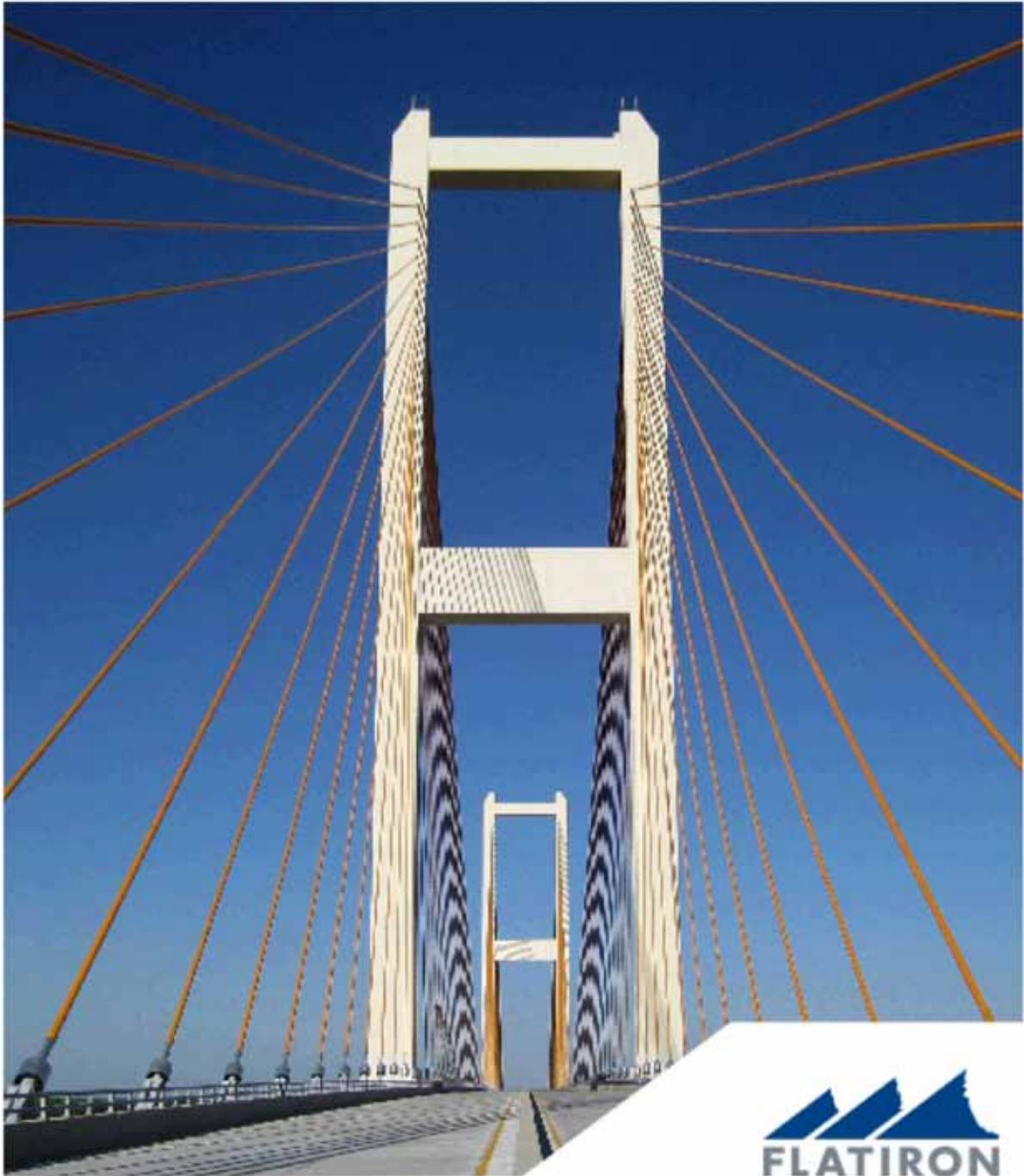
July 7-12
2012 AASHTO Subcommittee on Bridges and Structures Meeting
Hyatt Regency
Austin, Tex.

July 23-27 (Tentative)
2012 PCA Professors' Workshop
Skokie, Ill.

September 29-October 2
PCI Annual Convention and Exhibition and National Bridge Conference
Gaylord Opryland Resort & Convention Center
Nashville, Tenn.
Call for Papers
Abstracts due February 6

October 21-25
ACI Fall Convention
Sheraton Centre
Toronto, Ontario, Canada

October 29-30
ASBI Annual Convention
Turnberry Isle Hotel & Resort
Miami, Fla.



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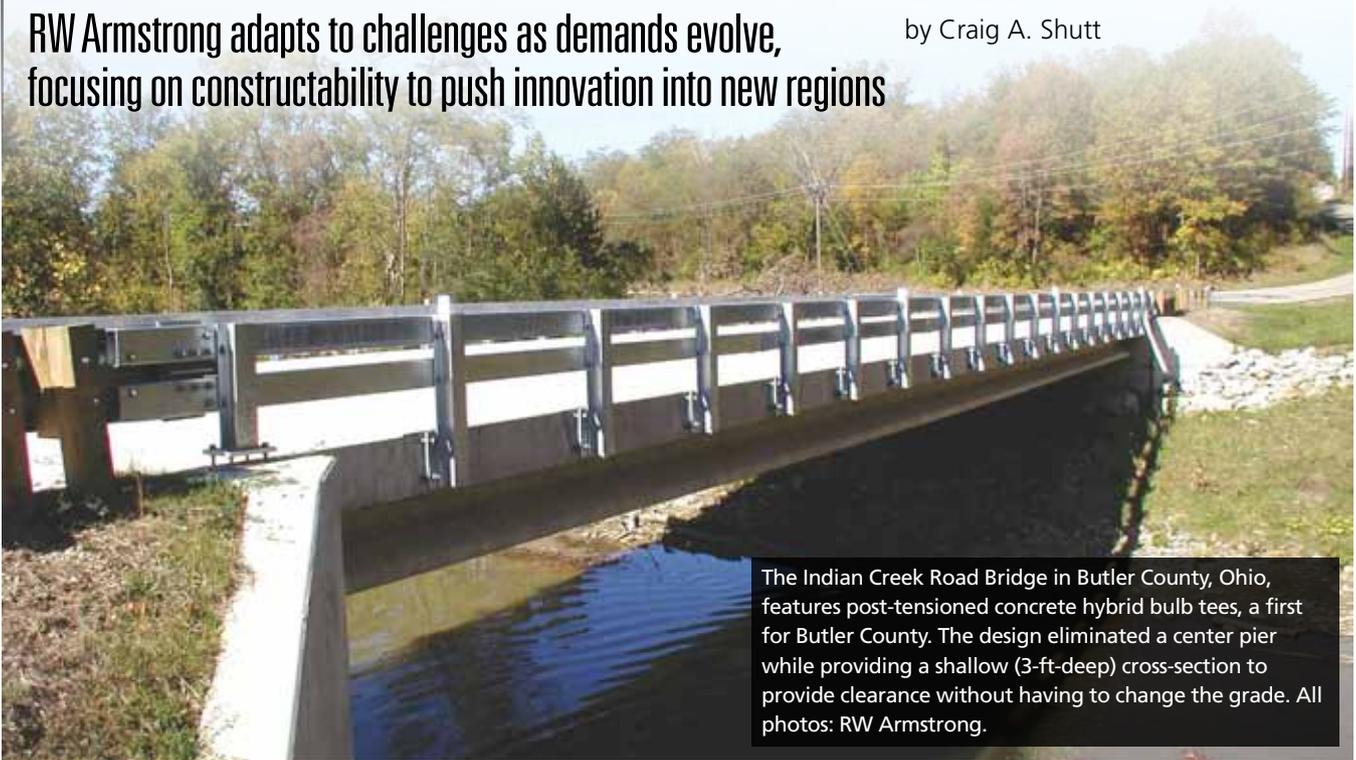
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Innovation on the *FLY*

RW Armstrong adapts to challenges as demands evolve, focusing on constructability to push innovation into new regions

by Craig A. Shutt



The Indian Creek Road Bridge in Butler County, Ohio, features post-tensioned concrete hybrid bulb tees, a first for Butler County. The design eliminated a center pier while providing a shallow (3-ft-deep) cross-section to provide clearance without having to change the grade. All photos: RW Armstrong.

We are a 'go-to' firm for fast-track and high-profile projects.

RW Armstrong's transportation practice has built its reputation on providing value-engineered solutions and working closely with contractors to deliver fast, cost-effective construction. It leverages this reputation to get its foot in the door in new markets and to bring state-of-the-art design and engineering solutions to clients and communities around the world.

Based in Indianapolis, Ind., the firm has served the Indiana Department of Transportation (INDOT) and surrounding state and local agencies for nearly 50 years. In the last decade, it has been involved with more than \$1.5 billion worth of transportation design and construction projects.

"We are a 'go-to' firm for fast-track and high-profile projects and INDOT's largest local consulting partner," says Troy Jessop, domestic structures team leader. "Because of our close association, we understand their decision-making

processes and have developed excellent working relationships with key personnel." Many of RW Armstrong's transportation staff previously worked at INDOT, which brings a wealth of experience and relationships to the firm.

Relying on Relationships

RW Armstrong also works closely with about 15 key heavy civil contractors, which regularly hire the firm to value-engineer a design, enhance constructability after the bid, or provide design-build services. "We are in a different mode than the typical design-bid-build firm," says Seth Schickel, Indiana bridge operations manager. "We often are called in by the bridge owner when an emergency occurs, and we work with contractors when problems arise. We take pride in working closely with contractors to find solutions."

Value-engineering work has been instrumental in RW Armstrong's expansion to 18 offices (13 domestic). "Gaining credibility and work in a new region takes time," says Jessop. "You need momentum and a talented staff to earn DOT and local agency business. It's hard to generate those first projects without a unique way to show value."

Typically, the company's national bridge team works with local contractors and performs value engineering or joins the contractor's design-build team. That gains attention and the momentum that leads to higher-profile projects. This strategy proved successful with the Columbus, Ohio, office, Jessop says, and the team now is focusing on the same template to expand its Austin, Tex., office.

Trying New Techniques

RW Armstrong has also found success in the Midwest by leveraging its expertise on post-tensioning projects. "There are few reputable post-tensioning players in this region, so we often come in with post-tensioning solutions when clients get into difficult situations," says Schickel. Typically, city and county clients are more open to those solutions, he notes, because they see benefits and are willing to try a new approach that will save money.

One example is the 113-ft-long Indian Creek Road Bridge in Butler County, Ohio, which replaced a deteriorated truss structure. County officials wanted a single-span bridge because the stream collects debris, Jessop explains. "It was a

50 Years of Designs

RW Armstrong was founded in 1961. Today the firm provides construction management, design, planning, and program-management services to projects involving buildings, transportation structures, aviation, and other categories.

With nearly 500 employees in 18 international offices (including 13 domestic), RW Armstrong ranks No. 37 in *Engineering News-Record's* list of program-management firms, No. 54 in construction-management firms, and No. 150 in design firms. The firm also has been ranked among the top firms for Best Places to Work in Indiana by the Indiana Chamber of Commerce and the *Indianapolis Star*.

simple crossing, but they didn't want a typical solution of a three-span structure on the existing alignment."

RW Armstrong designed a precast concrete hybrid bulb-tee structure that required only a 3-ft beam depth. The beams were prestressed to aid transport and post-tensioned for final load conditions. The structure is the first in Butler County to use post-tensioned, wide-flange, modified bulb-tee girders.

In another new application, precast concrete hybrid bulb tees were used in Indianapolis on the 82nd Street Bridge over I-465 to replace a four-span, steel-beam bridge. The new two-span precast concrete bridge features 72-in.-deep bulb tees with a 60-in.-wide top flange and a 40-in.-wide bottom flange. The spans are 164 ft each, making them among the longest nonpost-tensioned, two-span precast concrete girders in the state.

"Our goal is to create the best design possible, and that often entails educating our client about the benefits of an engineering solution they are unfamiliar with," says Schickel. "We

The Edwin C. Moses Boulevard Bridge features 48-in.-deep precast concrete U-beams, a first for Ohio. The approach allowed wider beam spacing while creating an aesthetically pleasing girder shape, of which designers took full advantage.

always want to present the best solution and make our case to implement new, innovative ideas."

Another example was a design created for the city of Dayton on Edwin C. Moses Boulevard as it crosses Wolf Creek. The structure reused the existing substructure and replaced the superstructure with 48-in.-deep precast, prestressed concrete U-beams. The design marked the state's first use of prestressed U-beams, which allowed wider beam spacing (12 ft 3 in. on center) and created an elegant edge profile. (For more on this project, see the Winter 2011 issue of *ASPIRE*™.)

Speed, Cost Drive Designs

Bridge owners are beginning to accommodate unfamiliar design concepts for two main reasons: speed and cost. "The need to get bridges built faster has made more states open to new ideas," says Jessop. "There is a big push to build quickly, and more often this emphasis results in using precast concrete options. Steel availability has varied over the last several years and often takes longer to fabricate, but it could offer longer span capabilities. That's much less true today."

Ten years ago, RW Armstrong's designers would have the occasional fast-track project in-house at any time, Schickel notes. "Today, they're all fast-track projects, because owners see that completing the work quickly benefits the community and the users."

Accordingly, the team continues to evaluate new concepts, such as preassembling more components and using self-propelled modular transporters (SPMTs). "A significant amount of our time now is spent not just designing bridge components but also assisting contractors with accelerated-bridge concepts, such as falsework design and lifting devices required for these new types of construction," says Jessop.

The need for speed also has prompted more contractors to use a large amount of precast concrete such as precast pier caps and columns, he adds. "This is a relatively new trend on both large and small projects."

Budget restrictions are changing design approaches, Schickel adds. "With the economy as it is, efficiency is on everyone's mind, so we have to prove to the public that the money is being spent prudently. We spend a lot more time developing preliminary designs and working out every detail to ensure the design is as cost-effective as possible before we present it to the client and the public."

That can be seen on the \$487-million U.S. 31 reconstruction and upgrade project currently underway in Hamilton County, Ind. This corridor consists of 12 miles of reconstruction north of Indianapolis, and includes eight grade-separated interchanges. Among the structures are 30 precast, prestressed concrete girder bridges, eight precast





Our goal is to create the best design possible, even if it's unfamiliar to the client.

Schickel. "We know things will change—schedule, budget, scope—but we don't know when or how. So we continually look for new ways we can adjust."

One area with significant value to clients is the firm's knowledge of funding types. RW Armstrong has a staff devoted to helping clients obtain funding, Jessop says. "We've evolved from simply creating studies that point out needs to helping clients justify expenses and obtain funding. Smaller clients

in particular need assistance, so that's become a bigger part of our role as consultants."

Replacement versus rehabilitation has become a bigger question as owners look to save money, which can result in a move toward ineffective returns on investment. "We want to help them spend wisely in the short term and not give in to the pressure to do lower-budget quick fixes," says Jessop. "We want solutions that serve the client now and will be durable and cost-effective over the long term."

That also creates pressure to produce precise estimates, he says. "There's been a shift to wanting perfect plans with exact quantities. Design fees are becoming tighter while expectations are higher for accuracy of plan quantities and elimination of change orders. With pressure to perform the lowest capital

cost quick fixes, there is a need to expand our reports to examine full life-cycle costs and other factors."

To that end, the company has created a weighted-matrix analysis that compares structure types and construction techniques based on the owner's prioritized goals. Such a matrix, which was used on the Moses Bridge, weighs capital costs plus aesthetics, durability, life-cycle costs, and environmental impact. "It helps clients evaluate their priorities and allocate their budget to achieve their key goals," says Jessop.

Examples of client goals can be seen on specialty projects, such as airport taxiways, where blast resistance and durability might rank higher than aesthetics. "That may justify a more massive concrete box structure that we wouldn't necessarily use on projects where those are not requirements," he explains. "The matrix helps clients see how each factor impacts the others and leads to the best design solution overall."

Aviation Synergies

The RW Armstrong Structures group often works with the firm's Aviation practice when specialty structures are required, Jessop notes. "We get called into their projects when they have to deal with an interesting structure—navaids, taxiway bridges, and others."

Several such projects have been completed recently. They include Taxiway B at the Tampa International Airport, which was developed on

To replace an existing four-span steel-beam bridge at 82nd Street over I-465 in Indianapolis, Ind., RW Armstrong designers used a two-span precast concrete bridge with hybrid bulb tees. The two 164-ft spans are among the longest nonpost-tensioned girders in the state.

concrete flat-arch structures and four post-tensioned concrete bridges. Several public meetings and design charrettes were held to fully engage the public and help explain the project and minimize inconvenience.

"This project required a lot of preliminary design. We even had other in-house staff value-engineer our work to ensure we had the right type of interchange bridges at each location," says Schickel. "We needed to push hard to meet the scope and budget on an accelerated time frame and design a solution that met the needs of all stakeholders."

Design Scope Changes

Design scope has become a volatile concept, notes Jessop. "Years ago, we followed the client's project scope and the fees developed for that scope. Today, it's a new game. We're constantly adjusting project scope in the early stages, investigating more alternatives and plans as we go, which adds challenges to establishing sound contracts and design fees." This also requires designers to be "flexible and innovative on a day-to-day basis," adds

The \$487-million U.S. 31 reconstruction and upgrade project in Hamilton County, Ind., involves 12 miles of reconstruction and construction of a variety of precast and post-tensioned concrete bridges. The design team gained considerable feedback from the public and used a variety of methods to communicate, including a website devoted to the project.





RW Armstrong's transportation team often works closely with its aviation team, such as at the Port Columbus International Airport in Columbus, Ohio, where cast-in-place, post-tensioned, variable-depth box girders were used to create a new taxiway. The project was built on grade, then soil excavated from beneath it to avoid needing falsework.

an extremely fast-track, design-build schedule to meet the deadline for federal stimulus funding. The \$5.7-million project features a post-tensioned concrete box girder bridge, which provided the aesthetics the owner sought for this high-profile crossing. RW Armstrong provided the front-end design-build criteria package for the taxiway on the accelerated schedule.

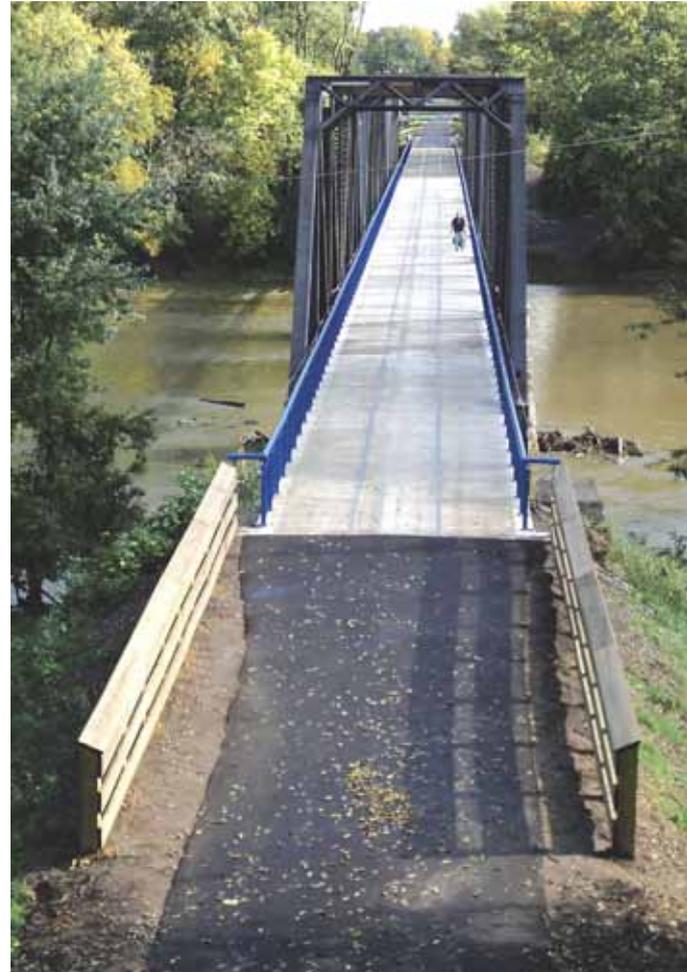
Another such project was the single-span, cast-in-place, variable-depth, post-tensioned concrete box-girder design for the new taxiway at the Port Columbus International Airport in Ohio. Three-dimensional finite analysis and modeling were performed to determine construction staging and long-term creep and shrinkage effects. (For more on this project, see *ASPIRE*, Winter 2009 issue.)



A focus on context-sensitive solutions has led to more attention on aesthetics, such as this use of reveals and textures on the MSE walls on a bridge over I-465 in Indianapolis, Ind.

Aesthetics are playing a larger role in every project, the designers note, with context-sensitive solutions becoming a high priority. "We're doing much more with formliners and tints, because they're easy and make a big impact," says Schickel. "The public likes those details, but engineers traditionally shied away from them because they add complications and have no structural design function."

One of the more interesting bridge applications is the conversion of abandoned railroad structures into pedestrian and bicycle trails. Existing steel truss structures have ballast and ties removed, a cast-in-place concrete deck placed and decorative safety rails installed. At the Nickel Plate Trail in Peru, Ind., the trail owners asked for the deck to be embossed with recessed grooves to pay homage to the original steel railroad tracks.



"Aesthetic ideas that would have gotten us kicked out of a contractor's office years ago are now gaining acceptance," says Jessop. "Contractors and clients are increasingly open to new ideas and fabricators are capable of creating a much wider range of shapes and forms today. Previously, we were limited to adding tinted sealers and formliners, but with the improvement in formwork and falsework, we can be much more creative with aesthetic concepts.

RW Armstrong's designers are helping to reuse abandoned railroad trestles, like this one in Peru, Ind., by replacing ballast and deteriorated ties with a grooved concrete deck that provides a smooth surface for pedestrians and bicycles.

As these concepts develop, our relationships with contractors are crucial to ensure that our ideas can be built."

For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.

Pennsylvania Looks to Highlight an Important 'Utility Bill'—Transportation

by Barry J. Schoch, Pennsylvania Department of Transportation



Every day, Americans pay for the ability to call a family member across the country, watch their choice of hundreds of television channels, and keep running water and electricity in their homes. These are bills people are used to—a payment for accessibility to services. In Pennsylvania, I would like citizens to look at their transportation system in the same way.

We need to look at our transportation network investment like a utility bill. You may never drive to Kansas or even to the other side of the state, but funding is required to keep the system intact so people always have that option.

Mailing Pennsylvanians bills isn't an option for the Pennsylvania Department of Transportation (PennDOT); legislation and procedural changes are needed to increase funding for the state's transportation infrastructure. And in a state with \$3.5 billion in unmet transportation needs, ensuring that people understand transportation's impact on their quality of life and their wallet is essential.

Pennsylvania has the highest number of structurally deficient bridges in the country, and we maintain more miles of roadway than all of New England combined. By underinvesting in our infrastructure in the past, we've put ourselves in a position where we can't expand capacity because our maintenance needs are so great.

By the numbers, roughly 5000 of the 25,000 bridges PennDOT maintains are structurally deficient, or in need of repair. In addition, the state has closed 50 bridges, 650 more have weight restrictions, and 14,000 bridges have deteriorated or are nearing structurally deficient status. More than 8000 of the 40,000 roadway miles PennDOT maintains need to be repaired. Transit providers across the state are facing increased costs, aging equipment, and declining funding even amid ridership

increases. It's only a matter of time before long detours and increased congestion on worn-down roadways impact Pennsylvanians drastically.

The daunting figures stacked against PennDOT's budgetary constraints aren't for a lack of vigilance or effort. PennDOT ensures that every bridge is inspected at least once every 2 years. Federal recovery funding, coupled with state funding focused on improving bridges, has improved the state's structurally deficient bridges. Still, for every two bridges taken off the structurally deficient list, one is added—a fact that can be attributed to the state's average bridge age of 50 years. Without sustained and increased investment, the number of structurally deficient bridges and miles of poor roadway will begin to climb again.

Citing the well-documented need to improve the state's infrastructure, Pennsylvania Governor Tom Corbett is committed to finding funding opportunities the state can implement in the current economic climate. We are carrying out the administration's mission to achieve that goal in a way that makes sense for Pennsylvanians.

The reality is that people are being charged more by using more gasoline and increasing wear and tear on their cars by sitting in traffic and taking detours. Instead, they could pay 70

cents a week and we'll fix the problem. Even if they would pay \$2.50 a week, that's cheaper than wasting even half a gallon of gasoline a day in congestion.

An average person driving 12,000 miles per year uses 500 gallons of gasoline. Fifty cents in fuel taxes costs that driver \$250 a year, increasing to approximately \$300 a year when license and registration fees are added in.

Even if a person spends \$360 a year in fees and fuel taxes, that's about \$30 a month. I ask everyone to compare that cost to their monthly cable, cell phone, or internet bills. The return on investment for transportation is huge.

When people make the connection between the roads they take to work, the transit bus their relatives take to the store, and the bridges that carry trucks delivering groceries and other goods, the value of transportation investments becomes plain. If Pennsylvania increases its transportation utility bill, the investment will pay dividends for its businesses and citizens.

For more information on PennDOT, visit www.dot.state.pa.us.

Barry J. Schoch, P.E. is transportation secretary of the Pennsylvania Department of Transportation in Harrisburg, Pa.



Significant flood damage sustained in north central Pennsylvania with the combined rains of Hurricane Irene and Tropical Storm Lee during fall of 2011. Photos: PennDOT District 3 engineering staff.



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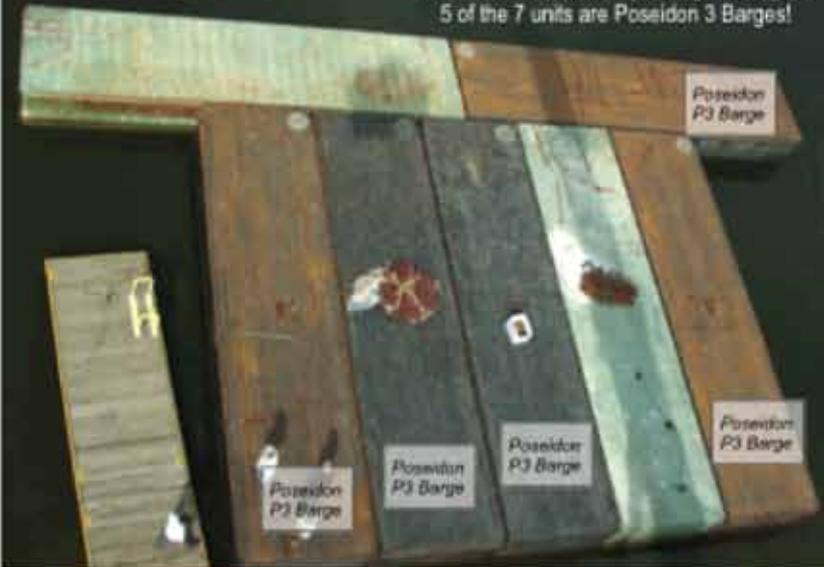
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PROJECT

Indian River Inlet Bridge— Surviving the Storms

by Eric T. Nelson, AECOM

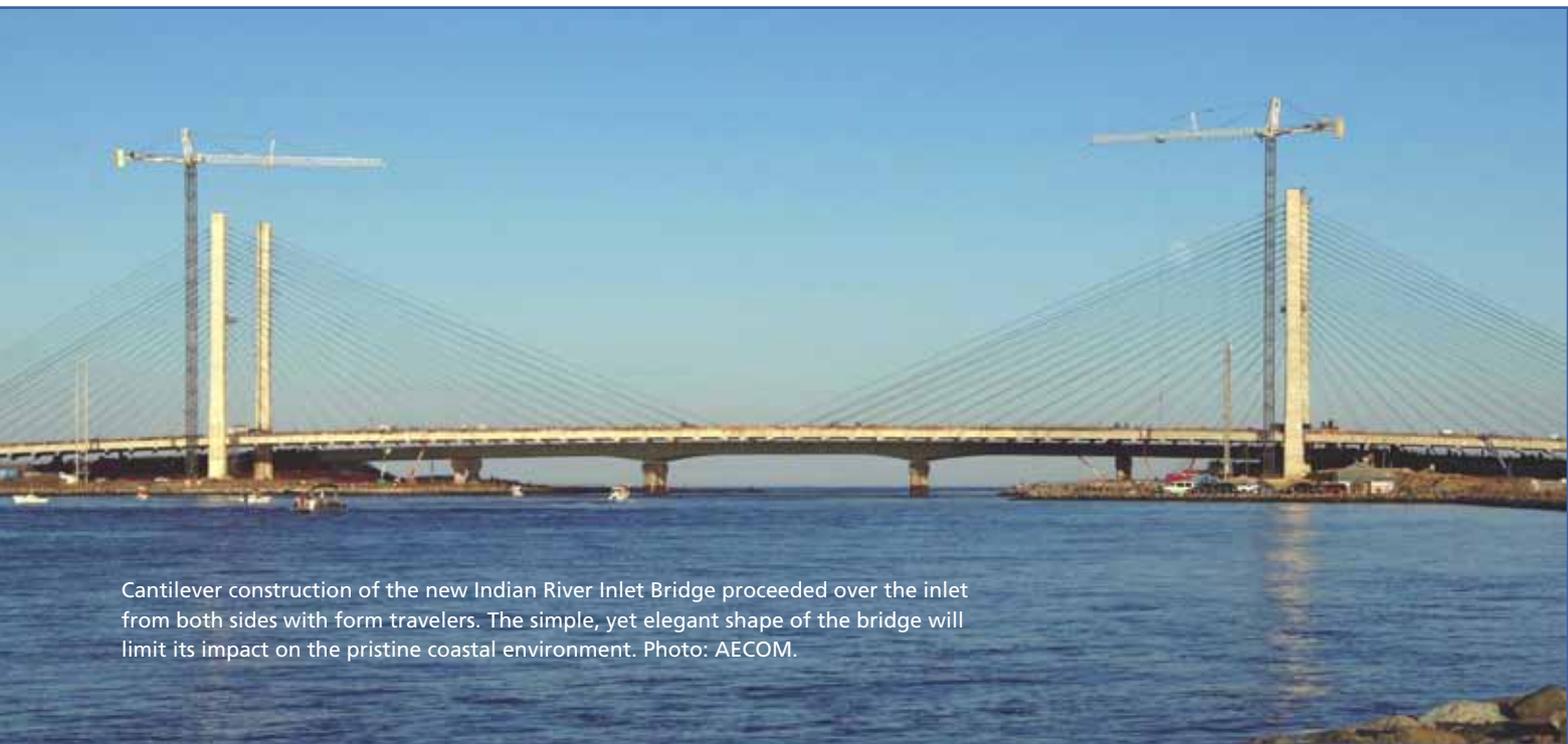
Cable-stayed design spans treacherous inlet with history of extreme scour

In the last week of August 2011, Hurricane Irene roared up the east coast of the United States leaving billions of dollars in property damage in its wake. Directly in its path was the ongoing construction for the new Indian River Inlet Bridge in Delaware. With this site being just yards from the Atlantic Ocean, this will not be the last such storm that the new bridge will have to withstand. In fact, bridging this inlet has proven very difficult over the years.

The new bridge will be the fifth bridge constructed across the inlet in just over 60 years. The first three bridges were battered by storms and extreme tides at the site, and the current bridge built in 1965 is now in jeopardy from severe scour and erosion of the inlet bed, with some scour holes near the foundations approaching 105 ft deep.

The Delaware Department of Transportation (DelDOT) has continued

to monitor the condition of the existing bridge closely, while construction of the new replacement bridge began in late 2008 under a design-build contract. The history of problems with extreme tides and scour of the previous bridges over the inlet led DelDOT to mandate that all piers for the new bridge had to be placed outside of the inlet. Additionally, DelDOT imposed a 900-ft horizontal clearance requirement to accommodate for the potential future widening of the



Cantilever construction of the new Indian River Inlet Bridge proceeded over the inlet from both sides with form travelers. The simple, yet elegant shape of the bridge will limit its impact on the pristine coastal environment. Photo: AECOM.

profile

INDIAN RIVER INLET BRIDGE / BETHANY BEACH, DELAWARE

DESIGN-BUILD TEAM: Skanska USA Civil Southeast, Virginia Beach, Va.—AECOM, Glen Allen, Va.

CONTRACTOR: Skanska USA Civil Southeast, Virginia Beach, Va.

BRIDGE DESIGN ENGINEER: AECOM, Glen Allen, Va., and International Bridge Technologies Inc., San Diego, Calif.

CONSTRUCTION ENGINEERING: AECOM, Hong Kong, China (Erection Analysis) and Finley Engineering Group Inc., Tallahassee, Fla. (Falsework)

CONSTRUCTION ENGINEERING INSPECTION: Parson Brinckerhoff, New York, N.Y.

STAY CABLE AND POST-TENSIONING CONTRACTOR: Freyssinet USA, Sterling, Va.

PRECAST CONCRETE PRODUCER: Bayshore Concrete Products Corporation, Cape Charles, Va., a PCI-certified producer

Use of precast and cast-in-place concrete over land sped construction.

inlet from the current 500 ft to 800 ft. These two criteria resulted in a bridge solution that consists of a three-span, cable-stayed bridge with two twin-pylons, a center span over the inlet of 950 ft, and two side spans of 400 ft each. The total length of the new bridge is 2600 ft, which includes the cable-stayed main spans and flanking 425-ft-long approach units on both ends.

The bridge site lies on a barrier island bounded by the Atlantic Ocean on the east and Indian River Bay on the west. This barrier island is part of the 2825-acre Delaware Seashore State Park. The Indian River Inlet Bridge is on State Route 1 (SR 1) that lies on the barrier island, connecting the towns of Rehoboth Beach to the north and Bethany Beach to the south of the Indian River Inlet. Dunes and beaches dominate the landscape to the east of SR 1, while tidal marshes and wetlands are located to the west.

The bridge roadway for the approaches and cable-stayed structures carries four lanes of traffic with shoulders and a 12-ft-wide sidewalk for pedestrians and bicyclists. The out-to-out widths of the approach and cable-stayed spans are 93 ft 3 in. and 106 ft 2 in., respectively.

Cable-Stayed Spans

The cable-stayed superstructure consists of cast-in-place concrete edge girders with both precast and cast-in-place concrete transverse floor beams, and a cast-in-place concrete deck. The cable



The use of precast concrete floor beams and cast-in-place construction on falsework for the portions of the bridge over land significantly sped construction because work could be completed simultaneously on several different fronts. Photo: AECOM.

system consists of 19 stays on each side of the four pylon towers to form two vertical planes of stays supporting the edge girders (152 stays in total). The stay cables consist of 0.62-in.-diameter, seven-wire, low-relaxation strands, and have 19 to 61 strands per cable. For improved corrosion resistance, each strand is coated with wax and encapsulated inside high-density polyethylene (HDPE) sheathing. Additionally, the strand-bundled stays are protected by an outside HDPE pipe, with the surface textured by a double helical fillet to reduce rain- and wind-induced vibrations. The stay cables are anchored in the edge girders and pylons in a modified fan pattern.

With the bridge being relatively close to the ground, the effects of concrete creep and shrinkage are mitigated by having only one permanent longitudinal connection of the superstructure to the substructure. At the north pylon, elastomeric bearings transfer longitudinal forces from the deck to the pylon. Bearings are located on each

Visual Sensitivity

Providing a context-sensitive design solution was one of the principal considerations for the design-build team. The design theme selected for the bridge was to provide unobtrusive views of the Atlantic Ocean and not overpower the beach communities near the site with a massive structure. The resort communities near the bridge have expressed great appreciation for the simple, yet elegant shape of the bridge and its minimal impact on the pristine coastal environment. The 248-ft-tall pylons are the tallest structures in this flat coastal region, but their slenderness combined with blue, outer cable-stay pipes evokes a nautical theme replicating tall masts of sailing ships. The low profile of the superstructure is only 6 ft deep and provides open vistas of the Atlantic Ocean and Indian River Bay. Boaters, as well as people living in the area have commented that the bridge is unique and has enhanced the oceanfront.

THREE-SPAN, CABLE-STAYED CONCRETE BRIDGE WITH FOUR-SPANS OF PRECAST, PRESTRESSED CONCRETE GIRDER APPROACH UNITS AT BOTH ENDS / DELAWARE DEPARTMENT OF TRANSPORTATION, OWNER

CAST-IN-PLACE CONCRETE SUPPLIER: Thoro-Goods Concrete Company, Millsboro, Del.

REINFORCING STEEL SUPPLIER: CMC Rebar, Wilmington, Del.

FORM TRAVELERS: Strukturas, Langesund, Norway

BRIDGE DESCRIPTION: A 2600-ft-long, three-span, cable-stayed, cast-in-place and precast concrete bridge with span lengths of 400, 950, and 400 ft with two sets of cast-in-place concrete pylons and fanned stays. Four approach spans of 106 ft 3 in. each at both ends of the bridge use bulb-tee beams with composite concrete deck. The substructures are cast-in-place concrete piers for the approach spans and the main spans. All substructures are supported by precast, prestressed concrete piles.

BRIDGE CONSTRUCTION COST: \$150 million



The stays are anchored in the white structural steel anchorage boxes in the pylons. The anchorage boxes take advantage of the high-tensile capacity of structural steel to resist the large horizontal tension resulting from the cable stays, while the vertical compression from the stays is handled by the concrete. Photo: AECOM.

Low permeability concrete and epoxy-coated reinforcement were used to achieve a 100-year service life.

longitudinal face of the pylon, so that they are acting only in compression. At the south pylon, the deck is free to move relative to the pylon. During construction, the bearings at both pylons were fixed so the spans were not totally free to move. Only after the closure in the main span was cast were the bearings at the south pylon released.

Each of the two continuous edge girders is 6 ft deep and 5 ft wide, and for the majority of the deck, the edge girders are centered on the vertical planes of the supporting stay cables. However, in order to avoid the edge girder framing into the pylons, the edge girder is configured to deviate around the pylons. This allows the edge girder to be aligned with the pylons in the regions where the stay cables are anchored, while still allowing the deck to move longitudinally at the free pylon.

The transverse floor beams are typically spaced at 12-ft on center and the cable support points are located every 24-ft along the longitudinal edge girder corresponding to the length of each cantilever segment. The

cable stays align with alternate floor beams except near the transition pier in the back spans where the stays are grouped closer together. The use of a closer floor beam spacing than has been used conventionally for this type of cable-stayed bridge, allowed the deck thickness to be only 8½ in. for the majority of the bridge, with a 10½-in. thickness only in the highly compressed regions near the pylons. This resulted in a significant savings in concrete weight and thus less demand on the stays and pylon foundations. Additionally, the closer floor beam spacing allowed easier deck form placement and removal.

A combination of both precast and cast-in-place concrete floor beams was used. Precast, pretensioned concrete floor beams were used in the side spans and the portion of the main span that is accessible by land, while the floor beams in the main span over the inlet used cast-in-place concrete. Since much of the bridge is easily accessible by land, it was beneficial to precast as many floor beams as possible to remove this operation from the critical path of construction. It also resulted

in one less concreting operation to be performed on-site, which saved both time and money. The precast floor beams are roughly I-shaped, 5 ft 9 in. deep at the crown point of the deck and approximately 4 ft 9 in. deep at the edge girders. The webs are 10 in. thick with 1-ft 10-in.-wide flanges. The top flange is 9 in. deep and the bottom flange is 1 ft 0½ in. deep. The ends of the precast floor beams are flush with the edge girder. Reinforcement extends from the floor beams into the edge girders. The cast-in-place concrete floor beams are rectangular with a width of 11 in.

Internal post-tensioning tendons were used in all of the transverse floor beams, and in portions of the edge girders and

Sustainability

Given the proximity of the Indian River Inlet Bridge to the Atlantic Ocean, the ability of the structure to withstand the corrosive marine environment was a high priority and DelDOT dictated that the new bridge be designed for a 100-year service life. Development of a project-specific corrosion control plan was required by the design-build performance specifications and intended to ensure that the specified service life for each structural component is achieved.

DelDOT also specified that high-performance, low permeability concrete be used in both the superstructure and substructure elements with a maximum allowable permeability of 1500 coulombs. Epoxy-coated reinforcement was used for the entire structure with a minimum concrete cover of 2 in. from all surfaces. Additionally, to mitigate potential alkali-silica reactivity, the cementitious materials used in the concrete mixes included 35 to 60% ground-granulated blast-furnace slag.

Finally, a polyester polymer concrete (PPC) overlay with a high molecular weight methacrylate resin prime coat will be applied to the top of the deck along the riding surfaces and pedestrian walkway of the main-span, cable-stayed portion of the bridge. The PPC baseline target thickness is 1-in.-average thickness and ¾-in.-minimum thickness.



The use of epoxy-coated reinforcement throughout the structure along with several other anti-corrosion measures will help the new Indian River Inlet Bridge achieve a planned 100-year service life in the corrosive marine environment near the Atlantic Ocean. Photo: AECOM.



Precast, pretensioned and post-tensioned concrete floor beams are supported by the edge girders with reinforcement that extends from the beams into the girders. Photo: AECOM.

deck. Anchors for the floor beams are located in the edge girders. All of the tendons on the bridge comprise 0.6-in.-diameter, seven-wire, low-relaxation strands in corrugated, high-density polypropylene (HDPP) plastic ducts. The tendon sizes range from four-strand tendons in the deck and up to 31-strand tendons in the edge girders.

Pylons

Each pylon consists of two, cast-in-place reinforced concrete hollow towers. In the longitudinal direction, the towers have a constant width of 11 ft. In the transverse direction, the pylon towers taper from 16 ft at their base to 12 ft at the top. The towers are approximately 248 ft tall above the ground level. The inside wall thickness of the tower on the side toward the deck is 2 ft 6 in., while the outside wall thickness is 1 ft 6 in. This results in the center of gravity of the tower section falling within 3 in. of the centerline of the stay cables, thereby minimizing the eccentric loading of the towers. Structural steel anchorage boxes are used to anchor the stays in the towers and transfer longitudinal tension across the section.

The pylon towers at each location are only connected together across the deck at the footing level by a grade beam. The cross strut conventionally used to connect twin pylon towers

together for stability above the deck level was eliminated. The lack of this strut significantly expedited the speed and cost-efficiency of the construction. Elimination of the cross strut resulted from a combination of two factors:

1. Judicious design that minimized the p-delta effect resulting from the centerline of the stay cables being only slightly eccentric to the center of gravity of the tower section.
2. Improved aerodynamic characteristics of the tower cross section by using a slender shape with rounded corners.

The pylons are founded on 10-ft-thick, cast-in-place concrete footings, which are supported by 42 prestressed concrete piles. Each 36-in.-square pile is 100 ft long and has a capacity of 1800 tons.

Approach Spans

Each 425-ft-long approach unit at each end of the bridge comprises four 106-ft 3-in.-long spans. These consist of 70-in.-deep precast, prestressed concrete bulb-t tee girders. The girders are composite with an 8½-in.-thick concrete deck. The spans are made continuous for live load by casting the beam ends integral within a diaphragm and placing the deck continuous over the top. Eight prestressing strands and nonprestressed reinforcement extend from the ends of the beams into the diaphragms.

The Indian River Inlet Bridge has a 950-ft-long main span and two side spans of 400 ft each. Photo: Skanska USA Civil Southeast.



Construction Sequence

The site for the Indian River Inlet Bridge presented a unique advantage seldom seen in long-span, cable-stayed construction in that more than half of the deck is accessible from the ground. This presented an opportunity to construct a significant portion of the deck on falsework. This is clearly preferred, as it is both less expensive and significantly faster than traditional form traveler construction. The entire 400-ft-long side spans and approximately 182 ft of the main span on both sides of the inlet—a total of 364 ft of the main span—were built entirely on falsework before any stays were installed. The first seven pairs of stays were then installed, and then only with the eighth stay was one-way incremental, cantilever erection started over the inlet with the form traveler. During construction with the form traveler, the stays were added incrementally; with the side span stay installed first and then the stay on the main span side installed as the form traveler advanced. The falsework was sequentially removed as the stays were installed.

As Hurricane Irene approached in August 2011, cantilever construction over the inlet was well underway. With the heavy form traveler on the tip of the cantilever, the structure was in a very vulnerable state. Anxiety was

already high on the site as the most powerful earthquake to strike the east coast of the United States in 67 years had just rattled nerves the week before. However, a post-earthquake inspection of the bridge revealed that all was well. Pre-installed 2½-in.-diameter, post-tensioning, hurricane tie-down bars were engaged to help stabilize the structure during the storm and everyone was then evacuated from the site. There were two tie-down bars at the ends of all four cantilevers. The bars were anchored to 36-in.-diameter steel pipe piles and stressed to 123 kips on the side-span cantilevers and to 161 kips for the main span cantilevers. The eye of the hurricane passed almost directly over the bridge with winds approaching 80 mph. In a testament to the robustness of the design and to the dedicated professionalism of the people constructing the bridge, Hurricane Irene passed through causing no damage to the bridge.

Closure on the main span was completed in October 2011 and the new bridge is scheduled to open for traffic in early 2012. While Hurricane Irene won't be the last storm to ravage the area, the citizens of Delaware can now be confident that the new Indian River Inlet Bridge will survive the storms and provide safe travel for them over the inlet for many decades to come.



Boat traffic was uninterrupted as cantilever construction of the bridge extended out over the Indian River Inlet. Photo: AECOM.

Eric T. Nelson, is a lead bridge design engineer with AECOM in Nashville, Tenn.

For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.

Views from above and below the pier table showing the edge girder deviated around the pylon towers to permit longitudinal movement of the deck. Post-tensioning anchorages have been placed at the sides of the floor beam not accessible from the outside face of the edge girder. Photos: AECOM.





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Bottom right bridge photo courtesy of Ray Thompson Photography

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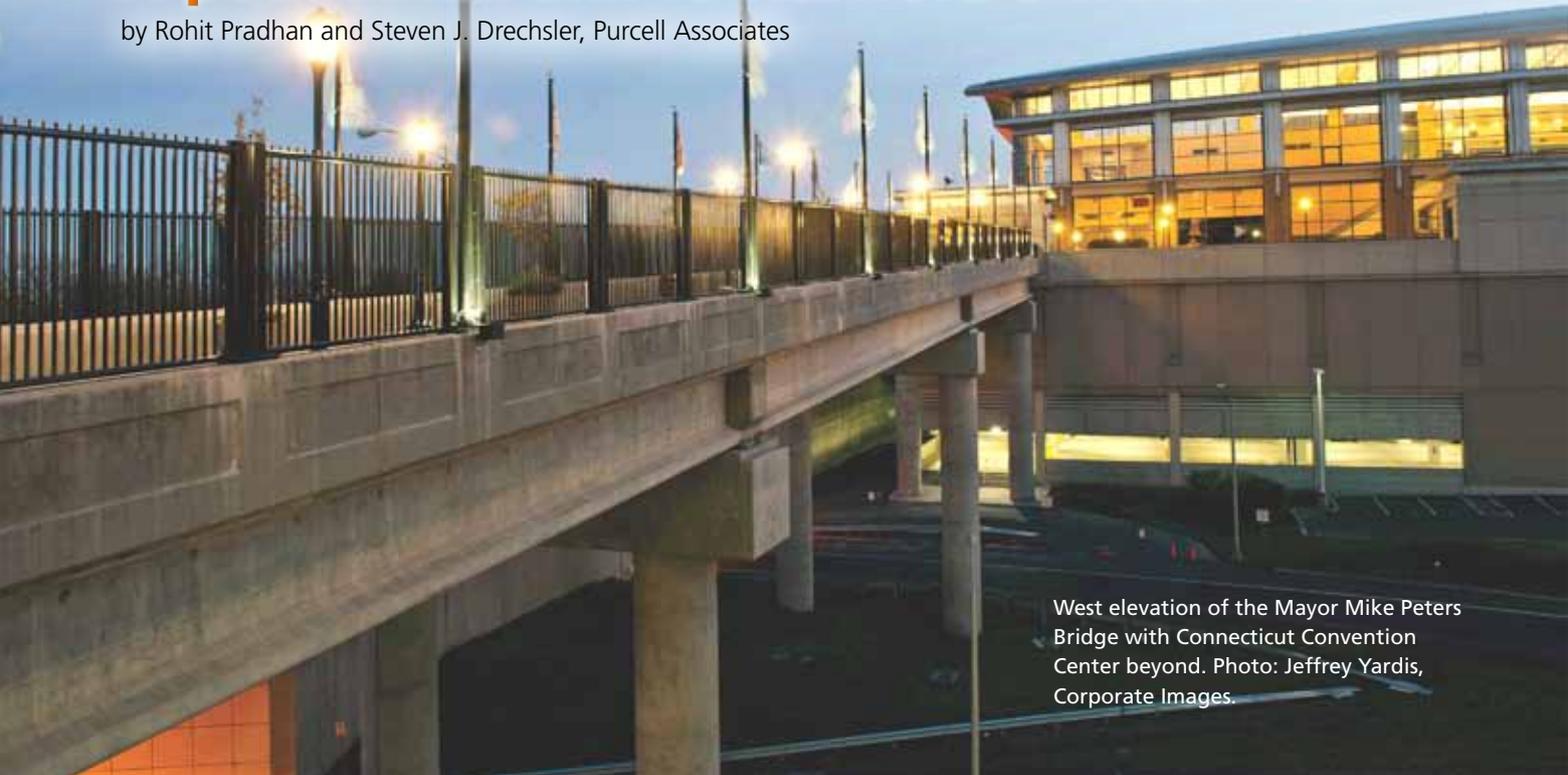


CRSI is a member of FTA. Photo by Ray Thompson

Mayor Mike Peters Bridge

A pedestrian link to Hartford's waterfront

by Rohit Pradhan and Steven J. Drechsler, Purcell Associates



West elevation of the Mayor Mike Peters Bridge with Connecticut Convention Center beyond. Photo: Jeffrey Yardis, Corporate Images.

The Mayor Mike Peters Bridge is part of the Adriaen's Landing development project at the easternmost edge of the city of Hartford, Conn. Adriaen's Landing is part of the revitalization plan for Hartford and one of the key elements of the state of Connecticut's vision known as the "Pillars of Progress." The state's development team broke ground on the project in the spring of 2001. Four key projects of Adriaen's Landing had been completed prior to the construction of the bridge: the Connecticut Science Center, the Connecticut Convention Center, the Hartford Marriott Downtown Hotel and the Front Street Retail project—

all within the 27-acre site adjacent to the Connecticut River. The Mayor Mike Peters Bridge is the final connecting element of the projects allowing pedestrian access to all of these attractions and the Connecticut River waterfront. The bridge also serves as a means of egress for the Science Center with an egress load of 1423 occupants in accordance with the state of Connecticut Building and Fire Safety Codes.

The New Bridge

The bridge has an approximate length of 268 ft, an overall width of 33 ft, and is located on an approximate

north-south alignment. It provides for pedestrian traffic over I-91 and I-84 on-ramps, with a vertical clearance of approximately 40 ft. The bridge consists of three spans of 63-in.-deep precast, prestressed concrete bulb-tee beams (PCEF-63) and precast, prestressed concrete deck panels made composite with the beams. There are four beams in the cross section spaced 9 ft 0 in. on center. The concrete design compressive strength was 6500 psi. The beams were designed as simple spans but made continuous for live loads with cast-in-place diaphragms at the intermediate piers. Reinforcement to resist tension from the negative moment

profile

MAYOR MIKE PETERS BRIDGE / HARTFORD, CONNECTICUT

BRIDGE DESIGN ENGINEER: Purcell Associates, Glastonbury, Conn.

PRIME CONTRACTOR: Loureiro Contractors Inc., Plainville, Conn.

PROJECT ADMINISTRATION: Connecticut Department of Transportation; Connecticut Office of Policy and Management; and Capital City Economic Development Authority

PROGRAM MANAGER: Waterford Development LLC, Waterford, Conn.

ARCHITECTURAL CONSULTANT: Milton Lewis Howard Associates Inc., Bloomfield, Conn.

MECHANICAL AND ELECTRICAL CONSULTANT: AI Engineers, Middletown, Conn.

ENVIRONMENTAL CONSULTANT: GZA Geoenvironmental Inc., Glastonbury, Conn.

GEOTECHNICAL CONSULTANT: Clarence Welti Associates Inc., Glastonbury, Conn.

was provided in the cast-in-place deck that was full depth over the piers. This reinforcement was spliced into the precast deck panels with dowel bar splicers. The precast panels were held back from the area over the piers. To extend the service life of the bridge, epoxy-coated reinforcement was used in all superstructure elements.

Precast Concrete Deck Panels

The precast deck panels are 8 ft long, 32 ft wide, and 8 in. thick. They are pretensioned in the transverse direction and post-tensioned in the longitudinal direction. The specified panel concrete compressive strength was 6000 psi. The panels are connected to the bulb-tee beams by pairs of bar loops extended from the beams into pockets cast into the panels. The pockets are 3 in. by 9 in. and spaced at 1 ft on center. The grout used to fill the block outs and in the haunch over the beams was a 5000 psi, nonshrink mix. The panels are post-tensioned together longitudinally in units of five or six. Spaces were left over the piers, at the Convention Center, and at the skewed approach to the Science Center where the deck concrete was placed full depth. The gaps over the piers were 11 ft wide. The precast concrete panels have a 4-in.-

thick structural composite overlay with decorative surface treatments.

Geometric Details and Substructure

The south end of the bridge is connected to the Convention Center with no skew, whereas the north end is connected to the Science Center at a skew angle of approximately 15 degrees. The center span is approximately 94 ft long. The north span is 73 ft long and includes a 10-ft-long cantilever beyond the end of the span and the south span is 101 ft long and includes a 15-ft-long cantilever beyond the span. The deck slopes down toward the Science Center on a 4.98% grade. The superstructure is supported on four reinforced concrete piers. The piers are two-column bents with 5-ft 6-in.-diameter columns and 6-ft-deep by 7-ft-wide pier caps. Each column is supported on a 6-ft-diameter by 50-ft-long drilled shaft socketed into bedrock.

Project Goals

The new bridge met the following criteria:

- Provide a safe area for 1423 people exiting from the Science Center in the event of an emergency.
- Provide a safe means for pedestrian

traffic to and from the Science Center.

- Support H10 vehicular loading in the event that emergency or maintenance vehicles need to use the bridge.
- Support asymmetric pedestrian loading that may occur during riverfront events.
- Provide aesthetic details that are consistent with the prominent structures that the bridge serves.
- Construct within the budgetary and time constraints.
- Provide design flexibility for location of the substructures to minimize disruption to the Interstate highways on-ramp traffic and to the functioning of the Science Center and the Convention Center.
- Provide sufficient clearance over the interstate highway on ramps and meet all Connecticut Department of Transportation safety requirements.

Structure Type Selection

A three-span precast concrete option was selected over a steel I-beam option because of its overall economy, durability of construction materials, and potentially low maintenance. Also, the precast option offered accelerated construction opportunities that would minimize disruption to the interstate highway entrance ramps below the bridge and primary vehicular entrances to the Convention Center and Science Center.

The bridge, under construction, connects the Connecticut Convention Center (left) with the Connecticut Science Center (right). I-91 is in front of the bridge. The west bank of the Connecticut River is visible in the lower left corner of the photo. Photo: Aerial Photography by Don Couture.



THREE-SPAN, PRECAST, PRESTRESSED CONCRETE BULB-TEE BEAM PEDESTRIAN BRIDGE WITH PRECAST, PRETENSIONED AND POST-TENSIONED CONCRETE DECK PANELS AND CAST-IN-PLACE CONCRETE SUBSTRUCTURE / STATE OF CONNECTICUT, OWNER

CONCRETE SUPPLIER: Tilcon Connecticut Inc., New Britain, Conn.

PRECASTER: Northeast Prestressed Products LLC, Cressona, Pa., a PCI-certified producer

BRIDGE DESCRIPTION: A 268-ft-long by 33-ft-wide, three-span, precast, prestressed concrete bulb-tee superstructure supported on reinforced concrete, column bent piers founded on drilled shafts. The span lengths are 73, 94, and 101 ft including 10-ft- and 15-ft-long cantilevers on the first and last spans respectively.

STRUCTURAL COMPONENTS: 63-in.-deep, precast, prestressed concrete bulb-tee beams; 8-ft-long by 32-ft-wide by 8-in.-thick precast, pretensioned and post-tensioned concrete deck panels with a 4-in.-thick composite concrete wearing course; reinforced concrete piers with 5-ft 6-in.-diameter columns and 6-ft-deep by 7-ft-wide pier caps; and 6-ft-diameter by 50-ft-long drilled shafts

BRIDGE CONSTRUCTION COST: \$5.9 million (\$667/ft²)

Challenges

The project posed several challenges. Significant among them was the fact that many underground utilities are located at the site. The utilities include an 84-in.-diameter sewer running north-south just to the east of the new bridge, a primary electrical duct bank, a fuel cell duct bank, storm drainage, and miscellaneous electric and abandoned utilities. Since the recommended foundation was 6-ft-diameter drilled shafts, it was critical that the utilities were accurately located in the field prior to the start of foundation work. Test pits were excavated at each shaft location enabling the design team to precisely locate each pier to avoid subsurface conflicts.

A program of vibration monitoring was instituted during construction given the proximity to major buildings and I-91. A limit of 2 in./second of peak particle velocity was established for safety of the adjacent structures.

Maintenance of traffic was an important consideration given the on-ramp traffic to the interstates and also traffic to the Convention Center and Science Center. Detours were set up to move traffic at certain times as well as limiting construction operations during scheduled events at the Convention Center.



Four lines of bulb tees were used in the superstructure with cast-in-place concrete diaphragms. Photo: Purcell Associates.



Ornamental lighting, flagpoles, planters, and fields of etched concrete, bordered by bands of integrally colored stamped concrete, were used to enhance the bridge aesthetics because of its prominent location. Photo: Jeffrey Yardis, Corporate Images.

The bridge was designed to meet both the *AASHTO LRFD Specifications* and the *Connecticut Building Code* (2003 IBC) seismic requirements. Because the bridge deck was approximately 40 ft above grade, the lateral seismic forces were significant. Designing adequately for these forces and controlling the bridge displacements resulted in 5-ft 6-in.-diameter piers. Seismic isolation joints were placed at each end of the bridge, isolating the structure from the buildings.

Due to the elevation difference at the ends of the bridges, it was critical that the grade of the walkway not exceed 5%, which would classify the bridge as a ramp according to the Connecticut Building Code. In addition, due to the winter exposure and the potential for sliding on the sloped walking surface, a glycol snow melting system was installed in the topping slab.

Architectural Features

Aesthetics was an important element of design since the bridge served as a connector between two landmark structures in the city of Hartford. Several aesthetic elements included the following:

- Stamped and acid-etched, integrally-colored concrete deck surfaces to compliment the plazas at each end
- Black color galvanized open steel rail pickets
- Ornamental above-deck light fixtures
- Planters to accommodate trees along the walking surface.
- Decorative flags along both parapets

Construction and Dedication

Construction of the bridge was started in April 2009. The bridge was named in honor of the late Mayor Mike Peters who served as Mayor of Hartford from 1993 to 2001. A dedication ceremony was held on July 26, 2011. The final connecting piece of Adriaen's Landing is now in place. The bridge will long serve as a legacy to the late mayor in the city he was known to love.

Rohit Pradhan is principal structural engineer and Steven J. Drechsler is senior structural engineer, both with Purcell Associates in Glastonbury, Conn.

For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.



The heaviest pick was approximately 50 tons. Interstate highway on-ramps were temporarily closed to allow for beam delivery and erection. Photo: Purcell Associates.

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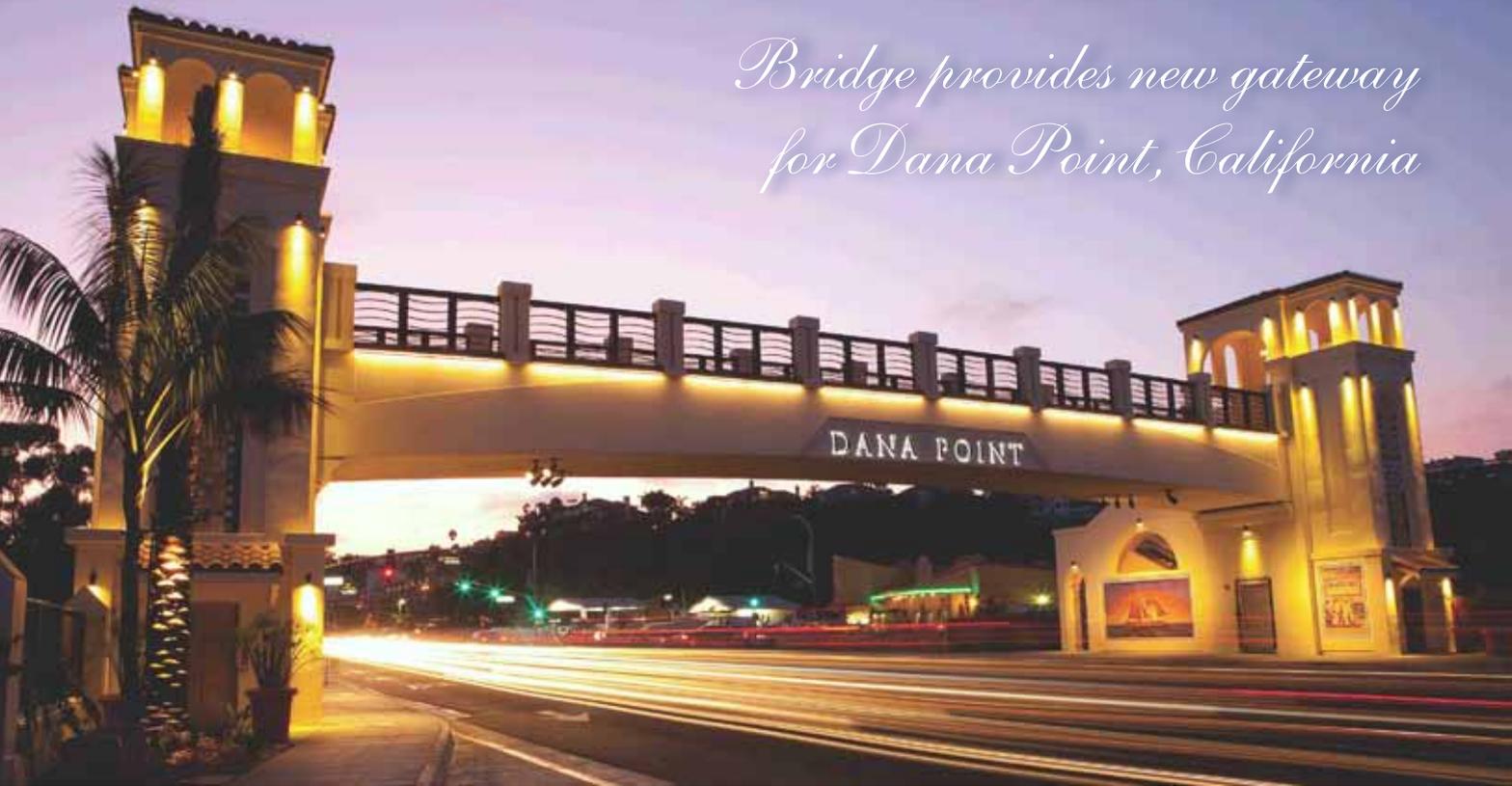
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PACIFIC COAST HIGHWAY PEDESTRIAN BRIDGE

by Pieter Goedhart, T.Y. Lin International

*Bridge provides new gateway
for Dana Point, California*



The Pacific Coast Highway Pedestrian Bridge seen at dusk stands as a gateway to the seaside resort community of Dana Point, Calif.
Photo: Rob Szajkowski, Photographer.

An iconic pedestrian bridge now spans historic Pacific Coast Highway (PCH). It is the centerpiece of a traffic congestion relief project undertaken by the city of Dana Point, Calif. The single-span precast, prestressed concrete girder pedestrian bridge carries the heavy foot traffic over this main north-south arterial that once caused protracted traffic delays due to its long turning and through red light times required for pedestrians. In addition to enhancing traffic operations, the bridge improves pedestrian safety at a busy intersection and provides an architectural gateway for the community.

Superstructure

The pedestrian bridge superstructure consists of two 109-ft 2-in.-long, variable-depth precast, prestressed concrete girders with precast concrete deck panels and a cast-in-place concrete deck between them to form an H-shaped cross section. Due to the right-of-way restrictions and the city's requirement to maintain full traffic operations on PCH, precast concrete girders were selected for the bridge span. This minimized the construction encroachment on traffic by eliminating the need for falsework in the roadway.

The girders are 18 in. wide and vary in depth from 8 ft 0 in. at their ends to 6 ft 5½ in. at midspan. While the bottom of the girder rises 2 ft 0 in. from support to midspan in a parabolic curve, the top of the girder rises 5½ in. to remain 50 in. above the vertical curve of the deck, which also rises 5½ in.

During preliminary design the engineer consulted with local precasters in order to optimize the girder design. The precasting was already complicated since all of the connection inserts, reinforcement couplers, architectural

profile

PACIFIC COAST HIGHWAY PEDESTRIAN BRIDGE / DANA POINT, CALIFORNIA

BRIDGE DESIGN ENGINEER: T.Y. Lin International, Riverside, Calif.

PRIME CONTRACTOR: Excel Paving Company, Long Beach, Calif.

PROJECT ENGINEER: Psomas, Santa Ana, Calif.

ARCHITECT: Thirtieth Street Architects, Newport Beach, Calif.

GEOTECHNICAL ENGINEER: GMU Geotechnical Inc., Rancho Santa Margarita, Calif.

PRECASTER: Coreslab Structures (L.A.) Inc., Perris, Calif., a PCI-certified producer

attachment hardware, and lighting conduit had to be in place prior to casting to prevent drilling into the prestressed girders. To simplify the precasting operation, the twenty-five, 0.6-in.-diameter prestressing strands followed a level path through the girder. The strands are near the bottom of the girder section at midspan and the increased depth at the supports eliminated the need for a harped strand configuration. By debonding a number of strands at the ends of the beams, the concrete stresses are maintained within specification limits. The specified concrete compressive strengths were 5000 psi and 4000 psi for the prestressed and cast-in-place concrete, respectively.

Along the top of each girder are nine evenly spaced 5-ft 10-in.-tall pilasters. Each pilaster consists of two, 6 by 6 in. hollow structural steel sections welded to an embedded plate in the top of the girder. They are framed with cold-

formed steel sections and coated with plaster. The pilasters support a 4-ft 10-in.-high architectural metal railing that spans between the pilasters. When combined with the portion of the girder above the deck, the top of railing is 9 ft 0 in. above the walking surface.

Bridge Deck

The 10-ft 0-in.-wide deck is aligned on a slight vertical curve with the crest at midspan and a maximum slope of 1.68%. There are a total of fourteen 4-in.-thick precast, prestressed concrete panels that span transversely between the girders. The panels are pretensioned with 3/8-in.-diameter strands spaced at 6 in. and reinforced with No. 4 bars at 12 in. on center both ways. The panels rest on steel angles that are bolted to the inside faces of the girders and are covered with a 3-in.-thick topping slab composite with the panels. In addition, the girders are connected with transverse, cast-in-place concrete diaphragms located at the abutments

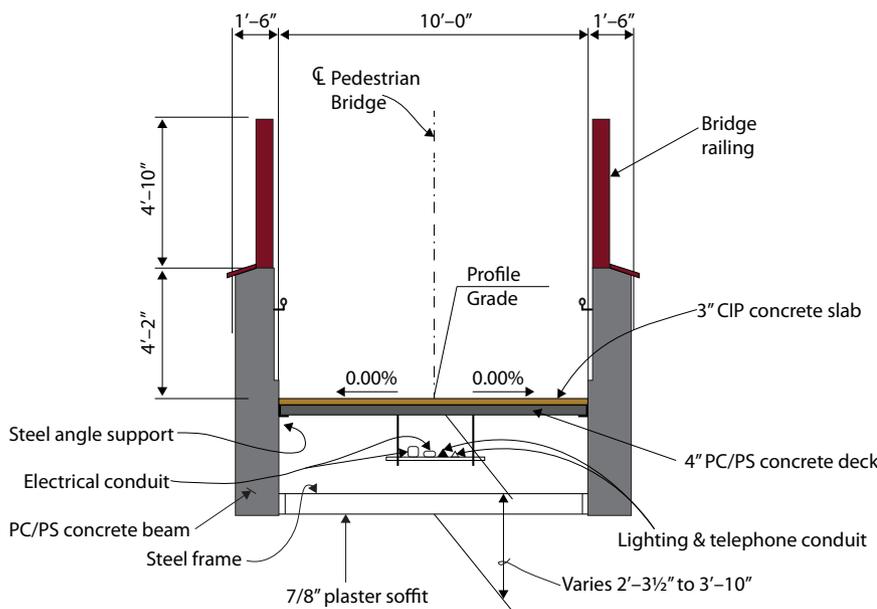


The girders also act as the parapet walls along the walkway of the bridge. Photo: Paul Savage, Photographer.

and at midspan below the deck to provide lateral stiffness. The bottoms of the girders are connected with a false soffit that hides the utility ducts that run beneath the deck. The soffit consists of steel framing between the girders with a plaster shell that appears to be monolithic with the girders. Since the power source is at one abutment, all electrical, landscaping, and telephone utilities had to travel through the bridge to the opposite abutment.

Substructure

The abutment towers are 48 ft 8½ in. long by 13 ft 0 in. wide and up to 46 ft tall. The footings are 2 ft 0 in. thick and are stepped at the elevator to allow the extra 4 ft 0 in. for the equipment. The stepped footing also reduced the amount of earthwork. The cast-in-place concrete walls are 12 in. thick and contain architectural reveals and openings throughout. The north side of each abutment provides a stairway



Typical section showing the components that comprise the bridge. Drawing: T.Y. Lin International.

SINGLE-SPAN, VARIABLE DEPTH, PRECAST, PRESTRESSED CONCRETE GIRDER PEDESTRIAN BRIDGE / CITY OF DANA POINT, CALIFORNIA, OWNER

BRIDGE DESCRIPTION: Decorative, cast-in-place concrete abutments supporting a single-span, 109-ft-long precast, prestressed concrete rectangular girder, 1 ft 6 in. wide that varies from 8 ft 0 in. deep at the abutments to 6 ft 5½ in. deep at midspan with 4-in.-thick, precast, prestressed concrete deck panels and 3-in.-thick cast-in-place concrete composite deck

BRIDGE CONSTRUCTION COST: Bridge cost \$3.1 million; total project cost \$6.0 million

AWARDS: California Department of Transportation, 2010 Excellence in Transportation Award, Major Structures; *California Construction* Best of 2009 Small Project Award of Merit; American Council of Engineering Companies (ACEC) California 2010 Award of Excellence Merit Award, ACEC Orange County Chapter 2010 Award of Excellence; ASCE Orange County Branch 2009 Project Achievement Award; Orange County Engineering Council 2010 Engineering Project Achievement Award

Sustainability, Aesthetics, and the Community

In order to create a sense of ownership in the project, the city worked with the community from preliminary design through completion. The project added new direct pedestrian access to the adjacent Doheny State Beach at the south abutment. Coordination with state officials resulted in the historic gateway and pilaster style of the park in the new entrance and boundary screen walls. A total of four large mosaics up to 15 ft 9 in. wide and 8 ft 6 in. tall on the street side of each abutment were created by local artists and depict the community's culture and heritage.

This unique bridge required creativity and extensive detail in order to achieve its distinctive appearance. The superstructure girders have formed recesses on the sides along with the city name pronounced with backlit 21-in.-tall stainless steel letters at midspan. At the top of the girders, LED lights run along the full length underneath the decorative railing and pilasters. The abutments contain a variety of decorative elements that include arch openings, corbels, ledges, and insets. Colorful tile accents enhance the stairway and landings. Decorative metal gates located in the openings at the sidewalk level complement the railing along the span. A color acrylic plaster coating is applied to all exposed surfaces, which provides a smooth uniform finish and ties all of the structural elements together. The combination of the LED lighting and strategically placed spotlighting with the detailed architectural elements makes this structure eye-catching both day and night.

Since the bridge is within one-half mile of the ocean, special consideration had to be made to resist the corrosive marine environment. One method was to use epoxy-coated reinforcement in the deck. A second method was to apply a 1/4-in.-thick acrylic plaster coating to all exposed concrete surfaces. This coating protects the exterior concrete as well as adds an architectural color finish. Prior to plaster application, the concrete was sand blasted in order to roughen the surface, given that the typical formed concrete surface is too smooth for the adhesion of the plaster. Another requirement for the plaster was that the entire superstructure had to be erected prior to application in order to avoid cracking due to dead load deflections.

access while the south sides incorporate elevator access, which maintains Americans with Disabilities Act (ADA) compliance and allows all persons to utilize the bridge. Beneath the stairs and landing are utility rooms that house the electrical equipment and controls for the lighting and elevator.

Geotechnical Improvements

Situated in Southern California, seismic considerations are a significant part of the design. The design earthquake is from the San Joaquin Hill Blind Thrust Fault that is located about 7 miles from the bridge site and can generate a peak ground acceleration of 0.4g with a 7.0 magnitude. Geotechnical investigations discovered a liquefiable soil layer within the upper 15 ft that has the potential to cause excessive seismic settlement. The typical solution to this problem was to use deep pile foundations, however, the combination of weak soil conditions, the presence of shallow groundwater, and sensitive nearby land use made deep foundations expensive and

problematic. As an economical solution, the design team developed an alternative approach using permeation grouting. Permeation grouting consisted of injecting high-pressure grout into the liquefiable soil layer at injection points placed on a grid system spaced at 3 ft in both directions. Each point contained a perforated 2-in.-diameter grout pipe that was injected with a low-slump grout at a pressure of 1000 psi. The limits of the permeation grouting extended 5 ft beyond the footprint of the abutment footing to a depth of 15 ft. When completed, it created a dense subsurface platform that limited the seismic settlement and provided sufficient bearing capacity.

The Pacific Coast Highway Pedestrian Bridge improves traffic operation, provides a safe pedestrian crossing, and provides a structural icon and gateway for the community. The various uses of concrete combined with the extensive architectural detail make for a sustainable, functional, and aesthetic structure that is appreciated by both pedestrians and the traveling public.



Shown in the precaster's plant, the girders contain many embedments to facilitate connections in the field. Temporary trusses provide lateral stiffness during handling and erection. The parabolic soffit was formed by the use of a curved precast concrete filler in the bottom of the form. Photo: Coreslab Structures (L.A.) Inc.



Large murals and other architectural details can also be observed from the roadway. Photo: Paul Savage, Photographer.



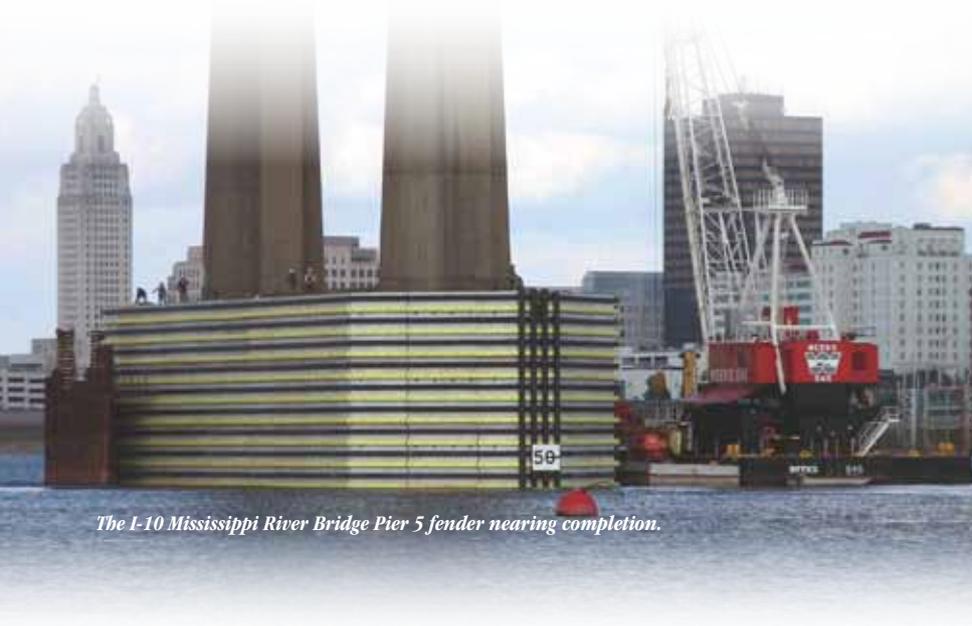
Spanning the Pacific Coast Highway, Dana Point's new gateway includes elevators to provide access for those with disabilities. Photo: Coreslab Structures (L.A.) Inc.

Pieter Goedhart is a bridge engineer with T.Y. Lin International in Riverside, Calif.

For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.

Pier 5 Fender Replacement on the I-10 Mississippi River Bridge

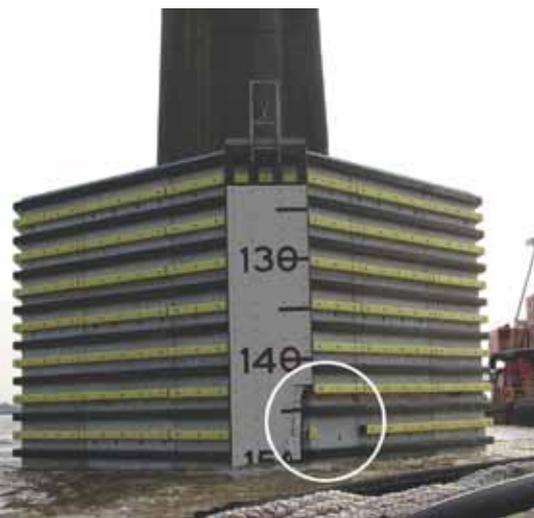
by Richard Potts,
Standard Concrete Products



The I-10 Mississippi River Bridge Pier 5 fender nearing completion.

The project involved removal of the existing steel and timber fender system protecting Pier 5 on the I-10 Mississippi River Bridge, East Baton Rouge, La., and replacing it with modular concrete open cell box system. The innovative concept was the selection of a sacrificial precast concrete box for the fender system in a zone of heavy ship impact. You might say they were thinking outside the box.

Minor damage at the lower corner of the fender during construction was repaired by replacement of the attached marine timbers.



The original bridge construction was completed in 1968. The Pier 5 caisson was capped with a distribution block, forming a shelf to support the fender system. The fender protects a sub-shaft between the top of the caisson and the pier columns. Beginning 19 ft below the water surface and extending to 45 ft above, the fender completely surrounds the pier and was installed in five tiers. Pier 5 supports the bridge's 1235-ft-long main span over a 500-ft-wide shipping channel. The design impact loadings are a six hopper barge column, or a three tanker barge column, or a ship of 100,000 deadweight tonnage traveling at 10 mph.

Precast concrete modules for this project are large cellular boxes stacked to create a fender wall. Of the 138 modules, 100 were side modules, 20 were corner modules, 10 were nose modules, and eight were supplied as replacement sections for future collision repairs. All modules were required to be cast prior to beginning erection. Composite marine timbers manufactured from recycled plastic and reinforced with fiberglass were attached and coal tar epoxy applied prior to loading on barges. The perimeter dimensions

of the largest box are 14.5 ft by 10.7 ft by 12.8 ft. The heaviest weighed 86 tons before timber attachment.

The vision for this unique concept was developed by Paul Fossier, project manager for the Louisiana Department of Transportation and Development and design engineers Zolan Prucz and Buck Ouyang with the New Orleans office of Modjeski and Masters. The general contractor was Weeks Marine in Cranford, N.J. The precast concrete was supplied by Standard Concrete Products in Mobile, Ala.

A modular precast concrete box allows the section to be erected with vertical alignment guides. It is gravity supported on the distribution block and braced for impact by concrete fill between the back of the precast unit and the face of the pier shaft. The open cell at each joint between boxes is filled with concrete to distribute shear and anchor a tieback. The mass of the system and remaining open cells allow for controlled crushing of the boxes to absorb and deflect a major impact. A minor impact would have damage limited to replacing marine timbers at the surface. This was demonstrated during construction when Pier 5 was struck by a commercial barge just off center at the pier nose. The minor damage was repaired by replacement of the marine timbers.

Richard Potts is vice president and chief engineer with Standard Concrete Products in Savannah, Ga.

A corner module being slid into place for the Pier 5 fender.



Beauty on the Banks

Aesthetically pleasing arch design requires innovation and environmental sensitivity

by Jim Markus and Gwendolyn I. Lewis, King County, and Kevin Kim, Jacobs Engineering

The York Bridge replacement project was a collaborative design and construction effort between King County and the city of Redmond, Wash. It demonstrates the ability to solve tough engineering challenges while minimizing costs and being sensitive to the environment and the community. The new bridge, with its gracefully arched, cast-in-place concrete substructure and 42-in.-deep precast, prestressed concrete girders (Washington State Department of Transportation Type W42G), required rebuilding, widening, and raising the approach roadways.

The existing bridge, which crossed the Sammamish River at NE 116th Street in Redmond, had become structurally deficient and functionally obsolete. Sizable flexural cracks had developed in the girders, requiring a low-posted load limit that restricted the bridge's usefulness. The bridge's piers also

disrupted the river's flow and created dangerous, at-grade crossings for pedestrians and bicyclists along the trails on both sides of the river. The location also contains the multi-use 60 Acres Park recreational area that attracts large numbers of visitors, creating a traffic bottleneck.

Bridge Lengthened, Elevated

The bridge was designed to be 220 ft long, which is 103 ft longer than the original bridge, and 51 ft 3 in. wide overall, which is more than 25 ft wider. The bridge and approach roads were elevated 15 ft so the trails continue uninterrupted beneath the bridge, greatly improving accessibility and safety for pedestrians, bicyclists, and equestrians.

The primary goals in selecting the bridge's design and material were to minimize construction time and create

an aesthetically pleasing appearance. In addition, the city of Redmond had recently completed a \$14-million project downstream at NE 90th Street, and city officials were concerned that the new bridge might pale in comparison. There also were numerous agencies to work with due to the area's environmental sensitivity and the desire to maximize shoreline habitat for endangered salmon.

An extensive comparative analysis was performed early in the process. Concrete always was considered to be the best material, but finding the most efficient design solution was critical. The design process also was impacted by the desire to gain as much federal funding as possible. Federal funds would cover only the costs for the lowest-cost design alternative, with other sources needed to cover any premium. Fortunately, the created design proved to be the low-cost option, as well as the most

The new York Bridge in Redmond, Wash., is longer and wider than the original structure, allowing it to span multi-use trails on both sides of the river. The shape of the pedestrian lookout can be seen by the shadow on the girders. All photos: King County, Washington.



profile

YORK BRIDGE / REDMOND, WASHINGTON

BRIDGE DESIGN ENGINEER: King County Department of Transportation, Seattle, Wash., and Redmond Public Works Department, Redmond, Wash.

ENGINEERING CONSULTANTS: AECOM (formerly Entranco and DMJM Harris), Seattle, Wash.

PRIME CONTRACTOR: Mowat Construction Co., Woodinville, Wash.

PRECASTER: Concrete Technology Corp. Tacoma, Wash., a PCI-certified producer

CONCRETE SUPPLIER: Cadman Inc., Bellevue, Wash.

aesthetically pleasing and relatively fast to build.

Poor Soil Hampered Work

One of the biggest challenges arose from the extremely poor soil conditions, especially on the west bank. This soil consisted of significantly compressible peat, as much as 195 ft deep. Removing this with a deep excavation and subsequent backfill was prohibitively expensive and technically not feasible. The soft soil also covered a city sewer line that would have been damaged by compaction settlement.

Instead, the team installed expanded polystyrene (EPS) blocks as an environmentally friendly alternative to build up the approaches. The material is an extremely lightweight fill weighing only 1 to 2 lb/ft³. The EPS blocks do not biodegrade, produced no net effect on the soil or groundwater and reduced muddy runoff into the river.

Full-height precast concrete panels, 4 ft wide and 6 in. thick, were used as retaining walls to cover the front faces of the EPS embankment. A total of about 18,000 ft² of walls were used at all four corners of the bridge. The tops of the walls were connected to the reinforced concrete load-distribution slab that capped the EPS embankment. One of the retaining walls was located directly above a large, deep sewer line. To mitigate some of the weight on the sewer line, 2 by 6 ft EPS blocks were placed under the wall to distribute the weight of the panel.

Arched Substructure

The concrete arch used for the piers and substructure also created challenges. To reconcile the desire for an arch-shape design with the functional needs of the bridge, the team created a shallow cast-in-place concrete profile spanning the river. At each end of the arch, inclined

piers provided intermediate supports for the superstructure. This results in four 55-ft spans for the precast, prestressed concrete girders.

Typically, most of the structural support in an arch-designed bridge results from compression. However, the York Bridge's arched substructure is flat enough that it doesn't perform as a true arch, placing it between an arch and a beam. Providing foundational support for the piers, where the arch and the inclined columns meet, created fabrication challenges.

The foundations to support the arch and the inclined columns consisted of cast-in-place, 2-ft-diameter concrete piles with a steel casing extending 120 ft into the soil. This foundation was made extremely robust due to the pier columns and the arch contributing both gravity loads and horizontal thrusts.

Forms for the arched substructure were supported by falsework that spanned the river. The arch itself was created in one continuous placement to ensure aesthetic continuity for its full length. Admixtures were used in the concrete to make it more workable and ensure it flowed around the reinforcement.

The reinforcement was congested, especially at the location where the arched slope meets the inclined columns. Large-scale detail drawings were created for the cast-in-place arch to indicate where bars should be placed and what could be eliminated as redundant.

A cast-in-place concrete crossbeam was placed at the apex of the arch and at the tops of the inclined columns to provide support for the precast concrete girders, a common design technique in this area due to the high seismic zone. They were structurally integrated



To provide a robust foundation for the columns on both sides, 120-ft-long cast-in-pipe concrete piles were used to carry both gravity loads and thrust from the arch. At each column pier, a crossbeam was constructed on falsework to support the precast concrete girders and deck.



Support for the precast concrete girders was provided at the arched superstructure's apex with a cast-in-place concrete crossbeam.



A total of about 18,000 ft² of walls were used on both approach fills.

220-FT-LONG, FOUR-SPAN REPLACEMENT BRIDGE CONSISTING OF A CAST-IN-PLACE ARCHED SUBSTRUCTURE, PRECAST, PRESTRESSED CONCRETE GIRDERS, CAST-IN-PLACE CONCRETE DECK, AND PRECAST CONCRETE RETAINING WALLS / CITY OF REDMOND AND KING COUNTY, WASHINGTON, OWNERS

RAILING DESIGNER: Cliff Garten Studio, Venice, Calif.

BRIDGE DESCRIPTION: Cast-in-place reinforced concrete arch with inclined columns at each end supporting 42-in.-deep precast, prestressed concrete beams and a 7.5-in.-thick composite concrete deck

BRIDGE CONSTRUCTION COST: \$12 million

AWARDS: 2009 Silver Award for Structural System from the American Council of Engineering Companies

Unique Environmental Treatment

The bridge project achieved several environmentally friendly goals. One involved embedding approximately ninety, 30- to 40-ft-long wooden logs, nearly horizontal, in the riverbank about two-thirds of their length underground. The logs were arranged to create a natural river shoreline while providing pools for the fish, ripples in the water that oxygenates it and higher ground for migratory waterfowl. The changes required 22 permits and partnerships with numerous stakeholders, including the Corps of Engineers, city, county, state agencies, and the Muckleshoot Indian tribe.



Expanded polystyrene lightweight fill, which is only 1/100th the weight of typical soil, was shaped and placed on the west approach to avoid adding weight above an existing sewer line and minimize settlement of the soft in-situ soils.

with the girders using prestressing strands and reinforcing bars extended from the girders. Compression seals were provided in expansion joints between the end diaphragms sitting on cantilevered abutment walls and the concrete approach slabs. The bridge has a 7.5-in.-thick cast-in-place composite concrete deck. Epoxy-coated reinforcement was used in the concrete bridge deck to provide corrosion resistance.

The project exceeded the owners' expectations on many levels even though it had to overcome a variety of difficult challenges to do so. The bridge serves as a model for creating an aesthetically pleasing structure under adverse conditions while providing a cost-effective, environmentally friendly and responsive solution to the community's needs.



The cast-in-place deck features epoxy-coated reinforcing bar to provide corrosion protection.



The interweaving decorative railing had to adjust to the vertical and horizontal curves and asymmetrical shape of the bridge, which included sloping bulb-outs on each side to provide lookouts for pedestrians.



The shape of the substructure arch is flat enough that it functions partially as an arch and partially as a beam. It was cast in one continuous pour to ensure a smooth surface.

Jim Markus is managing engineer for the King County Road Services Division and Gwendolyn I. Lewis is project manager for the King County Department of Transportation in Seattle, Wash. Kevin Kim is a senior project manager with Jacobs Engineering and formerly was the project manager for Entranco, in Bellevue, Wash., during the design phase. Steve Gibbs, project manager for the city of Redmond, also contributed to this article.

For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.

Artistic Railing Added

As a final touch, a decorative artistic metal railing and screen were bolted to both sides of the bridge deck and concrete barrier. This effort resulted from a King County regulation requiring 1% of construction funding to be set aside for artistic additions on selected projects. The city of Redmond contributed an equal share to the fund, which was coordinated by the county's 4Culture cultural-services agency.

The railing accommodated the curved lookouts along both sides of the bridge. On one side, a 6-ft-wide sidewalk gradually curves out over the river, beginning just before midspan, until it is 12 ft wide; then curves in again to 6 ft wide at the bridge's end. The 10-ft-wide sidewalk on the other side curves out to 16 ft wide beginning just before midspan; then curves back to 10 ft wide at the bridge's other end. Both lookouts are 126 ft 7 in. long.

Texas' Longest Beams

by Chris Leonard, Adam Mainka, and James Dubuisson, Heldenfels Enterprises Inc.



Fourteen precast concrete Type VI modified beams that were 164 ft 8 in. long were the longest ever used in the state. All photos: Heldenfels Enterprises Inc.

Texas has a reputation for growing and building things large, and its precast concrete bridge beams are no different. For the recent State Highway 130 project on the Central Texas Highway system, 14 Type VI modified beams 164 ft 8 in. long were fabricated.

The beams were produced for twin bridges over CR-179 on the toll road project, which includes 77 bridges along its 40-mile southern leg. The two bridges are each 385 ft long. The beams' extraordinary lengths were necessitated

by the bridges' 47.5-degree skew. Each bridge has three spans of 110, 165, and 110 ft. The Type VI modified beam was the only shape approved by the Texas Department of Transportation that could provide the required span.

The beams were modified by reducing the bottom flange width to 26 in., while also reducing the top flange and web widths. This provided the weight reduction to achieve the span length. The beams were fabricated three at a time and were pretensioned with eighty-

eight, ½-in.-diameter, 270 ksi, low-relaxation strands. They were gang-stressed (all at once) to 2728 kips including 38 harped strands, with the greatest harped strand located at 70 in. from the bottom of the beam. The average concrete compressive strength at transfer was 7010 psi and 10,200 at 7 days to meet a minimum design compressive strength of 7127 psi. The average camber at transfer was 1⁷/₈ in.

Each beam weighed 161,400 lb, just under the state's "super-heavy" limits. The beams were delivered on trailers equipped with both self-leveling bolsters to keep the beams level in transit and steerable rear wheels to navigate tight turns.

The components were offloaded and erected by Archer Western Contractors with no disruptions.

As new beam shapes now being introduced are accepted, modifying Type VI beams in this way will prove unnecessary. Even so, it shows the lengths to which designers, precasters, and girders can go to achieve their goals.

Chris Leonard is director of operations, Adam Mainka is quality control manager, and James Dubuisson is shipping coordinator, all with Heldenfels Enterprises Inc. in San Marcos, Tex.

The beams were delivered on trailers equipped with self-leveling bolsters and steerable rear wheels.



Presidio Viaduct

South Access to the Golden Gate Bridge

by Ahmed M. M. Ibrahim, John F. Walters, and Ofelia P. Alcantara, California Department of Transportation (Caltrans)



Rendering of the Presidio Viaduct. All photos, drawings, and rendering: Caltrans.

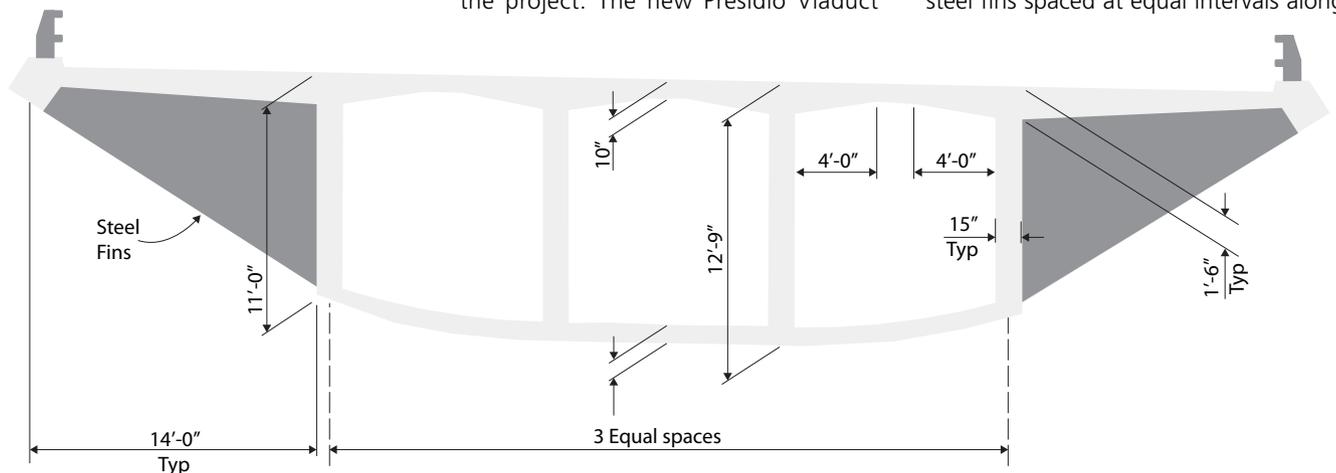
The existing south access road to the iconic Golden Gate Bridge, known as Doyle Drive, is structurally and seismically deficient and needed to be replaced. The roadway is facing the same problem that threatens other parts of our nation's infrastructure—the ravages of time and heavy use. Originally built in 1936, Doyle Drive has reached the end of its useful life.

The Presidio Parkway project, the Doyle Drive replacement, will result in a dramatic visual and structural change for the corridor. The \$1.045 billion project is divided into two phases. The first phase, currently underway, involves construction of one of two new viaducts, one of four cut-and-cover tunnels, and an at-grade temporary bypass at the eastern end of the project. The new Presidio Viaduct

currently under construction is one of the landmark structures of this extensive project.

Several bridge types were considered during the design phase, including parabolic, prestressed concrete box girders, steel tubular trusses, and Warren steel trusses with composite concrete deck and soffit.

The selected bridge is a six-span, cast-in-place, prestressed concrete box girder with three main spans of 275 ft (Spans 2, 3, and 4). Spans 1, 5, and 6 have lengths of 188 ft, 184 ft, and 143 ft respectively, resulting in a total bridge length of 1340 ft. The bridge has a uniform superstructure depth along its length, with the depth varying transversely. The depth is 12.75 ft at the middle of the cross section, but curves upward to a depth of 11 ft at the face of the exterior webs. The superstructure cross section includes a 14-ft deck overhang on each side with architectural steel fins spaced at equal intervals along



Typical cross section of Frame 1.

profile

PRESIDIO VIADUCT / SAN FRANCISCO, CALIFORNIA

BRIDGE ENGINEER: California Department of Transportation, Sacramento, Calif.

PRIME CONTRACTOR: CC Meyers Inc., Rancho Cordova, Calif.

CONCRETE SUPPLIER: CEMEX, San Ramon, Calif.

POST-TENSIONING SUPPLIER: Schwager-Davis Inc., San Jose, Calif.

REINFORCEMENT SUPPLIER: Harris Salinas Rebar Inc., Livermore, Calif.



In too many viaducts, the design focus is restricted to the bridge itself. The need to knit back together the spaces under the bridge and relate the bridge to the uses around it is often forgotten. The visual quality and sometimes even the security of the space underneath are ignored. The Presidio Viaduct makes none of those mistakes.

A major goal of the project is to recreate and restore, in so far as it can reasonably be done, the topography and landscape of the Presidio before the Golden Gate Bridge was built, and to make the visible elements of the Golden Gate approach structures as unobtrusive as possible. The aesthetics of this viaduct are really not about the bridge itself; but about what goes on under and around it.

The long spans minimize the number of piers, making it easy to see through the bridge from all angles. The bridge presents little obstacle to the flow of space through it. The piers themselves are simple shapes with no visible pier caps or articulation. The common geometrical shapes tend to fade from our notice.

The curved underside of the post-tensioned concrete box girder is shaped to blend in with the steel braces for the overhangs, visually unifying the parts into one continuous element. The box presents a smooth and featureless underside, with no details that would draw our eye or create visual contrasts. The concrete soffit reflects light into the space under the bridge, keeping the underside spaces bright and supporting the planting. The regularly spaced steel overhang braces establish a rhythm that relates well to the features of nearby buildings, allowing viewers to measure the size of the bridge in comparison to its surroundings. Plus, they create an opportunity to visually tie the viaduct to the Golden Gate by the use of color.

Future users of the Presidio will find it a pleasing structure to be around, one that is an asset to the Golden Gate National Recreational Area.

each span. In span 6, due to traffic clearance limitations, the superstructure depth is reduced to 6.5 ft, decreasing to 4.75 ft at the face of the exterior webs. The columns are rectangular, 8 by 10 ft with the longer faces curved in a 13-ft radius. The viaduct is joined to a 320-ft radius, reinforced concrete connector bridge that leads to Pacific Coast Highway 1. The connector bridge has five spans ranging from 100 to 108 ft in length, with a constant superstructure depth of 6 ft. The connector varies from 33 to 40 ft in width.

Foundation Type

Geological conditions at the site vary drastically along the bridge alignment. The soil strata contain varying depths of sandy/silt layers, along with stiff clay layers underlain by bedrock. The depth to bedrock varies dramatically along the longitudinal alignment of the bridge

The high liquefaction potentials at Bents

3 and 4 dictated the use of pile shafts for the bridge foundations. Historically, these foundation types have performed well in seismic events under similar soil conditions and are superior to spread footings and pile caps as they reduce the possibility of lateral spreading.

Cast-in-drilled-hole shafts with rock sockets were used at all bents. To mitigate the possibility of caving during construction, 12-ft-diameter, permanent steel casings were installed into bedrock at Bents 2, 3, and 4. Additionally, 11.5-ft-diameter rock sockets were installed into bedrock at these bents to a depth of 30 to 40 ft below the permanent steel casing tip elevation.

Seismic Design Considerations

The San Andreas Fault lies approximately 6 miles southwest of the project site and has a maximum moment magnitude of 7.9. The

Presidio Viaduct is classified as a post-earthquake "Recovery Route" and as such, seismic design of the viaduct considered two levels of earthquakes, Functional Evaluation Earthquakes (FEE) and Safety Evaluation Earthquakes (SEE). A FEE has a smaller magnitude and a probabilistic hazard for such an event with a mean return period of 108 years (i.e., 50% probability of exceedance in 75 years). A SEE has a greater magnitude with an acceleration response spectrum derived from the envelope of the median deterministic Maximum Credible Earthquake for the region, with a probabilistic hazard for such an event with a mean return period of 1000 years (i.e., 7.5% probability of exceedance in 75 years).

Stiffness Balancing

The drastic variation of the soil profile along the bridge alignment resulted in very stiff columns at Bents 5 and 6 compared to Bents 3 and 4. The related

CAST-IN-PLACE, POST-TENSIONED, CONCRETE BOX GIRDER BRIDGE WITH CAST-IN-PLACE RECTANGULAR COLUMNS AND CAST-IN-DRILLED-HOLE SHAFTS / CALIFORNIA DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: A 1340-ft-long, cast-in-place concrete box girder bridge with variable width and bifurcation. The span lengths are 188, 275, 275, 275, 184, and 143 ft. The section depth is constant at 12.75 ft, except the last span that has a 6.5 ft depth. Cross section has 14-ft overhangs supported by steel fins spaced evenly at about 15 ft centers. The substructure is 8 by 10 ft single or double column bents supported on 12-ft-diameter, cast-in-drilled-hole shafts.

BRIDGE CONSTRUCTION COST: \$38.5 million

AWARDS: 2011 ASCE Geotechnical Design Bridge Project of the Year Award, San Francisco, Calif.; 2011 *Roads and Bridges*, Top 10 Bridges in the U.S.

Aesthetic Considerations

Multiple design charrettes were conducted during the planning phase of the project to receive input from stakeholders on design objectives and the preferred type of the new viaduct. The results included these design and architectural criteria:

- Remain subordinate to the Golden Gate Bridge in scale and size
- Maintain continuity by using similar light poles and see-through bridge rails
- Enhance views of the San Francisco Bay by minimizing the number of columns
- Use both concrete and steel materials in construction

change in stiffness within the structural frame leads to incoherent seismic performance both longitudinally and transversely.

The project's design criteria required that the stiffness of individual bents within a structural frame vary by less than 50%. In the case of adjacent bents or columns, the variation in stiffness should not exceed 25%. To overcome the variation in bent-column stiffness and achieve uniform seismic performance, two measures were taken:

- Column isolation casings were used at Bents 5 and 6 to effectively lengthen individual columns, thereby reducing column stiffness.
- A seismic hinge was used to divide the bridge into three separate structural frames and eliminate pounding during a seismic event. Frame 1 consists of Bents 2 through 4. Frame 2 consists of Bents 5 and 6. Frame 3 consists of the four-bent connector.



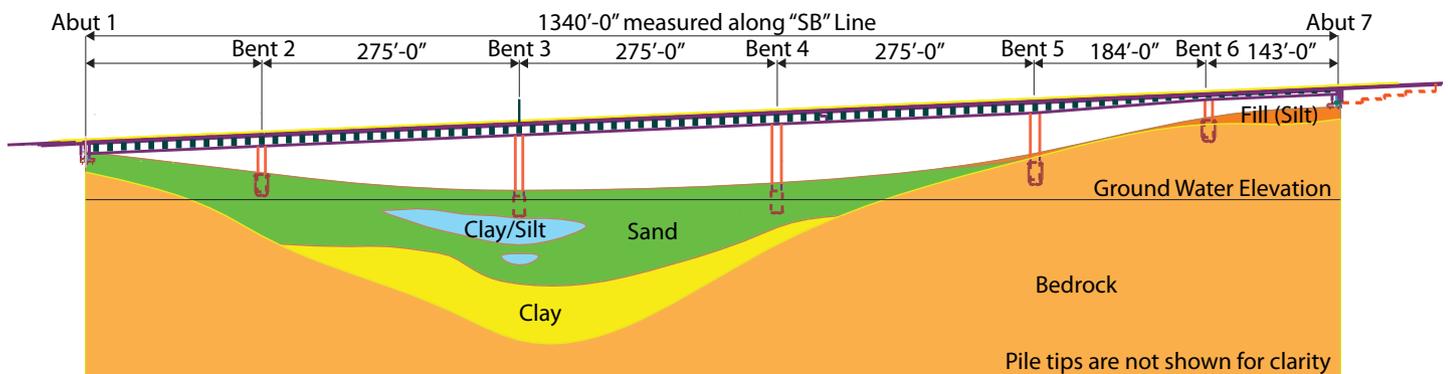
Aerial view of the Presidio Viaduct during construction. Doyle Drive is on the right and the Highway 1 Connector Bridge curves to the left.

Column Reinforcement Configuration

With the soft/loose sandy soil at Bents 3 and 4, displacement demand (obtained from linear response spectrum analysis) at the top of the columns was determined to be 32 in. and 31 in. respectively. Large rectangular columns (8 by 10 ft) do not typically have enough displacement capacity to meet the large demands determined at this bridge. To make up for this, a new column reinforcement configuration was used for this project. Four separate eccentric hoops, with cross ties and headed bars for shear transfer, were used to provide the largest possible plastic deformation capacity for each bent to meet the seismic demands. The specified 28-day concrete compressive strength for the substructure was 5000 psi.

Superstructure

As described earlier, the bridge is designed as three structural frames. Frame 1 is much wider and consists of spans 1 through 3. It has a three-cell box girder cross section. Frame 2—spans 4 through 6—consists of a two-cell box girder. Frame 3 is the Highway 1 Connector Bridge that has five spans with a three-cell box girder with a shallower cross section. Frames 1 and 2 have a deck overhang of 14 ft. The overhangs on all three frames are supported by a combination of steel fin outriggers and post-tensioning. The steel fins were initially conceived to meet aesthetic goals and later incorporated into the structural design of the overhangs. Transverse post-tensioning in the deck used three or four 0.6-in.-diameter, 7-wire strands in



Presidio Viaduct soil profile.



Unique reinforcement arrangement for the 8 by 10 ft rectangular columns.

1 by 3 in. flat ducts spaced from 2.5 to 4 ft. The jacking force varied from 131 to 175 kips. The structural steel fins were integrated with the formwork and cast monolithically into the cross section. The 256 fins are spaced uniformly approximately every 15 ft along each span.

Due to long span lengths, considerable prestressing was required in both frames 1 and 2. In addition to full length post-tensioning, partial length post-tensioning was required to achieve the desired performance. Frame 1 has four webs with six post-tensioning ducts. Frame 2 has three webs with six post-tensioning ducts. The ducts have diameters of either 4 or 4½ in. and contain 19 or 25 Grade 270, 7-wire, low-relaxation strands with a diameter of 0.6 in. The total number of strands in Frames 1 and 2 is 551 and 412, respectively. The corresponding jacking forces are 24,200 kips and 18,100 kips. The frame lengths required that the stressing be done from both ends.

The specified concrete for the superstructure was Caltran's typical ternary mix that required supplemental cementitious materials in combination with portland cement to assure longevity. The specified compressive strength for the superstructure was 5000 psi at 28 days.

Construction Challenges

Of primary concern was the construction of the large diameter deep drilled shafts through poor soil conditions. The permanent steel casings reduced the potential for delays resulting from repairs of anomalies in the drilled shafts. However, repairs due to caving were required during the construction of the rock socket at Bent 2.

The majority of falsework erected was of the standard type used in California. However, 10 precast, prestressed concrete girders, each 108 ft long, were used to span the culturally sensitive Presidio Pet Cemetery underneath the Presidio Viaduct. These precast girders provided a platform on which superstructure-supporting falsework bents, typically made of steel pipe posts with W section cap and sill beams, could be erected.

Throughout the construction of the project it was critical to work with all stakeholders in order to minimize impacts to the operations, structures, and environment of the Presidio of San Francisco and the Golden Gate National Recreation Area. The Presidio Viaduct is an engineering feat that surmounted complex site conditions and will complement the unique surroundings of an urban national park.

Ahmed M. M. Ibrahim is senior bridge engineer, John F. Walters is senior bridge engineer and construction engineer, and Ofelia P. Alcantara is supervising bridge engineer, all with the California Department of Transportation in Sacramento, Calif.

For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.

Precast, prestressed concrete girders were used to span the culturally sensitive Presidio Pet Cemetery and support the falsework bents.



The steel fins that support the 14-ft-long cantilevers are shown in the structure and in place during construction of the concrete formwork.



Placing concrete in the soffit of the box girder.



CREATIVE CONCRETE CONSTRUCTION

Creative Reuse of "Surplus" Girders

by Fred Rouse Jr., N. Dillon Beck, and Daniel R. Shiosaka, Stanley Consultants and Patrick Dent, Central Arizona Project

Water is Arizona's most precious resource and the Colorado River satisfies much of the demand. The 335-mile-long Central Arizona Project (CAP) canal continually conveys Colorado River water to Maricopa, Pinal, and Pima counties in central Arizona. While delivering water is a core element of CAP's mission, CAP also ensures all of Arizona's entitlement is put to beneficial use in Arizona. Water that is not directly used can be stored underground to offset groundwater overdraft or stored to be recovered at a later date, according to Arizona's groundwater code.

CAP currently manages six direct recharge projects. The newest, the Superstition Mountains Recharge Project (SMRP), is located in Pinal County, just east of the Town of Queen Creek.

When planning the SMRP, CAP and Stanley Consultants conducted several design concept workshops to carefully examine key design, construction, and operational parameters to ensure that the CAP's needs were met or exceeded. The key question was, "What is the best way to withdraw water from the CAP canal?"

Other recharge projects used a pump turnout structure and a channel or culvert, to direct water to massive pumping stations. Gravity turnouts require a complex (and hydraulically disruptive) cofferdam to contain canal flows while the "live tap" is made. Part of the canal's reinforced concrete lining must be removed, a new turnout connection built, and the lining repaired. These efforts can take months.

Stanley Consultants proposed a unique bridge-mounted pumping station that spans the CAP canal. Six vertical, turbine pumps draw water directly from the canal like giant straws. This innovative concept allowed for bank-to-bank construction with no disruption to canal

Erecting girders weighing nearly 65 tons involved choreography at both ends and an "aerial bandoff" of one end across the canal.



Aerial view of the bridge-mounted pumping station. All photos: Central Arizona Project/Central Arizona Water Conservation District.

operations. This cost-effective configuration is more sustainable because vital components are deck-mounted above grade, with no submersed facilities.

After the design concept was adopted, the CAP and Stanley Consultants collaborated on another "green" idea. Seven precast, prestressed concrete AASHTO Type VI modified girders, produced for a highway bridge project, were cast about 3 ft too short, and might have been discarded. But the Arizona Department of Transportation procured replacement girders of the correct length and gave the "short" girders to the CAP (rather than discarding them), who stored them for several years. After confirming adequate length and strength, Stanley Consultants designed the pump station bridge to specifically match the "recycled" girders. The bridge is 112 ft 4 in. long at centerlines of bearings, 62 ft wide, and has an 8-in.-thick, composite cast-in-place concrete deck. The bridge supports the six pumps that each contribute a working load of 18 kips to the structure. In addition to providing for the pumps, the bridge provides an important vehicular crossing over the canal.

This project showcases the durability and versatility of precast, prestressed concrete AASHTO girders—essentially using salvage from a transportation project as key building blocks for a critical water resources project.



Aerial view of canal, recharge basins, and the pumping station.



All six pump cans extend below deck into the canal and three pump-motor assemblies are mounted above.

Fred Rouse Jr. is a principal environmental engineer, N. Dillon Beck is a structural engineer, and Daniel R. Shiosaka is a principal structural engineer, all with Stanley Consultants, and Patrick Dent is water systems supervisor with the Central Arizona Project, all in Phoenix, Ariz.

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Control of Concrete Cracking in Bridges



by M. Myint Lwin,
Federal Highway Administration

Concrete is a quasi-brittle material with a low tensile strength. Applied loadings, deleterious chemical reactions, and environmental effects can result in the development of tensile stresses in concrete. When these tensile stresses exceed the tensile strength, the concrete will crack. The extent and size of cracks have an effect on the performance of the bridge. However, the adverse effects of cracking can be minimized by proper selection of materials and proportions, attention to design and details, and quality control and quality assurance in fabrication and construction. This article outlines practices in control of concrete cracking to ensure better short- and long-term performance of bridges. Concrete can be used satisfactorily for an extended period of time without any significant loss of aesthetics, service life, safety, and serviceability.

It is important to understand why cracks develop in bridges. Much of the cracking in concrete can be traced to volumetric instability or deleterious chemical reactions. The volume instability results from response to moisture, chemical, and thermal effects. External loading is responsible for generating the majority of the tensile stresses in a bridge. Table 1 Classification of Cracks provides basic information on the main causes of cracking in concrete.

The impact of cracking on durability, especially corrosion, is detrimental to the performance of highway bridges. In particular, tidal exposures initiate dry-wet cycles and provide a constant source of salts to enter the cracks, significantly exacerbating deterioration. Similarly, cracked concrete in contact with sulfate rich soil can lead to accelerated sulfate attack.

Studies show that crack width has a significant influence on the corrosion process. When the cracks are relatively small (< 0.04 in.), they have little impact on the corrosion process and the structural performance. However, larger cracks (> 0.04 in.) increase the corrosion rate and lead to poor structural performance.

The LRFD Specifications

The *AASHTO LRFD Bridge Design Specifications* has provisions for crack control to assure serviceability, aesthetics, and economy. Article 3.4.1, Load Factors and Load Combinations, Service Limit States I, III, and IV are intended to control crack width and tension in reinforced concrete, prestressed concrete, and segmental concrete members. Article 5.6.3.6, Crack Control Reinforcement, is intended to control the width of cracks by redistribution of internal stresses using the strut-and-tie models for determining internal force effects. Article 5.7.3.4, Control of Cracking by Distribution of Reinforcement, is intended for the distribution of tension reinforcement to control flexural cracking. Article 5.8.2.7, Maximum Spacing of Transverse Reinforcement, is intended to provide crack control related to shear and torsion. Article 5.10.8, Shrinkage and Temperature Reinforcement, is intended for the control of cracking due to shrinkage and temperature effects.

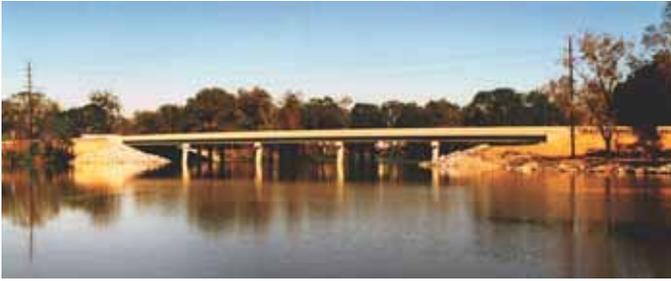
Transportation Research Circular

The Transportation Research Circular EC-107 (2006), *Control of Cracking in Concrete: State of the Art*, was prepared by the Transportation Research Board (TRB) Basic Research and Emerging Technologies Related to Concrete Committee (AFN 10).

The circular discusses causes of cracking, testing, and ways to minimize stresses and strains that cause cracking in bridges and pavements. The most common cause of premature deterioration in concrete bridges and pavements may be attributed to the development of cracks. The reasons for cracking are identified in the circular with guidance for prevention and crack control in structural design and detailing, selection of materials,

TABLE 1 Classification of Cracks

Type of Cracking	Form of Crack	Primary Cause	Time of Appearance
Plastic settlement	Over and aligned with reinforcement, subsidence under reinforcing bars	Poor mixture design leading to excessive bleeding; excessive vibration	10 minutes to 3 hours
Plastic shrinkage	Diagonal or random	Excessive early evaporation	30 minutes to 6 hours
Thermal expansion and contraction	Transverse	Excessive heat generation; excessive temperature gradients	1 day to 2-3 weeks
Drying shrinkage	Transverse, pattern, or map cracking	Excessive mixture water; inefficient joints; large joint spacings	Weeks to months
Freezing and thawing	Parallel to the surface of concrete	Lack of proper air-void system; nondurable coarse aggregate	After one or more winters
Corrosion of reinforcement	Over reinforcement	Inadequate cover; ingress of sufficient chloride	More than 2 years
Alkali-aggregate reaction	Pattern and longitudinal cracks parallel to the least restrained side	Reactive aggregate plus alkali hydroxides plus moisture	Typically more than 5 years, but weeks with a highly reactive material
Sulfate attack	Pattern	Internal or external sulfates promoting the formation of ettringite	1 to 5 years



The Charenton Canal Bridge, La., was constructed in 1999 and inspected 4 years later for cracks in the deck. The only cracks observed were transverse ones in the negative moment region over the intermediate piers. Photo: Louisiana Department of Transportation and Development.



The Route 104 Bridge, Bristol, N.H., was constructed in 1996. A bridge deck survey 8 years later showed only two longitudinal cracks with a total length of 10 ft. Photo: New Hampshire Department of Transportation.

concrete mixture design, and construction practices in concrete placement, finishing, and curing. Methods for crack repair are also provided in the circular. A list of about 150 references is provided.

FHWA Webinar

On September 15, 2011, FHWA in cooperation with the National Highway Institute (NHI) conducted a webinar on “Control of Concrete Cracking in Bridges and Pavements.” The webinar was co-sponsored by FHWA’s Highways for LIFE program, NHI, and TRB as part of the

ongoing Innovations series.

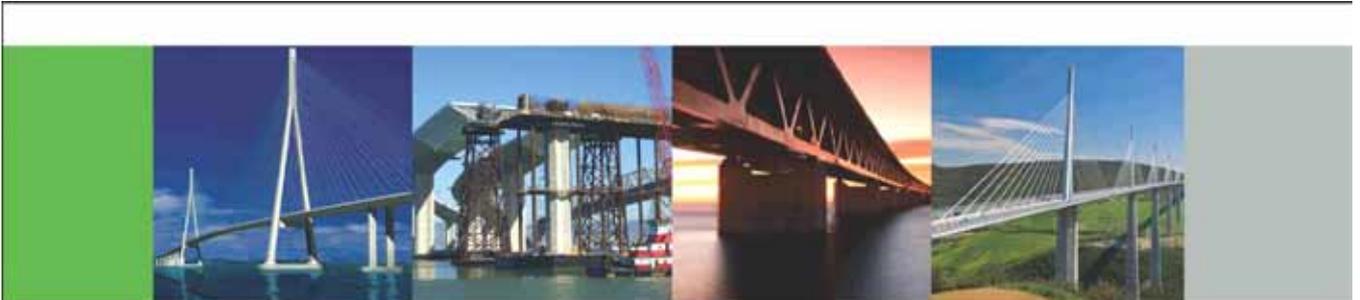
The webinar was moderated by Myint Lwin, director of the FHWA Office of Bridge Technology and Ben Graybeal, FHWA research structural engineer. Three featured speakers shared their knowledge and experience on three topics:

- Causes, Testing, and Detection of Cracking
- Controlling Cracks
- Prevention of Cracks in Concrete

A recording of the webinar may be viewed at <http://fhwa.adobeconnect.com/n134083201109>.

Closing Remarks

By virtue of its low tensile strength, concrete cracking is natural and often unavoidable. Proper structural design and detailing, selection of materials, mixture design, and construction practices can keep cracking to an acceptable level. Understanding the causes of cracking can lead to finding effective ways to prevent, control, and repair cracks. National standards, such as those by AASHTO and ACI, and reports such as those by PCI, have provisions for crack control and repair to assure serviceability, aesthetics, and economy of bridges.



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Innovative Beam Launcher Helps Small Cranes Make a Big Impression

by Philip Radler



The nearly completed West Pioneer Road Bridge spans the East Branch Fond du Lac River. When weather warms, the contractor will stain the formed stone finish to replicate the limestone rock found in the area. Photo: Paul Sponholz, Fond du Lac County, Wis.

Wisconsin's Fond du Lac County and the city of Fond du Lac had a problem: A two-lane bridge carrying 15,000 vehicles per day along West Pioneer Road and over the Fond du Lac River was rapidly deteriorating. Holes in the top flange of the box had been covered with steel plates to maintain traffic, but the old structure was posted with a load limit of 10 tons. This impeded a vital transportation corridor linking residential neighborhoods, business districts, and industrial areas in the city.

Gremmer & Associates Inc. was selected as project engineer to complete roadway design and manage construction of the new bridge. Subconsultant AECOM designed the 88-ft-wide, single-span, precast, prestressed concrete girder replacement bridge, which provides for five traffic lanes, a sidewalk, and a multi-use trail across the 99-ft-long span.

AECOM worked with the Wisconsin Department of Transportation to incorporate the state's new 36-in.-deep, 34-in.-wide girder section (36W[®]), eliminating the need for costly full-retaining abutments. The 8-in.-thick composite concrete deck is supported by fifteen 99-ft-long concrete girders that weigh almost 66,000 lb each.

To handle beam placement, Pfeifer Brothers Construction Company Inc. designed and built an adjustable beam launcher. Weighing just 22,275 lb, the launcher is a track-like structure

that can be set across the span with just one crane, yet it is strong enough to support the girders. Once the launcher is in place, one end of a beam is lifted and secured to a trolley that rolls on rails atop the launcher. With the other end of the beam still secured to the delivery truck, the truck backs up to roll the beam across the launcher, putting it within reach of a crane at the opposite abutment. That crane picks up one end of the beam, and works in tandem with the first crane to put each beam in position. This innovative solution allowed the girders, manufactured by Spancrete of Green Bay, Wis., to be set over just a 2-day period, and using smaller cranes.

Now one of the biggest

and the busiest bridges owned by the county, the completed structure features an additional parapet on the deck that separates live traffic from the multi-use trail. The abutments and parapets are accented with rustic ashlar concrete form liners and decorative black combination railings.

Philip Radler is a freelance writer in Hawthorne, Calif.



The leading end of the beam was mounted on a trolley on the beam launcher. The delivery truck pushed it across the Fond du Lac River until it could be reached by the near crane. Together, the two cranes lifted and set the beam in place. Photo: Steve Hinkley, retired, city of Fond du Lac, Wis.



The 8-in.-thick composite deck is shown being formed on the Wisconsin 36W[®] beams. Epoxy-coated reinforcement was used to help ensure a long service life. Photo: Jim Lucht, AECOM.

PRESTRESSED CONCRETE BRIDGES



PHOTO OF ROUTE 70 OVER MANASQUAN RIVER IN NEW JERSEY (PHOTO COURTESY ARORA ASSOCIATES).

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Oklahoma's Bridge Blitz

Governor's aggressive \$550-million, 8-year plan to wipe out deficient bridges in Sooner State raises the bar nationwide

by Craig A. Shutt

In October 2011, as the Oklahoma Department of Transportation (ODOT) was observing its 100th anniversary, it received an unprecedented birthday present: Gov. Mary Fallin announced an aggressive plan to address all currently known, structurally deficient bridges on the state-highway system. The \$550-million plan would essentially fully fund the existing 2012-2019 Eight-Year Construction Work Plan, which ODOT has found to be an effective tool in working efficiently to replace and maintain bridges.

The announcement was "a pleasant surprise," says Bob Rusch, state bridge engineer. "The Work Plan has proven to be a reliable and effective way to achieve key objectives," he says. More attention has been paid to addressing Oklahoma's growing inventory of deteriorating bridges in recent years, but much more has been needed, adds David Streb, director of engineering. Now, the program will receive that additional funding.

The two-phase initiative will address all of the state's current 706 structurally deficient highway bridges by the end of the decade, Streb explains. The first phase replaces or rehabilitates 539 structurally deficient bridges, including 126 added to the existing Work Plan. Phase Two, which requires legislative approval, increases funding to replace or rehabilitate the remaining 167 structurally deficient, highway-system bridges that weren't included in the Work Plan. The construction is expected to consist of about half replacement projects and half rehabilitation, says Rusch.

Eight-Year Blueprint

The Work Plan is created each year by ODOT and approved by the Oklahoma Transportation Commission. Updated annually with plans for the 8th year, it outlines design and construction work based on current funding levels. "Over the years, it has allowed the department to stay on top of its goals and create credibility for the department with the public and the legislature," says Streb.

The current 8-year plan includes the largest number of bridges ever targeted for work and already represents a renewed focus on highway improvements, he notes. Current law gradually increases transportation funding each year until a \$435-million cap is reached in 2017. The new plan will add \$15 million annually to the increase and raise the cap to \$550 million, without raising state taxes.

The plan also includes county bridges by increasing funding for the County Improvements for Roads & Bridges initiative from \$80 million to \$105 million annually. It also allows recycling of highway bridge beams, which will be done with beams from the 8800-ft-long I-40 Crosstown Expressway Bridge in Oklahoma City. Its beams will be shipped to counties for local bridges. This work will be complemented by ODOT's recent release of the first half of new LRFD county-bridge standards, which consist primarily of precast, prestressed concrete beams.

The program's design work will be provided by outside contractors, a rarity in the state, as shorter-span and rural bridges often are designed in-house, says Rusch. Most of the

replacement bridges will feature concrete, which has been the material of choice for most state bridges for decades.

2002 Turning Point

Oklahoma officials have understood the need for more attention to substandard bridges since the pivotal moment during the Memorial Day weekend in 2002 when two barges collided with a pier on the Webbers Falls Bridge in Muskogee County, Streb explains. The accident caused a 580-ft section of the I-40 steel bridge to collapse, killing 14 people.

The bridge was immediately repaired, replacing three steel approach spans with precast, prestressed concrete I-beams to speed out material fabrication and speed construction. The three concrete approach spans ultimately were erected faster than the remaining steel span, making an impression for concrete's capabilities. The bridge was restored to service in only 65 days.

Also leaving an impression was the deteriorated state of many of the highway bridges onto which vehicles had to be rerouted during construction, says Streb. "That led us to focus on inventorying and improving the number of deficient bridges in the state." They discovered that Oklahoma had the third highest number of structurally deficient bridges in the nation, with the majority built during the interstate construction boom in the 1950s and 1960s.

The decline arose from flat funding from 1985 to 2005, providing no opportunity to impact the growing list, explains Rusch. "An attempt to raise the gasoline tax to fund an expanded program was resoundingly defeated, but the legislature saw that defeat as a mandate to generate funds from existing sources." The result was a commitment of an additional \$100 million in 2007 to address the state's 137 load-posted bridges. The current program will eliminate those restrictions, although 32

The Western Avenue Bridge over I-40 in Oklahoma City represents ODOT's first use of precast concrete U-beams and of self-consolidating concrete. SCC ensured smooth flowability through the complex reinforcement and delivered an aesthetically pleasing appearance.



bridges since added to the list also will have to be addressed, he says.

The vast majority of bridges in the state consist of short-span structures crossing streams or highways, Rusch says. “These structures almost universally consist of concrete bridges of various kinds, including precast concrete beams with compressive strengths up to 10,000 psi.”

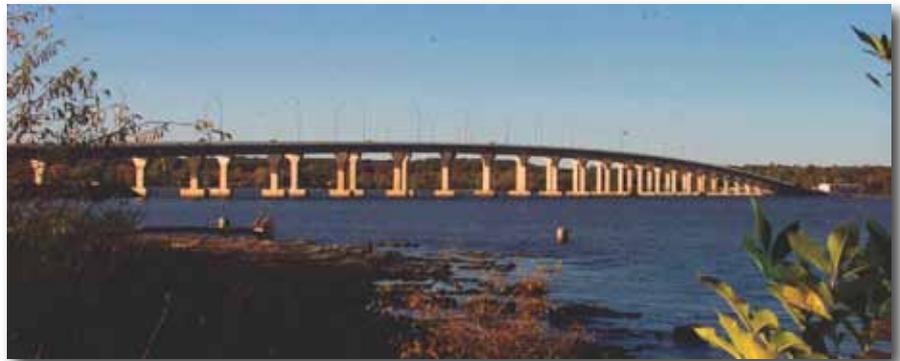
Key Concrete Designs

A variety of notable bridges have been constructed that take advantage of concrete’s capabilities, notes Greg Allen, assistant to the chief engineer. These designs include:

- **State Highway 74 (Lake Hefner Parkway) at Hefner Road in Oklahoma City:** Built in 1991, this 215-ft, single-span, cast-in-place concrete structure features the state’s second-longest concrete span. “The box girder design was used to span the parkway without a center pier,” Allen explains. The bridge was built on a new alignment, with the existing Hefner Road remaining open during construction.
- **U.S. 59 over Grand Lake (The Sailboat Bridge) near Grove:** This 3043-ft-long bridge is the state’s only precast concrete segmental, box girder bridge. Consisting of 25 spans, each 121.7 ft long, and match-cast segments, the design was a response to the required bridge length. It gained its name from the fact that the majority of sailboats can pass beneath it. “Its clearance was set after public meetings were held and sailboat configurations were researched,” Allen explains. Another unique aspect was the creation of the initial wearing surface as an integrally cast portion of each segment. The bridge was deemed to have the best riding surface in the state.
- **State Highway 4 over South Canadian River between Mustang and Tuttle:** This 1751-ft-long, precast, prestressed concrete bulb-tee structure has twelve 146-ft-long spans, the longest precast concrete spans in the state. “The design aimed to minimize piers in the water by using Texas Type J bulb-tee beams, which allowed an extra 10 ft of length in each span compared to the deepest section used in Oklahoma,” says Allen.



The 215-ft-long, single-span, Lake Hefner Parkway Bridge in Oklahoma City features Oklahoma’s second longest concrete span. The cast-in-place concrete, box girder structure spans the parkway without a center pier. All photos: Oklahoma Department of Transportation.



“The Sailboat Bridge” near Grove, the only precast concrete, segmental box-girder bridge in the state, features 25 spans at 121.7 ft each.



The longest precast, prestressed concrete spans in the state are featured on the SH 4 Bridge over South Canadian River between the towns of Mustang and Tuttle. The 1751-ft-long bridge has 12 spans of Type J Texas bulb tees, each 146 ft long.

The Eight-Year Construction Work Plan had created credibility with the public and the legislature.



The two-span, precast, prestressed concrete SH 102 Bridge over Turner Turnpike near Wellston was the state's first structure to feature a special aesthetic treatment consisting of colored components and an embedded concrete theme cap at the juncture of the center pier and superstructure.

- **State Highway 102 over Turner Turnpike in Wellston:** Built in 2008, this two-span, precast, prestressed concrete bridge contains AASHTO Type IV beams spanning 109 and 114 ft. It was the state's first bridge to feature a special aesthetic treatment. The bridge features color tints as well as a special concrete "theme cover" where the median pier joins the superstructure. The cover has the battle-shield emblem from the state flag embedded in the concrete and overlaid with ceramic tiles. Since this use, several other projects have received this aesthetic treatment.

New Design Ideas

"We continue to look for new techniques to resolve key challenges," says Streb. One such can be seen in the Western Avenue Bridge over the realigned I-40 highway in Oklahoma City. In 2010, it became the first bridge in the state to use precast concrete U-beams.

"That design was selected because the girders provided a more aesthetically pleasing appearance to the box-girder shape," explains Rusch. Aesthetics were enhanced by using self-consolidating concrete, although that wasn't the intention, he adds. The U-beams were fabricated in Texas, where they are more commonly used. But the fabricators wanted to create the girders in two placements, casting the bottom slab and then the walls. ODOT suggested SCC to ensure full coverage without honeycombs in the congested space. "The fabricator was unfamiliar with SCC, but the resulting girders fulfilled all the structural needs and provided an excellent aesthetic appearance," he says. "That bonus ensured these concepts will be added to our arsenal of options."

Oklahoma needs as many options as possible to meet its challenges, the designers say. Environmental regulations protect a variety of endangered fish, mussels, clams, and birds from impacts from both construction and structural impediments. "To meet the needs of these regulations without slowing down our schedules, we're focusing more attention on how to get projects started more quickly," says Rusch.

ODOT evaluates a variety of concepts that allow for faster construction, he adds. One technique learned from the Webbers Falls project is to use maturity meters during curing of the concrete. They are used to determine the concrete's strength as it cures, which allows forms to be stripped faster while ensuring that the component will function

as a structural member. "The meters worked so well that we have used them on several projects since to speed construction."

"We are always looking for ways to build a better mousetrap so bridges can be constructed quicker, more economically, and better," says Allen. Those techniques will be necessary as the

Sooner State's bridge program becomes front and center during the next 8 years of aggressive replacement and rehabilitation.

For more information on Oklahoma's bridges, visit www.okladot.state.ok.us.

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Abstracts due FEBRUARY 6, 2012

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September 29—October 3

Gaylord Opryland, Nashville, Tennessee

PCI is accepting abstracts for technical papers and student posters to be presented at the 2012 PCI Convention and National Bridge Conference in Nashville, Tennessee. Abstracts and papers will be peer-reviewed and accepted papers will be published in the conference proceedings.

The PCI Convention and National Bridge Conference is the premier international venue for the exchange of ideas and state-of-the-art information on precast concrete design, fabrication, and construction. The event attracts an average of 1,000 participants each year and provides an outstanding opportunity for networking, education, and sharing of ideas. Don't miss out on this excellent opportunity to share your knowledge—submit your abstract today!

Submission Requirements

Abstracts should be submitted electronically. Visit www.pci.org and click on the Call for Papers and Student Posters button to access the submission site.

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Bridges at the Foot of the Lake

by Paul M. Sponholz, Fond du Lac County



This 65-ft-long span, precast, prestressed concrete girder bridge carries Fond du Lac County Highway C over the West Branch of the Fond du Lac River in Eldorado, Wis.



A Fond du Lac County highway crew is shown installing a 20-ft span, three-sided precast concrete structure to carry County Highway B over Parsons Creek.

Fond du Lac County lies at the southern tip of Lake Winnebago, the largest lake in Wisconsin. The county's name is a French phrase meaning "foot of the lake." The county's population is about 101,000 with over 43,000 living in the city of Fond du Lac, the county's largest city. The county is at a crossroads of important highways connecting major Wisconsin cities and is a significant dairy and agricultural region of the state. The county owns and maintains 382 miles of highways, the majority of which are rural collectors, along with 61 county bridges with spans longer than 20 ft.

The county has long chosen concrete bridges because of the minimal maintenance needed. Of the 61 structures, 48 are concrete. Two concrete spans have been widened with steel girders. Three bridges are steel, one which was widened with concrete girders. Two bridges are timber. The other eight structures with spans long enough to be included on the national bridge inventory are steel culverts.

The average bridge length is 54 ft, with the

longest being 377 ft. The widest and newest bridge, West Pioneer Road Bridge over the Fond du Lac River, is 88 ft wide and featured in this issue on page 42. All bridges cross water except for two that span railroads.

The average bridge age is 37 years. Two are tied for being the oldest at 90 years. A concrete slab span bridge on Highway Q in Johnsbury was built in 1921 and then widened in 1976. In 2006, county crews completed minor repairs and milled and resurfaced its concrete deck. It is expected to continue service for many years to come. The other 90-year-old bridge is scheduled to be replaced in 2013.

County engineering staff inspects all 61 bridges every 2 years at a minimum and make maintenance recommendations as needed. The county has an aggressive maintenance program to get the most life out of its bridges using its own crews to do the work such as sealing deck cracks, patching decks, and making concrete repairs using formwork or shotcrete. Crews mill and resurface one or two decks a year with concrete.

The county replaces about one bridge a year through the federal bridge program. On occasion, county crews construct smaller bridges that are not federally funded with cast-in-place concrete or precast components.

Besides the bridges longer than 20 ft, there are numerous smaller span bridges. Many of these small bridges were constructed in concrete in the 1930s then later widened with steel girders. The concrete in many cases is still in good condition, but the steel often is in poor shape. While not part of the federal inspection requirements, the county is working to formally



At 377 ft long with four spans, Fond du Lac County's longest bridge carries County Highway RP over the Canadian National Railway.



Built in 1921, this concrete slab span bridge carries County Highway Q over the South Branch of the Manitowoc River. It was widened in 1976 and its deck was resurfaced in 2004. Concrete slab span bridges make up many of the county's bridges.



After removing delaminated concrete, sandblasting exposed corroded reinforcement, and painting the reinforcement with an epoxy coating, a Fond du Lac County highway crew applies shotcrete to repair concrete under the deck.

inspect and document the condition of these bridges regularly, recognizing safety concerns and the significant costs to replace them with local funding only.

Assisting local governments, the county serves as the bridge Program Manager working with the Wisconsin Department of Transportation to manage 107 municipal and township bridges in the county. County staff also inspect most of these bridges.

Paul M. Sponholz is Fond du Lac County Highway Engineer in Fond du Lac, Wis.

2012 CONCRETE BRIDGE AWARDS COMPETITION

CALL FOR ENTRIES Deadline February 29, 2012

ELIGIBILITY The Portland Cement Association invites entries for its **Thirteenth Biennial Bridge Awards Competition**. Eligible structures for the 2012 competition must have been essentially completed between September 2009 and September 2011, and must be located within the United States or Canada.

BRIDGE CRITERIA All types of bridges—highway, rail, transit, pedestrian, and wildlife crossing—in which the basic structural system is concrete, are eligible. Entries are equally encouraged for cast-in-place or precast concrete bridges with short, medium, or long spans. Newly constructed, reconstructed, or widened structures qualify for the competition.

WHO MAY ENTER Any organization, public or private, may enter. Multiple entries are welcome.

AWARDS Commemorative plaques will be presented at the opening session of the American Concrete Institute's Fall Convention to be held in Toronto, Ontario, Canada, October 21-25, 2012.

ENTRY For an entry form and to view previous award winners visit: www.cement.org/bridges

PCA Portland Cement Association

Expanded Shale, Clay and Slate Institute Releases Internal Curing Resources



The Expanded Shale, Clay and Slate Institute (ESCSI) announces the release of several Internal Curing resources that have been developed over the last year.

Internal curing is achieved by incorporating prewetted expanded shale, clay and slate (ESCS) aggregate into the concrete mixture to deliver moisture to the hydrating cementitious materials from within the concrete. The absorbed moisture in the ESCS is not a part of the concrete mixing water and therefore does not increase the effective w/cm .

ESCSI has released an online guide for calculating the quantity of prewetted ESCS lightweight aggregates for internal curing. Users can input their mixture requirements into the guide which will calculate the minimum quantity of prewetted ESCS lightweight aggregate needed to provide the moisture for internal curing of cementitious materials in a concrete mixture. This calculator is located in the Internal Curing section of the ESCSI website: www.ESCSI.org.

"*Internal Curing: Helping Concrete Realize its Maximum Potential*," an ESCSI brochure that was just released, explains the benefits of internal curing and how internal curing is the common sense addition to improve the sustainability of concrete. ESCSI also published a guide specification for internally cured concrete that can be used to modify a conventional normal weight concrete mixture to provide internal curing of the concrete by replacing a portion of the normal weight fine aggregate with prewetted fine or intermediate ESCS lightweight aggregate.

For more information about internal curing and ESCS aggregate, visit www.ESCSI.org.

Aesthetic Lighting and Security Lighting

by Faith E. Baum, Illumination Arts LLC



At the Biloxi Bay Bridge in Mississippi, a pedestrian pathway and small park engage the shoreline and allow for beachcombers to pass under the structure.

The goal of aesthetic lighting for a transportation structure is to create a beautiful and memorable lighting solution that is a reflection of the community and the context in which it is located. While the intent of aesthetically illuminating a signature bridge in particular is to create an iconic nighttime image for that community, it can also be used to artistically address a number of technical and utilitarian issues.

Examples of this can be seen in the designs for the Biloxi Bay Bridge in Mississippi and the Cypress Avenue Bridge in California.

Biloxi Bay Bridge

Along the shoreline of Biloxi Bay, as the bridge approaches its abutments, a pedestrian pathway and small park engage the shoreline and allow for beachcombers to pass under the structure.

Here the aesthetic lighting design seeks to highlight the concrete girder pattern under the bridge by placing narrow beam, metal halide floodlights between the girders. In these locations, light is reflected off the underside of the bridge deck, providing sufficient illumination for the pathway and circulation area and making pathway-specific lighting unnecessary. As an “intended consequence,” the lighting of the structure in this area improves security under the bridge, along the shore and in

the park, rendering security lighting redundant.

Cypress Avenue Bridge

Similarly, the Cypress Avenue Bridge in Redding, Calif., crosses both the Sacramento River and a local road, creating a large vertical abutment wall at the roadway underpass. Matching the scale of the river piers, the continuation of the pier lighting to this abutment wall provides a cohesive, aesthetic lighting solution, while also eliminating a potential safety and security hazard under the bridge.

Metal halide wallwashers illuminate the textured,

vertical surface, eliminating shadows and welcoming pedestrians to traverse the area beneath the bridge. Though roadway lighting is still necessary, the abutment wall lighting provides ample illumination for the landscaped pedestrian path that is adjacent to the wall. As with Biloxi Bay Bridge, the aesthetic lighting solution addresses a security lighting concern, saving energy and cost, and maintaining the aesthetic integrity of the bridge design.

A signature bridge structure is not designed to merely solve a transportation problem, and the most successful of such structures are those that seamlessly address operational, aesthetic, and contextual issues. For the lighting designer of such a complex structure, finding synergies in overlapping functions is one of the ways in which they can participate in solving some of the thorniest issues of safety and security. Working in partnership with the owner, design team, and local community, the lighting designer can help achieve all of the lighting-related project goals with a sensitive and artistic hand, while reducing first costs, maintenance costs, and energy costs.

Faith E. Baum is principal with Illumination Arts LLC in Bloomfield, N.J.



Light is reflected off the underside of the Biloxi Bay Bridge deck, providing sufficient illumination for the pathway and circulation area and making pathway-specific lighting unnecessary.



The Cypress Avenue Bridge in Redding, Calif., uses metal halide fixtures to illuminate the textured, vertical surface, eliminating shadows and welcoming pedestrians to traverse the area beneath the bridge.



At Biloxi Bay Bridge, the aesthetic lighting design seeks to highlight the concrete girder pattern under the bridge by placing narrow beam, metal halide floodlights between the girders.

EDITOR'S NOTE

For more on the Cypress Avenue Bridge, see the Summer 2011 issue of *ASPIRE*,™ page 36.

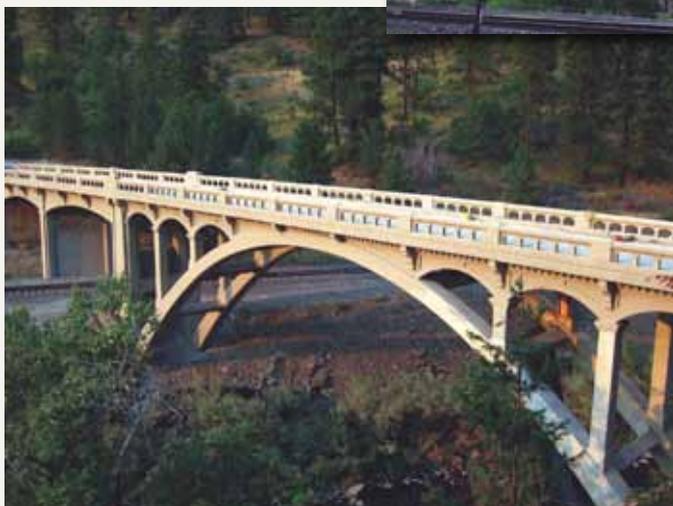


Historic Repairs

Classic bridge is revived with extensive repairs

by Craig A. Shutt

The Upper Perry Arch Bridge, spanning the Grande Ronde River and the Union Pacific Railroad in Perry, Ore., was designed by Oregon's first state bridge engineer, Conde McCullough. Built in 1923, the 309-ft-long bridge features classic McCullough design ele-



To rehabilitate the 309-ft-long Upper Perry Arch Bridge in Perry, Ore., which had severely deteriorated, 580 yd³ of concrete had to be cast in 35 placements, not including the 618 linear ft of precast decorative bridge rail.

ments: sweeping arches, railings of gothic-arched panels that support beveled handrails, and decorative brackets.

But the bridge's deterioration had been unchecked for so long that the Oregon Department of Transportation considered demolishing the bridge. After further inspection and input from an architectural committee, officials decided that rehabilitation was a viable option. The construction team on the project included engineering firm OTAK Inc. in Portland, Ore.; repair contractor Wildish Standard Paving in Eugene, Ore.; and material supplier Masons Supply in Portland, Ore. Officials wanted to salvage as much concrete as possible.

By adding a cast-in-place longitudinal center beam, deck thickness was reduced from 14 to 8 in., which minimized the amount of concrete needed and reduced the dead load of the bridge. Several expansion joints were also eliminated to minimize future maintenance costs. The anticipated extended service life is 50 years.

Deteriorated concrete had to be removed using handheld jackhammers and replaced with repair grout before other work began. All bridge rails, crossbeams, decks, spandrel posts, sidewalk brackets, and corbels were demolished and replaced. The arches and bents were salvaged, 1130 linear ft of cracks were injected with epoxy and unsound, deteriorated concrete was removed and replaced.

Repair work included over 2000 ft² of regular cast-in-place concrete repair (up to 2 in. in depth) and 810 ft² of deep concrete repair (up to 16 in. in depth). Over 2800 ft² of damaged concrete, 65% more damaged concrete than originally anticipated, was removed and replaced with 550 ft³ of the prepackaged repair mortar.

A total of 306 dentils and 68 sidewalk brackets (corbels) were demolished, formed, and cast in place. Special steel forms were used to fabricate 46 pieces of rail.

All placements for the main arch span were located equally from each side of the bridge to balance loading. The arch ribs supported the formwork and the work platform. After the formwork was removed, the entire structure was patched, ground, painted, and sealed.

The restoration met the goal of recreating the original look of the structure sought by McCullough 90 years ago while protecting the bridge from deterioration for another 50 years. The project was named 2010 Historic Project of the Year by the International Concrete Repair Institute, indicating its success.

This article is an abridged version of an article published in the November/December 2010 issue of Concrete Repair Bulletin and is published with the permission of the International Concrete Repair Institute. For more information on the organization, visit www.icri.org.

Historic Arch Bridge Widened

Precast concrete structure "hidden" inside concrete arch structure in Lexington, Ky.

by Daryl W. Carter, ENTRAN (now Stantec) and Jeremy Raney, Louisville Metro Public Works & Assets

Rehabilitating a historic reinforced concrete arch bridge requires careful consideration of all factors and close evaluation of the best way to retain aesthetics while providing long-term functionality. Both goals were achieved in widening the River Road Bridge over Harrods Creek in Jefferson County, Ky.

The goal for Jefferson County Public Works officials was to rehabilitate and widen the existing bridge, a three-span, reinforced concrete, filled-spandrel arch constructed circa 1912. The one-lane, 195-ft-long structure, eligible for listing in the National Register of Historic Places, was creating a bottleneck for traffic and safety concerns.

After reviewing options, designers drafted a plan to "hide" the structural support framework of a precast concrete bridge inside the spandrel walls of the existing arches. The new bridge deck spans over the existing spandrel walls to provide sufficient width for a two-lane bridge. The widened bridge consists of three spans (71 ft 6 in., 66 ft 4 in., 71 ft 6 in.), continuous for HS-25 live load. At 32 ft wide, it carries two 12-ft-wide traffic lanes, two 2-ft 10-in.-wide shoulders, and has 1-ft 2-in.-wide architectural concrete bridge rails on each side replicating the original concrete balustrade railing.

The bridge superstructure uses 42-in.-wide by 48-in.-deep precast, prestressed concrete spread-box beams, spaced at



The rehabilitated River Road Bridge hides the structural support framework of a precast concrete bridge inside the spandrel walls of the existing arches. Its deck cantilevers 7 ft 9 in. beyond the edges of the box beams to provide for a two-lane bridge.

6 ft 3 in. centers. This narrow beam spacing allowed three beam lines to fit between the existing spandrel walls, ensuring newly generated loads were isolated from the existing arches.

The beams, fabricated with 7500 psi compressive strength concrete, provide significant flexural strength, shear capacity, and have relatively shallow depth. They will also be durable in the moist environment and will not require painting.



The newly widened bridge provides better functionality and the same historic appearance as the original. Although local groups were wary, feedback has indicated that the results have been well received, and the project has been perceived as a success. All photos: ENTRAN PLC.

An advertisement for MI-JACK Travelift RTG cranes. The top half features the text "LIVE TRAFFIC" in large red letters. Below this is a photograph of a yellow RTG crane on a bridge deck, with a white truck passing underneath. The bottom half of the ad has a black background with the text "NO PROBLEM!" in large white letters. Below this, it says "Bridge Repair is easier when using the MI-Jack Travelift® RTG cranes to quickly set your load, without the need for a large area required by conventional cranes." and "Call Today, to find out more about how the MI-Jack Travelift® RTG crane can save you time and money on your next Bridge Repair project...". At the bottom, it provides the phone number "(800) 6-MI-JACK" and the website "www.mi-jack.com", along with the MI-JACK Travelift logo.



Precast concrete deck panels were cast with vertical open slots that align with epoxy-coated shear stirrups protruding from the box beams' tops. Once fit together, these joints were pressure-grouted.

Precast Concrete Deck Used

The bridge deck comprises twenty 32-ft-wide precast concrete deck panels with cast-in-place concrete closures between each panel. The panels vary in width from 5 ft 10½ in. to 7 ft 11⅝ in. They are approximately 1 ft 1½ in. thick at the crown and taper to 10 in. at the ends. Specified concrete compressive strength was 7500 psi. Panels are pretensioned transversely to the bridge to handle the large deck overhangs, which on one side supports a suspended 8-in.-diameter water pipe. No post-tensioning was used. The panels were topped with a waterproofing membrane followed by a ½-in.-thick asphalt overlay.

New abutment caps are supported on drilled shafts behind the existing arch rings, cored down through the existing arch thrust blocks to terminate in rock sockets. The pier caps are supported on micropiles drilled through the arch infill and pier stems. They are anchored 11 ft into solid rock.

The existing arch rings also were repaired during the construction. The repairs included chipping out deteriorated concrete, replacing corroded reinforcement, and applying epoxy concrete. Once repairs were completed, the exposed surface of the arches and spandrel walls received a masonry coating finish.

The bridge, which opened to traffic in August 2010, won the award for Best Rehabilitated Bridge in the Precast/Prestressed Concrete Institute's 2011 Design Awards competition.

Daryl W. Carter is a senior bridge engineer/project manager with ENTRAN (now Stantec) in Lexington, Ky., and Jeremy Raney is an executive administrator with Louisville Metro Public Works & Assets in Louisville, Ky. This article is a condensation of a paper presented at the National Bridge Conference held October 22-26, 2011, in Salt Lake City, Utah.

Rehabilitation, Not Destruction

Saving Cass County Bridge No. 123

by Mike Wenning, American Structurepoint Inc.

When Cass County Bridge No. 123 in Lewisburg, Ind., was slated for demolition, public outcry from the town was strong. This five-span Luten arch bridge was built in 1913 to carry CR 825 E over the Wabash River. A Luten arch is a patented concrete arch designed during that time period by Daniel B. Luten, of Indianapolis, Ind. Nearby residents relied on the bridge for daily transportation and respected it for its historic significance, but after years of deterioration, safety had become an issue.

Since plans did not exist for the bridge, significant survey, coring, and field inspection were required to acquire the necessary details. The goal was to return this ornamental bridge back to its original appearance while making it safer by incorporating modern design features. Many of the fine neoclassical elements of this bridge had been completely lost. Engineers relied heavily on historic reference and details gleaned from work on other Luten bridges.

Funding was a challenge from the beginning. During the process of seeking funds, the bridge deteriorated to the point that it had to be closed. Once funds were obtained, the Cass County Highway Department hired American Structurepoint to quickly prepare plans for construction.

The spandrel walls and arches were generally in good condition; however, the massive 8-ft-thick piers were in a dilapi-



Historic references helped determine the design of the piers, which had concentric components reconstructed with extensive detailing.



A temporary support system was placed under the arch on either side of the pier during the construction process.

dated state. Engineers had to determine a way to stabilize the arch while the main supports were replaced. The engineers, and Jack Isom Construction, developed unique methods to safely stabilize the structure during construction. A temporary support system was placed under the arch on either side of the pier. The contractor then excavated all fill from the arch and separately removed each pier in thirds. Some of the existing concrete was found to be in acceptable condition in some areas and allowed to remain, which provided added support during the pier reconstruction. Historic references were relied upon when determining the width and design of the piers,

which had concentric components reconstructed with extensive detailing.

Aesthetics and modern safety improvements were priorities during the rehabilitation. The original bridge was very narrow, just 18 ft wide. Therefore, a concrete deck that overhung the existing spandrel wall, and supported by it, was designed to provide a 24-ft width.

The original railings, one of the more unique architectural elements, had previously been removed. Through investigation and surveys, the spindles lining the rail were reconstructed, with the exterior surface perfectly matching the original work of almost 100 years ago. To modernize the railing, the precast concrete spindles were designed with a stainless steel dowel through their center with adequate strength to resist high-way impact loads. Proper care was given to concrete texture, which was of great importance.

Bridge No. 123 is now safer than ever before and was restored to replicate its original magnificent appearance. Utilizing quality materials will ensure the longevity of this structure, not only as it is used for transportation, but as it is admired by generations as a work of infrastructure art.

Mike Wenning is manager of the Bridge Department at American Structurepoint Inc. in Indianapolis, Ind.

Interested in Collaborating on the Long-Term Bridge Performance Program?

The Federal Highway Administration's (FHWA) Long-Term Bridge Performance (LTBP) program is envisioned as a 20-year comprehensive examination of the nation's bridges. The objective of the LTBP program is to compile a comprehensive database of quantitative information from a representative sample of bridges nationwide, looking at every element of a bridge. By taking a holistic approach and analyzing all of the physical and functional variables that affect bridge performance, the study will provide a more detailed and timely picture of bridge health and better bridge management tools.

The FHWA is seeking industry input, including but not limited to professional organizations, associations, companies and vendors with innovative ideas, tools and technology, in support of the LTBP program. The FHWA seeks suggestions in the form of a white paper, which includes an approach for collaboration between the organization and the LTBP program. Collaboration may include involvement such as the sharing of data, access to knowledge, or contribution of products, services, or expertise that supports the LTBP program. White papers are due by 3:00 p.m. (EST) on Friday, February 17, 2012, for consideration.

For more information on this opportunity, please read the full description in Federal Business Opportunities, <https://www.fbo.gov/>, Solicitation # DTFH61-12-RI-00002.

For more information on the FHWA's LTBP program please visit <http://www.fhwa.dot.gov/research/tfhr/programs/infrastructure/structures/ltpb>



U.S. Department of Transportation
Federal Highway Administration

Concrete Connections is an annotated list of websites where information is available about concrete bridges. Fast links to the websites are provided at www.aspirebridge.org.

IN THIS ISSUE

www.deldot.gov/information/projects/indian_river_bridge/index.shtml

This Delaware Department of Transportation website contains the latest information about the Indian River Inlet Bridge described on page 12. Virtual site tours, time-lapse videos, webcams, and photographs of construction are available in the Multi-Media Gallery.

www.presidioparkway.org

Visit this website for more information and photographs of the Presidio Viaduct (page 30). There are also two webcams available.

<http://fhwa.adobeconnect.com/n134083201109>

The FHWA webinar on "Control of Concrete Cracking in Bridges and Pavements" mentioned on page 36 is available at this site.

www.trb.org/main/blurbs/158019.aspx

Transportation Research Board Circular EC-107 titled *Control of Cracking in Concrete: State of the Art*, described in the FHWA article on page 36 may be downloaded from this website.

Environmental

<http://environment.transportation.org/>

The Center for Environmental Excellence by AASHTO's Technical Assistance Program offers a team of experts to assist transportation and environmental agency officials in improving environmental performance and program delivery. *The Practitioner's Handbooks* provide practical advice on a range of environmental issues that arise during the planning, development, and operation of transportation projects.

www.environment.transportation.org/teri_database

This website contains the Transportation and Environmental Research Ideas (TERI) database. TERI is the AASHTO Standing Committee on Environment's central storehouse for tracking and sharing new transportation and environmental research ideas. Suggestions for new ideas are welcome from practitioners across the transportation and environmental community.

Sustainability

<http://sustainablehighways.org>

The Federal Highway Administration has launched an internet-based resource designed to help state and local transportation agencies incorporate sustainability best practices into highway and other roadway projects. The Sustainable Highways Self-Evaluation Tool, currently available in beta form, is a collection of best practices that agencies can use to self-evaluate the performance of their projects and programs to determine a sustainability score in three categories: system planning, project development, and operations and maintenance.

www.pewclimate.org/docUploads/Reauthorization-and-HTF-Primer.pdf

If you have never understood the Federal Surface Transportation Authorization and the Highway Trust Fund, this primer may help you.

Bridge Technology

www.aspirebridge.org

Previous issues of *ASPIRE*[™] are available as pdf files and may be downloaded as a full issue or individual articles. Information is available about subscriptions, advertising, and sponsors. You may also complete a reader survey to provide us with your impressions about *ASPIRE*. It takes less than 5 minutes to complete.

www.nationalconcretebridge.org

The National Concrete Bridge Council (NCBC) website provides information to promote quality in concrete bridge construction as well as links to the publications of its members.

www.hpcbridgeviews.org

This website contains 68 issues of *HPC Bridge Views*, an electronic newsletter published jointly by the FHWA and the NCBC to provide relevant, reliable information on all aspects of high-performance concrete in bridges. Sign up at this website for a free subscription.

www.fhwa.dot.gov/Bridge/ABC

Visit this website for more information about the FHWA Accelerated Bridge Construction Program.

www.fhwa.dot.gov/bridge/abc/prefab.cfm

If you missed the FHWA webinars about Prefabricated Bridge Elements and Systems held in four sessions on August 16 and 17, 2011, the webinar is now available at this website. Under Webinars, click on one of the sessions. The concrete industry role is included in Session 3.

NEW www.abc.fiu.edu

This website contains information from the Accelerated Bridge Construction (ABC) Center of Florida International University about upcoming and previous webinars.

Bridge Research

NEW www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/nrcc52661.pdf

A research report by the National Research Council of Canada about the benefits of internal curing on service life and life-cycle costs of high-performance concrete bridge decks is available at this website.

NEW www.fhwa.dot.gov/research/publications/technical

Searching for transportation infrastructure-related reports, fact sheets, and other publications? For a list of FHWA research reports and technical publications, visit this website.

NEW www.trb.org/publications/Blurbs/165576.aspx

NCHRP Report 700 titled *A Comparison of AASHTO Bridge Load Rating Methods* documents an analysis of 1500 bridges that represent various material types and configurations using AASHTOWare[™] Virtis[®] to compare the load factor rating to load and resistance factor rating for both moment and shear induced by design vehicles, AASHTO legal loads, and eight additional permit/legal vehicles.

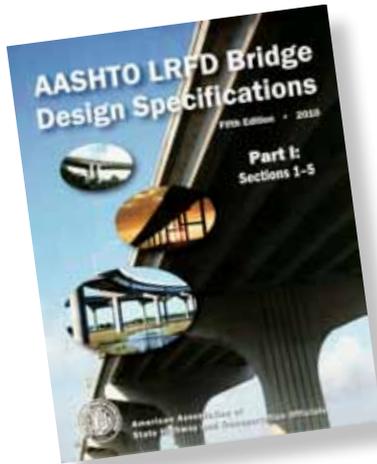
www.trb.org/PublicationsPubsNCHRPResearchResultsDigests.aspx

Research Results Digest 355 summarizing key findings from NCHRP Project 10-71 titled *Cast-in-Place Concrete Connections for Precast Deck Systems* is now available from this National Cooperative Highway Research Program website.

The Fatigue Limit States, Part 3



by Dr. Dennis R. Mertz



All the fatigue limit states for concrete structures defined in Article 5.5.3 of the *AASHTO LRFD Bridge Design Specifications* require the determination of the live-load stress range, Δf , due to the passage of the fatigue load as specified in Article 3.6.1.4. This fatigue load is the HL-93 design truck, identical to the HS20-44 truck of the *AASHTO Standard Specifications for Highway Bridges*, with a specified fixed rear axle spacing of 30 ft for the fatigue limit states. The use of the maximum rear axle spacing acknowledges that fatigue is governed by more typical force effects and not the maximum values of the strength limit states. The maximum rear-axle spacing spreads the load; thereby generating a lower moment and lower fatigue stresses. The dynamic load allowance (*IM*) associated with the fatigue limit states is 15%, a reduction from the 33% dynamic load allowance for the strength limit states, again acknowledging that fatigue is not governed by maximum force effects.

For simple span structures, the stress range is simply the live-load stress from the fatigue load for the critical truck location. For continuous structures, the stress range is the sum of the absolute values of the maximum live-load stress when the truck is on the span under consideration and the maximum live-load stresses when the truck is on all adjacent or more remote spans. In other words, it is the total excursion of stress due to the truck crossing the bridge.

The fatigue limit states for steel reinforcement of reinforced concrete components are checked

when the steel reinforcement experiences significant tension. In regions of compressive stress due to unfactored permanent loads and prestress, fatigue is considered only if this compressive stress is less than the tensile portion of the stress range resulting from the Fatigue I load combination, discussed in *ASPIRE*,TM Summer 2011; in other words, 1.5 times the tensile portion of Δf . Fatigue of the reinforcement need not be checked for fully prestressed components designed to have extreme fiber tensile stress due to Service III Limit State within the specified tensile stress limit.

According to Article 5.5.3.1, the section properties for fatigue stress calculations are based on cracked sections where the sum of stresses, due to unfactored permanent loads and prestress,

and the Fatigue I load combination is tensile and exceeds $0.095\sqrt{f_c'}$ ksi, a relatively conservative cracking stress limit (f_c' is in ksi). Otherwise, uncracked section properties can be used for fatigue stress calculations.

EDITOR'S NOTE

If you would like to have a specific provision of the *AASHTO LRFD Bridge Design Specifications* explained in this series of articles, please contact us at www.aspirebridge.org.



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