

ASPIRE™

THE CONCRETE BRIDGE MAGAZINE

SUMMER 2011

Cross Street Bridge

Middlebury, Vermont

STEWART STREET BRIDGE

Dayton, Ohio

**TEN MILE ROAD INTERCHANGE
OVER I-84**

Meridian, Idaho

**SW LINE FLYOVER BRIDGE,
NALLEY VALLEY INTERCHANGE**

Tacoma, Washington

**MIAMI INTERMODAL CENTER—
EARLINGTON HEIGHTS
CONNECTOR**

Miami, Florida

SOUTH MAPLE STREET BRIDGE

Enfield, Connecticut

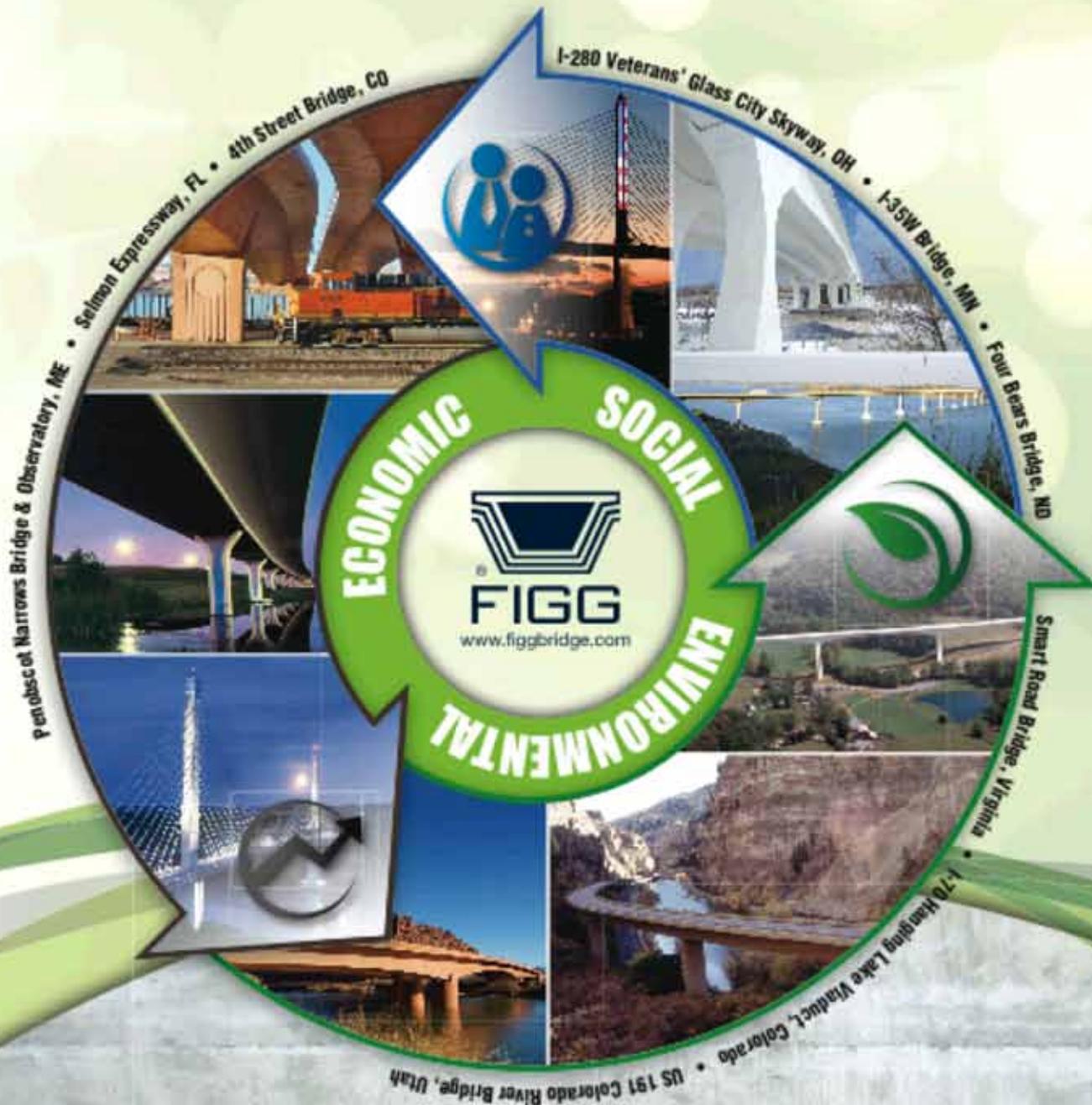
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**SR 519 INTERMODAL ACCESS
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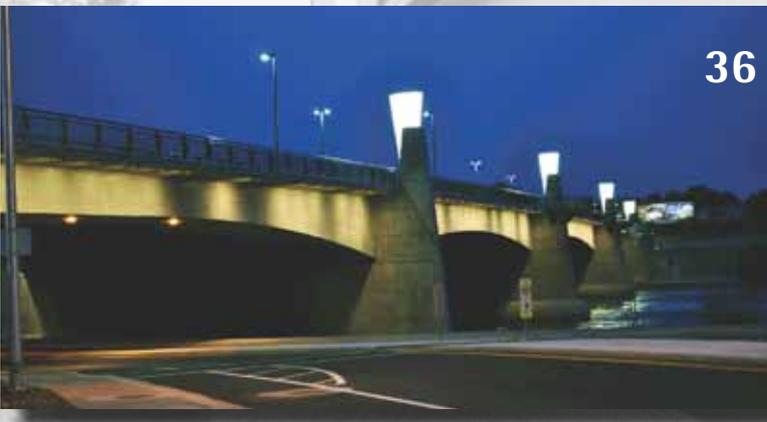
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Photo: Vanasse Hangen Brustlin Inc.



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Photo: Guy F. Atkinson Construction LLC.



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Photo: C. Hodge, T.Y. Lin International.

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Photo: Vanasse Hangen Brustlin Inc.

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Form Follows Function

John S. Dick, *Executive Editor*

Photo: Ted Lacey Photography.

Architect Louis Sullivan, in the late nineteenth century, said that “form ever follows function.” He has very often been quoted over the past 115 years.

In bridge design, it is often easier to follow that edict than in other areas of design. Bridges, within the public purview of ownership and maintenance, need to be built within constraints of economy and efficiency, with goals of durability and reliability. Shapes generally take the form of the forces they resist; there is usually little excess material.

Concrete is the material most easily and economically molded into any desired shape. It can be reinforced internally, conventionally or prestressed, to further reduce the size of shapes and the use of material. When a shape defines the forces it resists and appears slender and efficient, it achieves visual or aesthetic satisfaction in its application.

This issue of *ASPIRE*,™ features bridges that exceed these objectives. The Ten Mile Road Interchange in Meridian, Idaho, has an efficient hourglass shape to achieve its use as a single-point urban interchange (see page 18).

The Cypress Avenue Bridge in Redding, Calif., used a complex, phased construction sequence to maintain traffic and resulted in an aesthetically pleasing bridge that is tastefully illuminated to redefine the entrance to the city (see page 36).

The Stewart Street Bridge in Dayton, Ohio, takes a bold new form through manipulation of the substructure and an added, angular fascia band. It, too, employs unique lighting to make a statement as it leads to the University of Dayton (see page 14).

Versatility and value come to mind in contrasting the 2.4-mile-long Miami Intermodal Center—Earlington Heights Connector in Miami, Fla., and the single-span, 82-ft-long South Maple Street Bridge in Enfield, Conn., which was assembled in just 17 days (see pages 26 and 32 respectively).

Concrete is uniquely cost effective in nearly every circumstance. Its adaptability renders it a natural solution for many situations. The SR 519 Intermodal Access Project in Seattle, Wash., features two bridges that together comprise 10 spans and takes advantage of cast-in-place, conventionally reinforced concrete; cast-in-place, post-tensioned concrete; and precast, prestressed concrete girders intentionally cambered more than 12 in. to increase clearance over a rail yard. Both bridges were initially planned to be built in another material but used concrete after consideration of the constraints and cost (see page 42).

Two more bridges in this issue were built from concrete after being bid in another material: the SW Line Flyover Bridge and Temporary Eastbound Bridge of the Nalley Valley Interchange in Tacoma, Wash. See page 22.

Our hats are off to the design and construction firms responsible for all of the projects in this issue, not to mention the many innovative projects featured in the past. As always, we are looking for innovative concrete applications of all kinds. If you have a project that you would like to have considered, whether large or small, please visit us at www.aspirebridge.org and select “Contact Us.” We look forward to hearing from you.

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Cover

Cross Street Bridge, Middlebury, Vermont

Photo: Vanasse Hangen Brustlin Inc.

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

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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 2011/2012

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

August 9-12, 2011
Ninth International Symposium on High Performance Concrete
Rotorua Energy Events Center
Rotorua, New Zealand

September 13-16, 2011
PCI Quality Control & Assurance Schools, Levels I, II & III
Four Points Sheraton – O'Hare
Schiller Park (Chicago), Ill.

September 25-28, 2011
Western Bridge Engineers' Seminar
The Arizona Grand Resort
Phoenix, Ariz.

October 2-6, 2011
7th World Congress on Joints, Bearings and Seismic Systems for Concrete Structures
Green Valley Ranch Resort
Las Vegas, Nev.

October 12-14, 2011
International Concrete Repair Institute (ICRI) Fall Convention
The Westin Cincinnati
Cincinnati, Ohio

October 16-20, 2011
ACI Fall Convention
Millennium Hotel & Duke Energy Center
Cincinnati, Ohio

October 22-25, 2011
PCI Annual Convention and Exhibition and National Bridge Conference
Salt Lake City Marriott Downtown and Salt Palace Convention Center
Salt Lake City, Utah

October 31–November 4, 2011
National Bridge Management, Inspection, and Preservation Conference
Millennium Hotel – Downtown
St. Louis, Mo.

November 7-8, 2011
ASBI 23rd Annual Convention
Washington Marriott Wardman Park
Washington, D.C.

November 14-19, 2011
PCI Quality Control & Assurance Schools, Levels I, II & III
Embassy Suites Nashville Airport Hotel
Nashville, Tenn.

January 22-26, 2012
91st Annual Meeting Transportation Research Board
Marriott Wardman Park, Omni
Shoreham, and Hilton Washington
Washington, D.C.

March 18-22, 2012
ACI Spring Convention
Hyatt Regency Dallas
Dallas, Tex.

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

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

September 29-October 2, 2012

PCI Annual Convention and Exhibition and National Bridge Conference
Gaylord Opryland Resort & Convention Center
Nashville, Tenn.

October 21-25, 2012
ACI Fall 2012 Convention
Sheraton Centre
Toronto, Ontario, Canada

Editor,

I would like to take the opportunity to commend you on creating the perfect 1-2 punch with the PCI Journal and ASPIRE magazine. The Journal has for years brought us the latest and greatest in prestressed concrete and has always had a strong transportation and bridge focus. It presents research in a style that conveys very complex matters in a way that is easy to understand. With the addition of ASPIRE, we now have a companion publication focusing on the successes and deployment of innovative solutions we once read about in the Journal. Every issue makes me proud of the accomplishments of the bridge engineering and construction business. Each article leaves with some “nuggets” I can file away for future use on a project. The willingness of authors to share their innovative solutions is a credit to our industry. The manner in which it is conveyed is a credit to the entire ASPIRE staff. Thank you for this periodic piece of good news in my mailbox.

Francesco M Russo, PE, PhD
Michael Baker Jr. Inc.
Philadelphia, Pa

Editor,

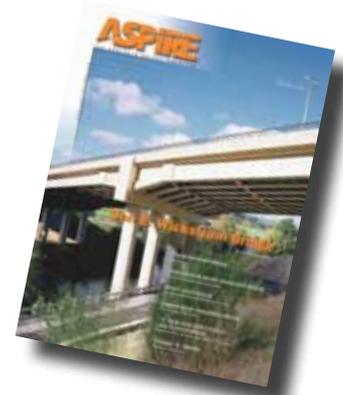
Is there any quick way I can go through your magazines for projects where integral abutments were utilized (without going to each edition separately)? I'll appreciate your response.

Andreas Paraschos
University of Maryland
College Park, Md.

[Editor's Note]

Yes, there is a way to search them all, Andreas. It will be easier if you download them all first. Put them in a folder on your hard drive.

Open any one of the issues in Adobe Reader or Adobe Acrobat Pro. Open the “Edit” menu and select “Search.” In the Search window, toggle “All PDF Documents in” and open the menu by selecting the carrot. Select “Browse for location...” From there, select the folder with all of the downloaded issues. Enter the word or phrase you need and the results of the search will be displayed in the results window. You can select each occurrence and it will take you to the page on which the item occurs.



Editor,

Dr. Dennis Mertz often provides great articles on interpreting the AASHTO LRFD Bridge Design Specifications. Are you aware of a 1-3 day course or some sort of correspondence course that provides a review of the new AASHTO code? Thanks for your help.

Reuben Zylstra
Foothills Bridge Co.
Boulder, Colo.

[Editor's Note]

The National Highway Institute has a 2-day course on LRFD for Highway Superstructures—Concrete. To check if a course is available go to www.nhi.fhwa.dot.gov/ and search for LRFD. Later this year, PCI will issue the next edition of its Bridge Design Manual, which has been updated through the 2011 Interim Revisions of the LRFD Specifications. Web-based courses are being planned surrounding the release of the updated manual.



Colorado River Bridge, Moab, Utah.
Photo: © Figg Bridge Engineers.

[Correction]

An oversight was brought to our attention following publication of the Spring 2011 issue. In the article, “In Harmony with Nature” about the Colorado River Bridge in Moab, Utah, we should have recognized the Contractor’s Construction Engineer, Summit Engineering Group in Littleton, Colo. Our apologies to Gregg Reese and his team!

Editor.

EDITOR'S NOTE

Additional copies of *ASPIRE* may be purchased for a nominal price by writing to the Editor through “Contact Us” at the *ASPIRE* website, www.aspirebridge.org. A free subscription can be arranged there using the “Subscribe” tab.

FOCUS

Vanasse Hangen Brustlin—

Building Bridges and Partnerships

by Craig A. Shutt

Focus on constructability creates close relationships throughout the team

Growing stakeholder needs, more challenging terrain, and new technologies require designers to work closer with everyone on the construction team. These trends play to the strengths of Vanasse Hangen Brustlin Inc. (VHB) in Watertown, Mass., where close collaboration is seen as a core strength.

“When we founded the business more than 30 years ago, the principals of VHB wanted to create a consulting practice that broke out of the typical model,” says Bob Brustlin, president and CEO. “No longer was it possible to succeed in our business with only technical skills. Process knowledge, an awareness of the context of the project, and political acumen were also needed.”

No Design Cocoons

A high level of collaboration has become critical, says Christopher D.

Baker, principal and national director of structural engineering. “Necessity is the mother of much invention these days,” he notes. “The biggest change in the industry is that we’re not in a little cocoon as designers today, where we go into a room and return with a design that we give to others to construct. Interaction and collaboration are real, and they create more efficient designs.”

The key to designing and building successful bridges today is “building trust with collaborators and the community,” he says. “It’s a different world today, and there are many more ‘stakeholders’ with specific needs. That requires everyone to work on the same page and to use everyone’s expertise to its fullest.”

Emphasizing collaboration encourages the firm to work in a design-build

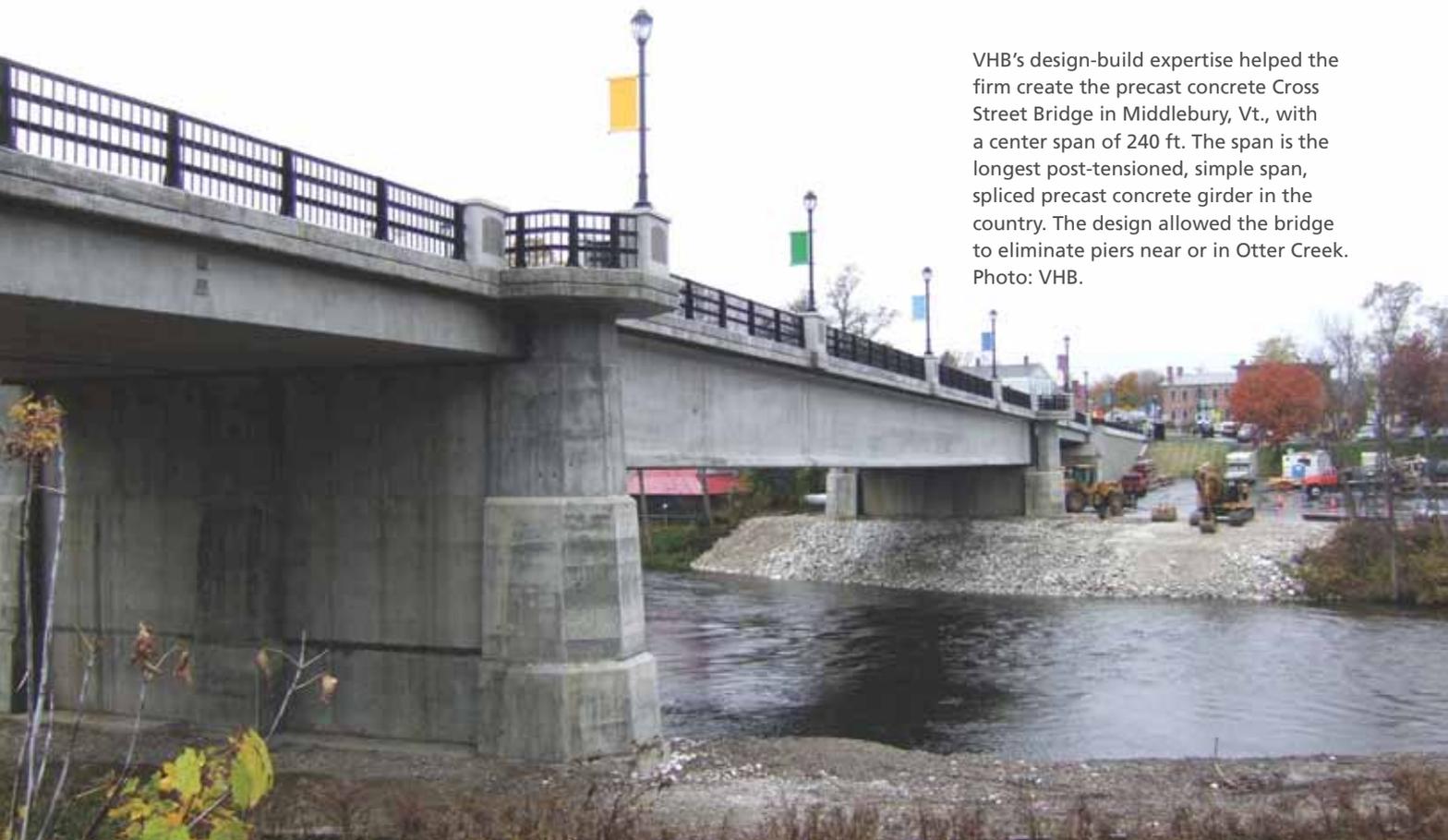
format. “Clients expect us to find the most cost-effective approach, whatever that requires,” Baker says. “So we really drill into costs and ask our partners for more efficient ideas.” The firm works with contractors as part of a design-build team and also produces documents for design-build teams on behalf of owners, including the Departments of Transportation for Rhode Island, Vermont, New Hampshire, and Massachusetts.

“The design-build process creates deep relationships for us, which are important today,” Baker says. “These integrated relationships help us understand all the needs on the project, even when we do design-bid-build projects.”

Cross Street Bridge

Those relationships came to the fore on the Cross Street Bridge in Middlebury,

VHB’s design-build expertise helped the firm create the precast concrete Cross Street Bridge in Middlebury, Vt., with a center span of 240 ft. The span is the longest post-tensioned, simple span, spliced precast concrete girder in the country. The design allowed the bridge to eliminate piers near or in Otter Creek. Photo: VHB.





The new Route 103 Bridge over York River in York, Maine, features two 55-ft-long end spans and five 80-ft-long interior spans that use four 36-in.-deep Northeast Extreme Tee (NEXT) beams. The bridge provides the first use of this new girder design, which has wider stems to support higher design loads. Photo: VHB. Inset photo: Dailey Precast.

Vt., the state's first major design-build transportation project. The project used only local funding—\$16 million worth—to create a three-span, 480-ft-long bridge consisting of precast concrete girders. The 240-ft main span, the longest precast, post-tensioned, simple span, spliced concrete girders in the country, eliminated the need for any piers near Otter Creek.

"This project was very much in keeping with the trend of clients and owners wanting to stretch the envelope in design and construction," says Mark A. Colgan, principal and director of transportation engineering. "No one takes 'no' for an answer. Instead, we ask if there is a way to make this work that's never been done." (For more, see the case history in *ASPIRE*™ Winter 2011 issue, page 32, and the city profile in the Spring 2011 issue, page 44).

The firm performs constructability reviews on its projects, Baker notes. It also has created three-dimensional reviews of crane placements to ensure every angle has been thought through for efficiency. "We don't do means-and-methods construction documentation to direct the contractors," he explains.

'It's a different world today, and there are many more 'stakeholders' with specific needs.'

"But we use our understanding of those techniques to help us improve constructability."

First NEXT Beam

In some cases, the firm produces dual documentation so owners can offer alternative designs to bidders. That resulted in an innovative approach for the Route 103 Bridge over the York River in York, Maine, completed in November 2010. The seven-span bridge features precast concrete Northeast Extreme Tee (NEXT) Beams, their first use in the United States.

The NEXT beam is similar to a standard double-tee beam except the stems are wider to accommodate bridge-design loads and to facilitate accelerated bridge construction, explains Steven Hodgdon, project manager. "The NEXT beam offers significant advantages over typical stringer-beam bridges," he says. "It may soon become a standard bridge system for medium-span bridges." (For more, see the Creative Concrete Construction article in *ASPIRE* Spring 2011 issue, page 46.)

A significant aspect of the design was that VHB provided an alternative design using standard precast concrete box beams. "Five of six bidders bid the NEXT-beam design," Hodgdon says. "It shows that we could produce bids competitive with standard designs in the first try with a brand new cross section. That provides a real stride forward in creating bridges with minimal risk, and it results from everyone trusting the participants."

Missisquoi Bay Bridge

Another project created with the dual-design approach was the Missisquoi Bay Bridge in Alburg, Vt., which replaced a badly deteriorated 1938 steel drawbridge. The 3600-ft, 23-span design, which featured a precast concrete trapezoidal segmental box beam design, is the longest bridge in Vermont. A steel design also was provided, with two complete sets of drawings.

VHB helped streamline the design process and overcome environmental issues, reducing the permitting

'As we all do these projects more, it will become the norm to build a bridge in a few months in the right applications.'

process to 5 years while incorporating design ideas that saved costs and future maintenance. The design team performed extensive permitting, including National Environmental Policy Act (NEPA) documentation and nine additional regulatory agencies.

"We had to overcome a number of challenges, including poor soil conditions, tight permit windows, and contentious water-quality issues," says Baker. "And we had to design an economical structure for an environmentally sensitive area and in a timely manner. This is the type of project where design-build can turn the corner on making dual-design effective."

VHB's efforts to ensure the most cost-efficient design extend to collaborators in other areas of the country. This is aided by the company's 20 offices along the East Coast. "Our transportation, land-development, and environmental professionals collaborate across offices and regions," says Brustlin. "Integrated Services' is more than just a slogan—it is how we tackle every challenge."

Little Bay Bridge

That network aided the alternatives provided for Little Bay Bridge in Dover, N.H. To ensure efficiency, the New Hampshire Department of

Transportation (NHDOT) allowed dual designs in steel and precast concrete. For the most economical option, VHB created a precast, post-tensioned bulb-tee girder alternative (which was selected) but allowed substitutions of Florida or Virginia bulb tees.

"Through our offices in New England, Virginia, and Florida, we talked with precasters to ensure they could deliver girders if needed," Baker explains. VHB even sent preliminary drawings to several fabricators to ensure the design could be produced. "We presented the documents knowing the alternatives could be fabricated, delivered, and constructed."

The goal with such efforts is to speed up construction. "The biggest trend today certainly is 'Get It Done,'" he says. "Everything we do emanates from that goal. Accelerated bridge construction (ABC) techniques are moving forward in many states, and they are driving a lot of discussions. Some states have a toe in the water, but others have dived in." Colgan agrees. "Everyone is asking how we can do things faster."

Lower Plains Bridge

Accelerated construction was used for the Lower Plains Road Bridge in Middlebury, Vt., which was destroyed by a powerful storm in August 2008. VHB not only had to design a replacement structure rapidly but consider the needs of four property owners, accommodate a river with flows of more than 16 ft³/second, coordinate aerial utility relocation, and include a waterline replacement project. The structure also

had to be built during the Vermont winter.

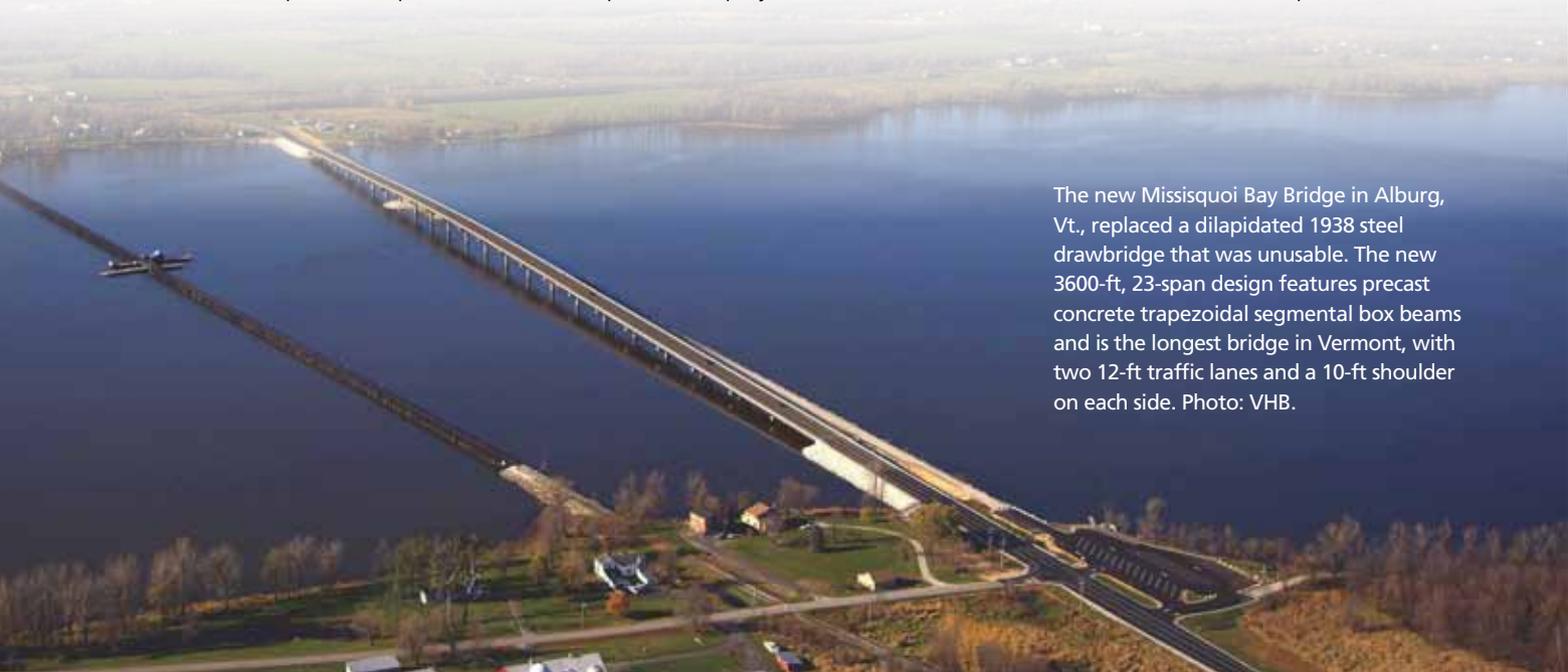
The designers created a single-span, precast concrete box-beam design with a shallow superstructure to accommodate the new water line. Precast and cast-in-place concrete options were provided for the abutments to accommodate ABC techniques. The design was bid by five contractors on January 12, 2009, and the new precast concrete bridge opened on May 5, 2009, on time and under the bid price of \$936,000.

"The combination of a new generation of managers at the owner level and an interest in getting things built quicker has opened the floodgates to more creativity and innovative design, fabrication, and construction," says Colgan. "Precast concrete allows many options for overcoming cold-weather substructure construction and keeps crews busy in winter. As we all do these projects more, it will become the norm to build a bridge in a few months in the right applications."

Lime Kiln Bridge

VHB's focus on innovation also extends to replicating the look of existing bridges, a growing challenge in New England, where many bridges have historic backgrounds. An example is the Lime Kiln Bridge in Colchester, Vt., the only open-spandrel concrete arch bridge in Vermont and one of the first in the country.

The 300-ft-long bridge, built in 1913, was rebuilt by combining precast concrete box beams and voided-deck beams with cast-in-place concrete



The new Missisquoi Bay Bridge in Alburg, Vt., replaced a dilapidated 1938 steel drawbridge that was unusable. The new 3600-ft, 23-span design features precast concrete trapezoidal segmental box beams and is the longest bridge in Vermont, with two 12-ft traffic lanes and a 10-ft shoulder on each side. Photo: VHB.



Creative techniques featuring a combination of precast concrete box beams and slabs, plus cast-in-place concrete arches allowed VHB to replicate the look of the original 1913 Lime Kiln Bridge at the Winooski River Gorge in Vermont. The combination replicated the original decorative geometrical features and ornamental railings, while adding safety and durability. Photo: VHB.

elements. "This was a very innovative design, with nice clean lines of solid slabs and box beams," says Colgan. "We continue to receive compliments for the success it was and the beautiful structure it is." (For more, see the Fall 2008 issue of *ASPIRE*, page 44).

The Vermont Agency of Transportation (VTrans) considered rehabilitating the structure, but that would have provided only 20 more years of service, Baker notes. And durability and life-cycle costs are driving factors today. "There are few dollars for construction and even fewer for long-term maintenance," he says.

VHB runs life-cycle cost analyses on each project to ensure owners know their true costs. "When you design a bridge with a 75-year life span and you can show that a concrete option will have little maintenance while a steel option will need to be painted in years 20, 40, and 60, it's an easy choice. Owners understand the long-term consequences."

New Techniques Growing

VHB's designers are encouraged by new techniques coming along. "High-performance concrete is becoming more standard, with 6000 to 8000 psi design compressive strengths more commonplace," says Baker. "We're moving closer to 10,000 psi,

although we haven't used it yet." High-performance concrete also is being used for its durability and low permeability rather than just strength, he notes, and new polymers and admixtures are aiding that capability.

"These ideas fit VHB well, because we always try to innovate," he says. "Innovation in our industry used to be glamorous, mostly for isolated applications. But now, owners really want to get things done, and that demands new approaches to design cheaper, quicker, faster, and with less impact. Innovation is no longer just cute, and prestressed and precast concrete are a big part of that."

The biggest challenge, says Brustlin, comes in rolling with the punches and staying on top of key markets as they grow. "VHB is in a good situation, because we balance private and public bridge work well, and public work has been strong due to the stimulus funding and enlightened thinking in some states, which has made infrastructure projects robust." As that has begun to slow, the firm is focusing on transportation technology and the transit-and-rail market, which is especially strong in New England.

Brustlin also sees the bridge market as a bright spot in the coming years.

VHB's Historic Roots

Although VHB was founded in January 1979, its structural-engineering practice has roots going back 50 years. In 1987, the firm purchased the well-established Congden, Gurney, Towle Inc., which had been designing bridges since the 1950s, including some of the first prestressed concrete bridges in Massachusetts.

VHB was formed as Vanasse/Hangen Associates when Rich Hangen and Bob Vanasse, along with John Kennedy, Bill Roache and Bob Brustlin, opened a traffic-planning and engineering firm in Boston. Brustlin became a partner in the early 1980s, creating VHB. Vanasse left in 1990 to start his own land-development company, while Hangen retired and now serves on VHB's board.

Today, the firm employs 900 people in 20 offices working on projects involving transportation, land-development, and environmental aspects of complex infrastructure and development initiatives.

The company focuses on four key territories, says Bob Brustlin, president and CEO: New England, New York, Washington, D.C., and Florida. In each area, recent acquisitions have bolstered the firm's standing. "Our goal is to be the prominent provider in our key markets rather than expand out beyond our capabilities."

"We have close relationships with states where there is a strong appetite to fund reconstruction and create replacement bridges. We feel good about 2011 and even better about what is coming, especially as the private sector revives."

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



by Linda Figg,
Figg Engineering Group

Concrete Segmental Bridges are the Sustainability Solution

"Is there a better way?" a customer asked. Taking that question seriously, 13 ideas for a sustainable concrete bridge were proposed, none of them ever used before in the customer's state. They agreed to all 13 ideas, even though they had never built a precast concrete segmental bridge. That project—the Victory Bridge in New Jersey—featured one of the first 440-ft-long fully match-cast precast spans in the United States, with twin bridges, each about 4000 ft long with precast piers. The first bridge was built in 15 months, the second in only nine. On budget and ahead of schedule, the Victory Bridge went on to win many awards including prominent recognition from the Federal Highway Administration's Highways for LIFE program. And it all came about because people were eager to consider a better way.

Sustainable bridge solutions are becoming more urgent in the face of challenges posed by climate change, diminishing energy resources, and aging and congested urban transportation networks. Taking bridge design to new levels of environmental responsibility requires exploring the many efficiencies inherent in concrete segmental bridges. Segmental design encourages ecologically aware land use and preservation, supports quality fabrication and local assembly, and enhances a community's quality of life. Capturing the power of imagination, function, and technology, segmental bridges yield measurable social, economic, and environmental benefits—a "triple bottom line" for sustainable success.

As a nation, we are faced with burgeoning population growth, estimated to increase in the United States by 94 million in the next 30 years. One way to help solve our growth challenges is to create greater urban density, and provide those who live in cities with a richer social, cultural, and transportation infrastructure. While mobility is key to economic health, well-planned transportation networks also reduce energy consumption across the board. Just as a high-rise building maximizes precious square footage, the Selmon Expressway in Tampa, Fla., which is elevated for 5 miles along the median of an existing roadway, provides six lanes of capacity in only 6 ft of space at ground level. Its lanes are reversible, easing peak-hour congestion: a trip that once took 40 minutes now only takes 10. By keeping traffic moving, stop-and-go vehicular emissions are reduced and air quality is improved. The concrete bridge is naturally quieter as well.

Reaching higher levels of sustainability demands bold use of innovative technologies. In this regard, concrete offers tremendous versatility, allowing modular fabrication, top down construction, and multiple concurrent operations. The 9 miles of precast concrete segmental bridges constructed for the AirTrain JFK, a mass transit link that has revolutionized commuting for millions of New Yorkers, were built in 20 months—adjacent to lanes carrying 160,000 vehicles per day—and utilized the same equipment design to build all spans. Using box girders in St. Paul's Wabasha Freedom Bridge in Minnesota enabled a context-sensitive design that

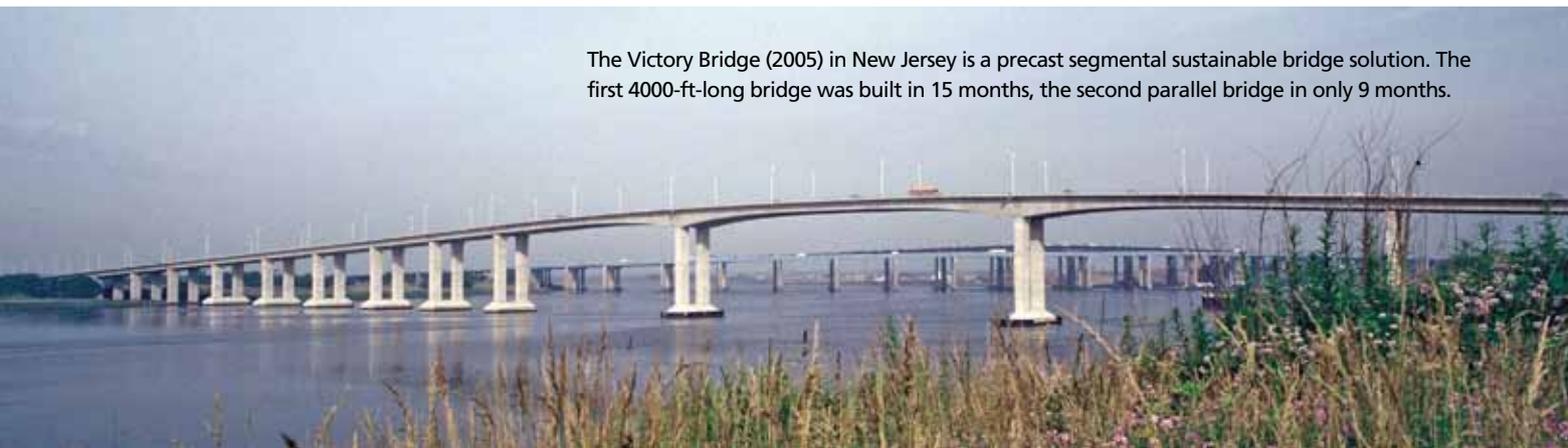


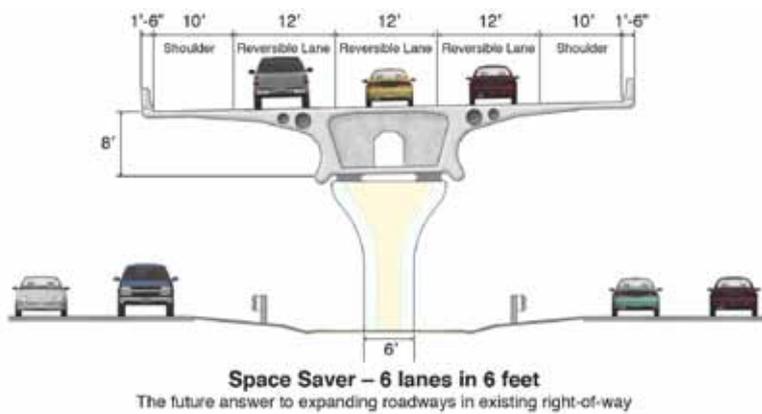
Capturing the power of imagination, function, and technology, segmental bridges yield measurable social, economic, and environmental benefits—a "triple bottom line" for sustainable success.

also carried and protected the utilities inside the box girder. Sophisticated new concrete mixes, such as ones used on the New I-35W Bridge in Minneapolis, Minn., significantly reduce carbon emissions and nanotechnologies scrub pollutants from the air. Concrete's carbon footprint is increasingly smaller, while high-performance mixes impede corrosion and increase long-term service life.

Concrete provides significant cost and time savings. Cost reduction through repetition was achieved at the Susquehanna River Bridge in Harrisburg, Pa., with spans erected every 3 days. The I-35W Bridge saw the placement of 120 concrete segments in 47 days for a 504-ft-long main span, ultimately

The Victory Bridge (2005) in New Jersey is a precast segmental sustainable bridge solution. The first 4000-ft-long bridge was built in 15 months, the second parallel bridge in only 9 months.





The 5-mile-long Selmon Expressway was built in span-by-span construction. Up to 2400 ft of bridge was completed in a month.

restoring a vital transportation link over the Mississippi River in just 11 months. Accelerated construction is matched by cost savings: the 4th Street Bridge in Pueblo, Colo., and the I-93 ramps and viaducts in Boston, Mass., are just two instances where tens of millions were saved by eschewing steel.

Green means using local materials wisely and with respect. Concrete lends itself to local fabrication and assembly. By using local labor and resources, less energy is needed to move materials and workers. Incorporating local aggregate and sand also ensures that the concrete will blend with its natural context. Segments for the Selmon Expressway, I-35W Bridge, Susquehanna River Bridge, and Four Bears Bridge, N.Dak., to name a handful of structures, were cast and stored at nearby sites. Concrete's inherently lower maintenance costs also offer longer life-cycle cost benefits. Boosting a regional economy also increases the quality of life, inspiring people to want to invest in a bridge that will be a part of their community for a long time.

Segmental bridges allow custom, context-sensitive solutions that respond to challenging site conditions and protect vulnerable ecosystems and wildlife habitats. The Allegheny River Bridge in Pittsburgh, Pa., for example, required building over parkland, a local road, two railroads, and two waterways. The shapes, lines, and shadows of the I-35W Bridge create an uninterrupted flow between the bridge and the Mississippi River—a natural treasure, a historic landmark, and a commercial asset—while complementing the contemporary

A bridge in harmony with the environment, the U.S. 191 Colorado River Bridge in Moab, Utah, respects the extraordinary site by blending into the canyon landscape.

architecture in downtown Minneapolis. The Four Bears Bridge, vulnerable to Lake Sakakawea's massive ice floes, resists ice-impact loads through an innovative circular pile layout and a precast concrete cofferdam that serves as both a form for the footing and a template for driving piles. North Carolina's Blue Ridge Parkway Viaduct was built from the top down, with segments placed in progressive unidirectional cantilever to protect the wildlife and environment of Grandfather Mountain. These features, along with black iron oxide added to the concrete mix to blend with Grandfather Mountain's rugged terrain, resulted in a viaduct that "belongs to, and is a part of, the mountain," as President Ronald Reagan memorably observed.

A bridge that is in harmony with the environment is also one that highlights and complements the surrounding landscape. Concrete segments enable minimal profiles and long spans that maintain vistas of extraordinary natural beauty, framing what Mother Nature has already designed. Concrete was the ideal solution for the U.S. 191 Colorado



River Bridge, located in the pristine setting of Moab, Utah. Utilizing long spans and staining the concrete to blend seamlessly with the region's famed red rock landscape yielded a bridge that appears to be born from the earth itself. Inspiring an emotional connection to the land helps people realize that they have something valuable to nurture and defend. Ultimately, people will protect what they love.

A hallmark of sustainability is the capacity to endure. Today, concrete bridges can be designed to last well beyond 150 years. A bridge that stands the test of time, measured in terms of its physical structure and its resonance with the community, spurs economic and social development. Existing businesses are able to grow and expand. New industries and residential communities spring up around the new bridge. Parks and bicycle paths are built. A bridge enhances life in so many different directions.



Nine miles of precast concrete segmental bridges constructed for the AirTrain JFK were built in 20 months—adjacent to lanes carrying 160,000 vehicles per day.

Designing in ways that will improve mobility, increase the local economy, preserve the environment, and enhance the quality of people's lives are goals worth striving for. Long life and low maintenance, combined with enduring aesthetics, make concrete segmental bridges the sustainability solution. There really are no boundaries.

CREATIVE CONCRETE CONSTRUCTION

Thin Brick on Cast-in-Place Concrete

by Buck Scott, Scott System Inc.



The 4-ft-square decorative columns along the bridge's railings provide an aesthetic accent that was created by embedding thin brick into a plastic template placed on the interior side of cast-in-place forms. Photo: Karlson Forming Supply Co.

The challenges of incorporating brick on concrete bridges can be overcome by installing thin bricks embedded into the concrete. This is easily done with templates that fit into the concrete forms.

This system was used on the 188-ft-long, two-span Margaret Street Bridge over Highway 36 in North St. Paul, Minn. and on the 247-ft-long Valley Creek Road Bridge over I-494 in Woodbury,

Minn. Officials at the Minnesota Department of Transportation wanted to maintain both neighborhood's aesthetics and make the bridges appear more like a city street than a standard concrete bridge. Lunda Construction in Black River Falls, Wis., built both bridges.

The design team harmonized the appearance with the environment by using brick accents on fascia, piers, and

decorative columns. They also wanted to avoid the disruptions to traffic caused by laying up brick and the need to maintain it through the years with tuck pointing and replacements caused by pieces dislodging due to traffic vibrations.

Designers selected a reusable vertical embedded-brick system that spaces thin brick for cast-in-place concrete applications. The system consists of a plastic template that holds the thin bricks, using snap-together interlocking tabs to create the desired brick pattern in the appropriate size and shape. Rubber gaskets firmly hold the brick in place.

Designers used Main Street Red brick from Metro Brick in Canton, Ohio. Once the concrete hardened, the forms and plastic brick template were pulled away, and the finished brick face was power-washed with 180 °F water to remove any mortar leakage or residue.

The system has been used on a variety of vertical cast-in-place concrete applications, including retaining walls and highway overpasses.

Buck Scott is president of Scott System Inc. in Denver, Colo.

Providing thin brick on all four sides of a column, even up to the edge, can be accomplished with the plastic templates, as seen on the right. When the forms and template are pulled away, the thin brick is left embedded in the concrete.



Photo: Minnesota Department of Transportation.



Photo: Karlson Forming Supply Co.

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Replacement of the

by Mike Avellano, Woolpert Inc.

Major Infrastructure Improvement in City of Dayton

The Stewart St. Bridge over the Great Miami River in the city of Dayton, Ohio, is adjacent to the University of Dayton. The original structure was constructed in 1911 by Gephart and Kline. It was designed by the Concrete-Steel Engineering Company of New York, N.Y., and the concrete-encased steel joist supported formwork system is often referred to as a Melan Arch System. It was a seven-span, 660-ft-long, four-lane closed spandrel, earth-filled arch bridge with a roadway width of 42 ft and a 6.5-ft-wide sidewalk on both sides. It had become functionally and structurally deficient. Since Woolpert opened its business in Dayton the same year the original bridge was constructed, it seemed appropriate that Woolpert be involved in this bridge replacement 100 years later.

The Replacement Bridge

The new bridge is a 72-ft-wide, six-lane structure with two 10.5-ft-wide sidewalks (including rail system) for a

total deck width of 93 ft. The bridge is set on a 6.7 degree skew with a tangent alignment. It is flanked by 30-ft-long approach slabs. There are constant grades over the first two and a half spans at each end and a short vertical crest curve over the middle 120 ft.

The replacement bridge includes five 110-ft-long spans, measured from the centerline of piers, and two 55-ft-long spans at each end for a total bridge length of 660 ft. The longest superstructure elements consist of 42-in.-deep by 48-in.-wide adjacent precast concrete box beams, which span 84.5 ft between centers of bearings, with a 6-in.-thick cast-in-place concrete composite deck. End span box beams are 41.3 ft long. Architectural precast concrete fascia panels are supported from the exterior box beams by steel tube extensions from the backs of the panels to plates embedded in the top of the beams or in the deck. The panels are 6 ft 8 in. tall and 2 ft 7 in. wide. The locations of embedded plates were closely coordinated with barrier rail post locations and light pole supports, eliminating conflicts during construction.

The choice of concrete as a design material resulted from the study to

The schedule was accelerated to just 18 months.

evaluate the final structure options, and is anticipated to match the durability of the 100-year-old concrete structure that was replaced. Over 1.5 million pounds of epoxy-coated reinforcement were used. To minimize future maintenance costs, semi-integral abutments were utilized and limited superstructure jointing was also incorporated.

Community Involvement

The project began with four technical group meetings where interested parties were invited to discuss the aesthetics, maintenance of traffic, and future traffic flow options. Several alternatives were presented, and in the end, the enhanced bridge replacement on the existing alignment option was chosen. Each option presented included preliminary drawings, renderings, and detailed descriptions of the upgrades, along with anticipated costs for each.

The project's architect gave significant consideration to the complex setting and integral nature of the bridge's

profile

STEWART STREET BRIDGE / DAYTON, OHIO

BRIDGE DESIGN ENGINEER: Woolpert Inc., Dayton, Ohio

PUBLIC INVOLVEMENT CONSULTANT AND CONCEPTUAL DESIGNER: T.Y. Lin International, San Francisco, Calif.

PRIME CONTRACTOR: Ahern and Associates Inc., Springfield, Ohio

BOX BEAM PRECASTER: Prestress Services Industries LLC, Decatur, Ind., a PCI-certified producer

SPANDREL PANEL PRECASTER: High Concrete Group LLC, Springboro, Ohio, a PCI-certified producer

SOLID TIE BEAM PRECASTER: Ahern and Associates Inc., Springfield, Ohio

Stewart Street Bridge

The Stewart Street Bridge over the Great Miami River in Dayton, Ohio, shown experiencing high water in the spring and at night with one of its many color displays. All photos: Woolpert Inc.

location. These included a 1950s-era residential neighborhood, the University of Dayton's sports arena and football stadium, modern office buildings, hotels, the region's largest hospital, a county fairground and the gateway to the University of Dayton.

Maintenance of traffic was an important consideration given the diverse adjacent uses and volume of local traffic. Detours were set to clearly move traffic for significant events (such as early round NCAA basketball tournament games) as well as day-to-day use. Establishing detours eliminated the cost for staged

construction and allowed the schedule to be accelerated from the 24 months originally planned to just 18 months.

A public involvement meeting was conducted where many possible aesthetic features for the structure were presented. Rail, lighting (above and below deck), and overlook options were discussed. Four structure alternatives were presented—a precast concrete earth-fill arch and three variations on a Y-type pier design. The three Y-type variations investigated included a true Y shape, a wider delta shape, and a hybrid Y shape that offered a compromise

between the Y and delta dimensions. Given the number of recent bridge replacements in the region that echoed the early twentieth century arched structure theme, the hybrid Y was enthusiastically chosen as the preferred design. This choice would enable the bridge team to develop "a design that is a legacy of the twenty-first century," according to one stakeholder.

Piers and Foundation

The maximum height of hybrid Y piers was 32 ft from pile cap to beam seat. Their details and construction presented one of the project's biggest challenges, given the skew and change in profile elevation, which was slightly different at each end. The top legs of the Ys at all piers were designed to be the same length so that the formwork could be reused. Elevations were adjusted by varying the heights of the pier stem below the legs and varying the beam seat elevations. The bridge team held several preconstruction meetings with the bridge contractor in an effort to make sure the forms would work

The upper surface of the fascia panel catches the light, creating a horizontal band, interrupted briefly at the piers. The lighting poles maintain the same angle.



SEVEN-SPAN BRIDGE USING ADJACENT PRECAST CONCRETE BOX BEAMS, SOLID PRECAST CONCRETE RECTANGULAR PIER TIE BEAMS, AND PRECAST CONCRETE SPANDREL PANELS ON CAST-IN-PLACE Y-SHAPED PIERS / CITY OF DAYTON, OHIO, OWNER

CAST-IN-PLACE CONCRETE SUPPLIER: Ernst Concrete, West Carrollton, Ohio

REINFORCEMENT FABRICATOR: Gerdau Ameristeel, Hamilton, Ohio

BRIDGE DESCRIPTION: A 660-ft-long bridge by 93 ft wide with seven spans (55 ft, 5 at 110 ft, and 55 ft) using 42-in.-deep precast concrete adjacent box beams, 48-in.-deep solid precast concrete tie beams, and precast concrete spandrel fascia panels supported on Y-shaped piers and with a cast-in-place, 6-in.-thick composite deck

BRIDGE CONSTRUCTION COST: \$14.8 million

Aesthetics

Several elements provide enhanced aesthetic appeal:

- Precast concrete spandrel panels give the bridge visual continuity along its length
- Horizontal slatted steel railings allow the river to be a part of the bridge crossing experience
- LED lighting illuminates the superstructure
- Custom-designed, above-deck light standards canted over the deck—a design inspired by the angular geometry of the piers
- Wide sidewalks and river overlooks at all four corners inspire a pedestrian-friendly passage, where students and hotel guests can congregate at the overlooks on their way to basketball games at the university arena
- For additional information about the lighting design, see the Creative Concrete Construction article on page 40.

A bridge with no skew would have been much easier to design and construct; however, keeping the existing skew helped maintain the bridge hydraulics with the requirement of no increase in backwater for the Miami Conservancy District prescribed maximum flood levels—a measure based on the historic flood of 1913. This was also the more environmentally friendly option, minimizing impacts on existing mussel beds both up and downstream of the bridge. The alignment also minimized additional right-of-way purchases.

The project integrates the 30-mile Great Miami River Bikeway, which passes beneath the bridge.

dimensionally and structurally through the construction sequence. As a result, there were no difficulties with the pier construction. The planning and diligence of an experienced bridge contractor paid off.

The piers are developed as strut-and-tie elements both transversely and longitudinally. A 3-ft-deep, cast-in-place transfer box girder is at the top of each leg, providing a tie for each leg transverse to the structure. Longitudinally, the legs of the Y were designed to be tied together with 48-in.-deep, solid, cast-in-place concrete beams, the upper 6 in. of which were to be cast with the 6-in.-thick



Legs of the Y-shaped piers are tied transversely with cast-in-place concrete box girders and longitudinally with precast concrete solid beams.



Solid, 42-in.-deep, precast concrete beams tie the legs of the Y-shaped piers and butt against the ends of 48-in.-deep, precast, prestressed concrete box beams spanning from pier to pier.



The dramatic effects of the precast concrete fascia panels can be seen during their installation.

deck. At the contractor's suggestion, these beams were changed to precast concrete of the same design to accelerate construction. They were attached with 1-in.-diameter dowels grouted into the transfer girder. They act as composite tee-beams after the deck is cast and cured. Given the aesthetic goals, budget constraints, and a shortened construction window that necessitated higher costs,

the bridge team made every attempt to keep the design simple and attractive to local bridge contractors. As a result, the cast-in-place transverse box beam and precast concrete beam elements were used in lieu of a post-tensioning solution.

Most of the substructure elements were supported by 16-in.-diameter, cast-in-place pipe piles below a 3-ft-thick by

12.5-ft-wide by 80-ft-long cast-in-place concrete pile cap. Pier 1 required six, 6-ft-diameter drilled shafts, 52 ft deep. This pier is between two existing utilities: a 36-in.-diameter water main and a 7-ft 9-in. by 5-ft 4-in. sanitary box sewer. By using shafts, encroachment was minimized and vibration from pile driving was eliminated.

Construction began June 1, 2008, and was completed in only 18 months. On November 30, 2009, dedication was held to celebrate the re-opening. Public appreciation of the bridge continues to grow ever since.



Mike Avellano is vice president at Woolpert Inc., in Dayton, Ohio.

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

Curvilinear rail and cantilever slab frame an overlook and view of the Great Miami River.



AESTHETICS COMMENTARY

by Frederick Gottemoeller

Founded at the confluence of four rivers, Dayton, Ohio, needs many bridges. The bridges, taken as a group, provide much of the civic character of Dayton. In the past, the typical Dayton bridge consisted of multiple earth-filled concrete arches. As these bridges are replaced, the challenge is to create new civic assets of equal quality within the resources of local budgets.

Dayton's rivers are mostly wide but not deep, allowing fairly short spans, well within the range of standard precast concrete girders. These have such overwhelming cost advantages that they are the default choice for new superstructures. Adding visual character to precast girder bridges without breaking the budget requires creative thinking about the other parts of the bridge: the piers, parapets, and railings. Most recent replacement bridges in Dayton include details aimed at making a precast girder bridge look a bit like an arch.

At Stewart Street, the city decided instead on a new approach. The bridge is adjacent to the University of Dayton's new research campus, so the city decided to create a bridge with a contemporary appearance but with the rhythm and scale of the traditional arch bridges. A Y-shaped pier provides a repeated, standardized, easy-to-build element that economically meets this goal. The triangular openings in the cross wall lighten the visual weight of the piers and make them more transparent. A precast concrete fascia covers and unites the edge girder and the barrier and recalls the monumentality of the traditional concrete arches. Its upper facet catches the light, creating a striking horizontal band sweeping from bank to bank, interrupted just briefly at the piers. Even the lighting poles pick up the angular theme.

With the new Stewart Street Bridge, Dayton has found a way to bring its tradition of monumental civic bridges into the twenty-first century.

Ten Mile Road Interchange

SPUI Bridge Ideal Fit over I-84 in Idaho

by Ted Bush,
HDR Engineering Inc.

The I-84–Ten Mile Road Interchange Bridge in Meridian, Idaho, features an hourglass-shaped, cast-in-place concrete box girder with 10 curved webs. Photo: Idaho Airships.

The I-84–Ten Mile Road Interchange project in Meridian, Idaho, will add much needed interstate access for a growing community. The interchange improves connectivity along I-84 and replaces an existing overpass. Five interchange types were considered. The standard single-point urban interchange (SPUI) was selected based on several factors, including construction cost, right-of-way impacts, anticipated year 2030 level of service, and environmental issues. The project also features widening of both Ten Mile Road and I-84, mechanically stabilized earth (MSE) walls, and a culvert.

SPUIs are becoming popular in urban areas throughout the United States due to their compact layout and efficient traffic management. The typical hourglass shape of SPUI structures, however, results in a geometrically complex bridge with complicated structural behavior. This SPUI is an

innovative solution for this region; the first designed in the state of Idaho and only the second SPUI constructed there.

Evaluation of Alternatives

Given the unique shape of SPUI bridges, framing configurations need to be carefully considered to minimize unused deck area and account for multi-directional load paths. Several alternatives were investigated. For each of the superstructure types evaluated, the design team developed conceptual designs and cost estimates. An important benefit of the project was the opportunity to replace the existing five-span structure with a single-span bridge that would accommodate widening of I-84 under the bridge. A single-span bridge would improve motorist safety by increasing visibility and eliminating a potential collision hazard. It also would reduce material requirements, construction duration, and impacts to median construction

operations. The additional structure depth required by the single-span bridge was accommodated by modifying the vertical profile of both the I-84 and Ten Mile Road approaches in the early stages of design.

Based on conceptual evaluations, the design team recommended a single-span, cast-in-place, post-tensioned concrete box-girder bridge with a splayed framing plan. In addition to lower construction cost, the recommended structure type reduced the tunnel effect caused by alternatives featuring larger bridge widths. It also provided future flexibility for median-related construction activities by eliminating the center pier. The stiffness and redistribution characteristics of the bridge offered excellent structural performance. Since there was no unused deck area, the bridge did not require additional safety railings and resulted in a more aesthetically pleasing

profile

TEN MILE ROAD INTERCHANGE OVER I-84 / MERIDIAN, IDAHO

BRIDGE DESIGN ENGINEER: HDR Engineering Inc., Boise, Idaho

FALSEWORK DESIGN ENGINEER: VAK Construction Engineering Services, Beaverton, Ore.

ROADWAY DESIGN ENGINEER: H.W. Lochner, Meridian, Idaho

PRIME CONTRACTOR: Idaho Sand and Gravel Company, Nampa, Idaho

BRIDGE CONTRACTOR: Concrete Placing Company, Boise, Idaho

POST-TENSIONING CONTRACTOR: DYWIDAG Systems International-USA Inc., Long Beach, Calif.

CONCRETE SUPPLIER: Idaho Concrete Company, Nampa, Idaho

The post-tensioning varied within the cross section due to curvature and variable web spacing.

appearance. Another benefit of the superstructure type was the provision for an enclosed, protected area for utilities.

Design Features

The 189-ft-long structure forms an hourglass shape with a variable width ranging from 158 to 206 ft. A minimum edge of deck radius of 200 ft offered improved constructability and controlled out-of-plane bending effects imposed on the curved girders. The bridge can accommodate future expansion of an additional lane in each direction along Ten Mile Road and an additional I-84 off-ramp left turn lane. A constant 1.4% vertical grade and 1% normal crown slope were specified for the interchange due to roadway stopping sight distance and drainage requirements.

The 8-ft 6-in.-deep cross section includes 10 straight girder webs in the center with five curved girder webs on each side. The straight girder webs are 12 in. thick and spaced at 9 ft 9 in. The curved girder webs are 15 in. thick with a spacing that varies from 5 ft 6 in. to 13 ft 2 in. The deck is 8½ in. thick and the bottom slab 6 in. thick. The top and bottom flanges and girder webs are thickened near the abutments to accommodate the general zone anchorage design and the larger web spacing required near the southwest and northeast corners of the bridge. Long-term durability and corrosion resistance to satisfy the minimum 75-year service life were addressed by the use of a

1-in.-thick expendable (nonstructural) top deck slab wearing surface, epoxy-coated reinforcement for the top deck slab and girder web reinforcement, and multi-levels of protection for the post-tensioning system.

The post-tensioning varied within the cross section due to curvature and variable web spacing. The curved girder webs required three tendons and the straight girder webs had four. All tendons used 0.6-in.-diameter low-relaxation strands. A varying post-tensioning force was used for the exterior curved portions of the structure to account for the friction loss difference from the varying radius and length of tendons. A jacking force of 3603 kips was specified for the straight webs while 3032 kips, 3076 kips, 3120 kips, 3164 kips, and 3208 kips were specified for the curved webs. The resulting total structure jacking force of 67,230 kips was applied through a total of 1530 strands. Commercial, Post-Tensioning Institute Type C prepackaged, thixotropic grout was used in the ducts to encase the tendons and injected from the low

point at Abutment 2 toward the vents at midspan and Abutment 1.

The superstructure is supported on 25-ft-tall, free-standing, cast-in-place

The center portion of the bridge contains 10 straight girder webs. Five curved girder webs were used on each side of the center portion to best approximate the required edge of deck roadway geometry. The straight girder webs were spaced equally at 9 ft 9 in. and the curved girder web spacing varied from 5 ft 6 in. to 13 ft 2 in. Photo: Idaho Airships.



Falsework construction had minimal impacts to I-84 motorists. Photo: Idaho Airships.



CAST-IN-PLACE, POST-TENSIONED CONCRETE BOX GIRDER, SINGLE-POINT URBAN INTERCHANGE / IDAHO DEPARTMENT OF TRANSPORTATION, OWNER

REINFORCEMENT SUPPLIER: Harris Rebar ABCO, Boise, Idaho

MSE WALL SUPPLIER: Hilfiker Retaining Walls, Eureka, Calif.

PROGRAM MANAGER: Connecting Idaho Partners, Boise, Idaho

BRIDGE DESCRIPTION: Single-span, hourglass-shaped, 189-ft-long by 158- to 206-ft-wide, cast-in-place, post-tensioned concrete box girder

STRUCTURAL COMPONENTS: Cast-in-place, post-tensioned concrete box girder with 10 curved, constant depth girder webs (205-ft-minimum radius, 935-ft-maximum radius) and 10 straight constant depth girder webs, supported on 25-ft-tall, free standing, cast-in-place concrete abutments located in front of 550-ft-long continuous mechanically stabilized earth (MSE) walls

BRIDGE CONSTRUCTION COST: \$8 million (approximately \$240/ft²)

A single-span bridge improves motorist safety.

concrete seat-type abutments. Given the hourglass shape of the superstructure, the abutment locations were designed to minimize the abutment lengths and provide the minimum horizontal clearance required to meet the anticipated ultimate build-out of I-84. The abutments are founded on three

Single-point urban interchange and two additional bridges during construction. Photo: Idaho Airships.



Additional Bridges

Two more bridges were designed and constructed on Ten Mile Road. Both are single spans, 100 ft long and are supported on approximately 20 ft tall integral abutments. One varies in width from 109 to 113 ft. The other varies in width from 111 to 119 ft. Both comprise fifteen 54-in.-deep precast, prestressed concrete bulb-tee beams spaced at a maximum of 8 ft on center. One bridge serves a subdivision near the intersection and the other on the opposite side of I-84 provides for future development as part of the city of Meridian, Idaho, Ten Mile Interchange Specific Area Plan.

rows of 18-in.-diameter steel piles. A combination of single- and two-stage, welded-wire reinforced mechanically stabilized earth (MSE) walls support the ramp and Ten Mile Road approaches. It was determined to be more economical to support the Ten Mile Road approach fill using a single-stage MSE wall rather than designing the abutment to resist lateral earth pressures. This resulted in a void between the two components that required many design and detailing revisions to the conventional approach slab.

The required minimum concrete compressive strength of the box girder superstructure was 5000 psi at 28 days and 4000 psi at the time of post-tensioning. All other structural components required a minimum concrete compressive strength of 4000 psi at 28 days.

The Right Bridge at the Right Time

I-84 serves as a vital link for transportation in Meridian and the surrounding area. It is the only interstate highway that provides a continuous direct connection between the states of Utah, Idaho, and Oregon. The new interchange is located within a heavily used 6-mile section between existing interchanges at Meridian Road and

Custom form liners used along parapets and walls. Photo: HDR Inc.

Garrity Boulevard. In several separate projects, the Idaho Transportation Department and Connecting Idaho Partners are also widening the interstate corridor within the Boise area to accommodate the high traffic demands caused by commuting motorists. The project team coordinated extensively with these adjacent separate projects throughout design and construction. The new Ten Mile Road SPUI opened at the end of May 2011.

Ted Bush is a bridge project manager with HDR Engineering Inc. in Boise, Idaho.

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

Aesthetics Considerations

Community stakeholders today are placing increasing emphasis on how a bridge fits into its environment. As such, structural aesthetics were an important consideration. The Idaho Transportation Department and the city of Meridian were presented with three aesthetic themes. The stakeholders selected a family-oriented theme for the project that included a custom running pathway pattern for the exterior face of all bridge parapets and along the SPUI bridge abutment stemwalls. An ashlar stone textured treatment was applied to all abutment stemwall and MSE wall panel surfaces. Custom family mural graphics were incorporated into the surface of the SPUI bridge MSE wall panels. The additional cost of the custom form liners required for the textured concrete surfaces was determined to be relatively low due to the large repeated use of the graphics on the project.





RSA TOWER

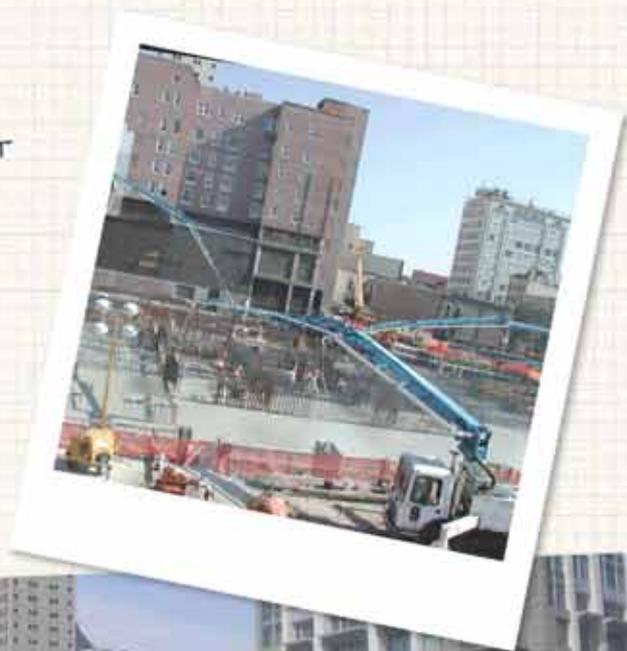
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The Westbound Nalley Valley Interchange

SW Line Flyover Bridge and Temporary Eastbound Bridge

by Jeremy Johannesen, McNary Bergeron & Associates



The Nalley Valley Interchange in Tacoma, Wash., is a major reconstruction of an interchange originally opened to traffic in 1971. It is being redesigned and reconstructed in several design-bid-build packages that will extend over several years. The westbound viaduct is the “jumping off point” for motorists on I-5 heading west to the Tacoma Narrows Bridge and the Olympic Peninsula on State Route 16. Because this SW Line flyover was first bid as a steel box girder bridge and ended up as the Washington State Department of Transportation’s (WSDOT) first precast concrete segmental bridge, the project proved to be a “jumping on point” for WSDOT as well. Volatile steel prices at bid time in October 2008 were the primary incentive for Guy F. Atkinson Construction LLC, Renton, Wash., to consider redesigning the two steel bridges on the project. However, this “first” use of a precast segmental bridge would not have happened without the contractor’s and owner’s desire to advance segmental precast concrete technology in the state. This article describes two redesigns. The second is described in the sidebar.

The SW Line Flyover Bridge nearing completion in the center of the photo.
Photo: Guy F. Atkinson Construction LLC.

profile

SW LINE FLYOVER BRIDGE, NALLEY VALLEY INTERCHANGE / TACOMA, WASHINGTON

GENERAL CONTRACTOR: Guy F. Atkinson Construction LLC, Renton, Wash.

VALUE ENGINEERING DESIGN: McNary Bergeron & Associates, Broomfield, Colo.

INDEPENDENT DESIGN REVIEW AND CONSTRUCTION ENGINEERING: Campbell Construction Engineering LLC, Redmond, Wash.



A partially erected cantilever shows the cross section and cantilever post-tensioning. Photo: McNary Bergeron & Associates.

Seismic Design

Redesigns can be challenging simply because the bulk of the engineering is performed post-bid. The larger challenge on this project was designing a concrete bridge that could be supported on a pier column that was not only designed for a steel bridge, but already had been built in a previous contract.

For this to happen required some amount of luck. First, the end span adjacent to the constructed pier was the shortest span on the bridge and there was some reserve capacity in the original design. Second, the key to the design was making an integral connection to the superstructure in lieu of bearings used in the original steel design. Using an integral connection significantly reduces the moment arm for longitudinal seismic loads. While the concrete bridge was approximately 33% heavier than the original steel design, the double-curvature in the columns resulted in comparable demands. Along with seismic advantages of the integral connection, there was the

Precast pier shells were erected over the column reinforcing to provide an integral connection. Photo: Guy F. Atkinson Construction LLC.

Redesigns can be challenging . . . the pier column had been built in a previous contract.

additional benefit of eliminating the cost and maintenance of the bearings at the interior piers.

Structure Description

In addition to inheriting a pier column, vertical clearances posed another challenge for the redesign. Based on a minimum depth-to-span ratio of 0.04, the required depth is 12 ft; slightly deeper than the original design. It required raising the profile of the bridge and the adjacent approach.

The four-span bridge is 1061 ft long with span lengths of 225, 295, 295, and 246 ft. It has a 43-ft-wide roadway, providing two travel lanes and shoulders. The superstructure consists of a single-cell box with a constant depth of 12 ft. The webs are typically 15 in. thick but increase to 20 in. at the piers. Similarly, the bottom slab transitions from 9 in. to 24 in. at the piers.

To minimize weight and satisfy shear demands in a relatively shallow structure required the introduction of inclined post-tensioning tendons. To increase ductility and continuity for seismic demands, the inclined tendons are located in the webs and anchored at each pier. Most of the precast segments were erected using balanced cantilever methods, allowing the contractor to limit lane closures and minimize falsework. A typical cantilever consists of 15 segments in all. The first five segments from the pier are 8 ft long with thickened webs and bottom slab as well as draped web tendons. The remainder of the segments are 10 ft long, and a portion of these have bottom slab anchorage blisters for the continuity post-tensioning.

The superstructure was constructed using concrete with a design compressive strength of 6000 psi. All the longitudinal tendons use nineteen 0.6-in.-diameter strands except the last three where only 12 strands were required. This provided for up to seven strands for contingency post-



1061-FT-LONG, FOUR-SPAN, PRECAST CONCRETE SEGMENTAL BOX-GIRDER BRIDGE / WASHINGTON STATE DEPARTMENT OF TRANSPORTATION, OWNER

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

SEGMENT FORMWORK: Aluma Systems, Kent, Wash.

BRIDGE DESCRIPTION: Four-span, single-cell, precast concrete segmental box girder with span lengths of 225, 295, 295, and 246 ft built using the balanced cantilever method

tensioning during construction. Each of the 15-segment cantilevers contains 14 pairs of longitudinal tendons in the deck slab over the pier. Continuity between the cantilevers is made using five pairs of tendons anchored in blisters and one pair that went from pier to pier to reinforce the bottom slab for seismic loads at the piers. As with the cantilever tendons, space was available in selected tendons to provide contingency capacity.

The overall width of the top flanges is 45 ft. Transverse post-tensioning in each segment consists of four, 0.6-in.-diameter tendons spaced at 30 in. on center to support the 10 ft overhangs. The top mat of deck reinforcement is epoxy coated.

Engineered Construction

Balanced cantilever construction is anything but a novelty. In this case, the contractor's means and methods for casting and handling segments as well as the construction of the pier tables, end spans, and deck corbels dictated the design and required some novel solutions.

Segments were produced using the long-line casting method. This involved beginning at the pier segment and match casting segments toward the middle of the span. Concrete slabs were constructed on which to cast the segments. These slabs defined the profile geometry. A polyethylene sheet and plywood on top of the slab provided a slip plane to separate segments prior to erection. The movable formwork was bolted to the slab at each segment joint. The long-line casting method allowed the segments to be cast and stored in one place and eliminated the need for large handling equipment in the casting



Cantilever construction shown adjacent to an end span. End span segments were supported on shoring designed to support 100 kips per leg. Photo: Guy F. Atkinson Construction LLC.

yard until segments were loaded for shipment to the bridge.

Match-casting the cantilever segments with the precast pier segments eliminated the need for a cast-in-place concrete joint and associated starter segment brackets during erection. Making the pier segment integral with the pier column was achieved by blocking out the webs and the bottom and top slabs to allow placement of the diaphragm reinforcement. The precast "shell" was erected by lowering it down over the pier column onto supporting brackets. There it could be aligned and made integral by the cast-in-place concrete diaphragm pour. See the Creative Concrete Construction article about pier shells on page 30.

Each segment weighed approximately 70 tons. They were held in place during erection by temporary external post-tensioning bars placed inside of the box. Once a pair of balanced segments was in place, the permanent tendons were installed and stressed and the temporary bars were removed.

Because the columns are integral with the superstructure and the seismic demands require relatively large columns, creep and shrinkage of the bridge superstructure can cause significant shear and bending stresses in the columns. Span jacking was used to offset shortening in the bridge. After making the continuity closures in the end spans, the interior spans were jacked apart with a force of 750 kips at each closure to create a 2 in. deflection in the 8-ft-square columns.

Successful Results

Some say that precast concrete segmental construction is considered to be cost effective for projects having 300 or more segments. While this structure only contained 112 segments, its success can be attributed to the economic alternatives that precast concrete offers and the ability to adapt these designs to suit difficult urban settings. And as this project illustrates, innovation and cooperation between owners and contractors can yield successful alternatives for the most difficult projects.

Jeremy Johannesen is a partner with McNary Bergeron & Associates in Broomfield, Colo.

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

Pier segment shell being loaded on transport equipment in the casting yard. Photo: Guy F. Atkinson Construction LLC.



Temporary Eastbound Bridge

Second Bridge Converted to Concrete

by Phil Marsh, McNary Bergeron & Associates

The temporary eastbound (TEB) bridge was constructed to temporarily bypass a portion of the interchange project for several years until the final construction phase is completed. The original WSDOT designed structure was a steel girder bridge with a composite cast-in-place concrete deck. As with the SW Line Bridge, the contractor proposed an alternative concrete structure to save time and money.

McNary Bergeron & Associates worked closely with the contractor, Guy F. Atkinson Construction LLC, Renton, Wash., and the precaster, Concrete Technology Corporation, Tacoma, Wash. (a PCI-certified producer), to determine the most cost-effective and practical solution for the superstructure. Ultimately, the selected alternative used intentionally-cambered, thin-flange deck bulb-tee girders with variable top flange thickness, generally from 3 in. minimum to as much as 7 1/8 in. Each of the eight simple spans (four spans at 83 ft and four spans at 95 ft) contains six lines of girders spaced at 7 ft on center, for a total deck width of 42 ft and a total of 48 girders. The 6-ft-wide top flange of the interior girders and 7-ft-wide top flange of the exterior girders provided an important advantage of eliminating deck formwork. Girders are a minimum of 50 in. deep at the thinnest deck thickness.

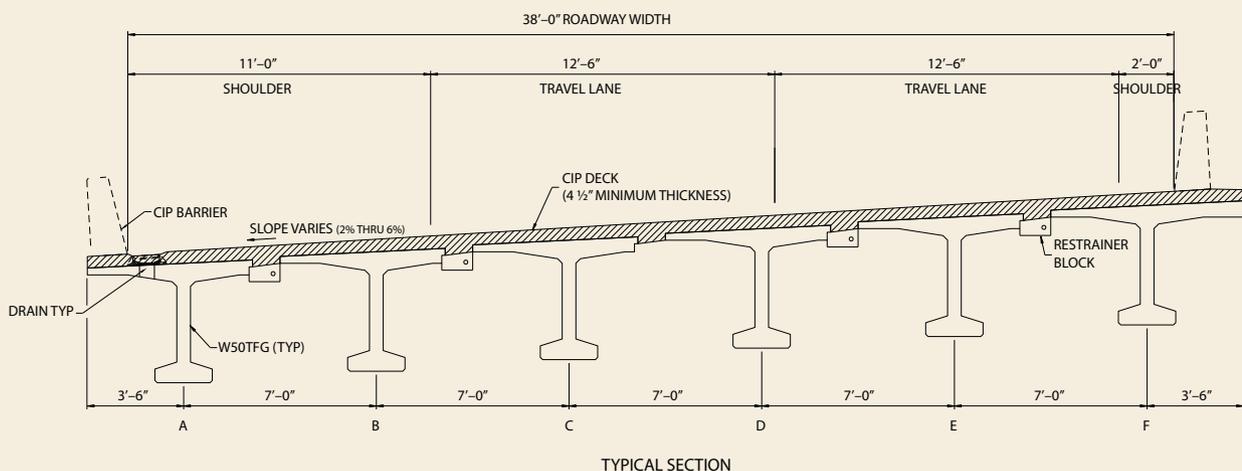
With conventional precast girders, geometric variability and excess girder camber is generally accommodated by increasing the haunch at the girder top flanges. However, in this case the haunch thickness would have required a thickened deck across the entire structure width, adding unnecessary seismic mass and undoing its viability as a cost-effective alternative to steel.

Using specialized articulated forms, the precaster was able to individually camber or sag each girder to the designer's specifications. The bridge has a vertical and horizontal curve, and variable cross slope from 2 to 6%. Much of the geometric variability in the TEB deck profile (including grade, curvature, cross slope, and camber) was approximated by adjusting forms during fabrication, thereby reducing the amount of additional deck thickness needed to achieve the final profile. The formed profile camber varied from +1.5 to - 4.5 in.

The precaster measured the camber of each girder at 28 days from the time of casting. This allowed the designer to fine-tune the bearing pad heights and girder end elevations to produce the optimal deck profile. Though minimized by the articulated forms, it was anticipated that any differential camber between adjacent girders could be problematic. To accommodate any differential, a 1-ft-wide longitudinal closure strip was field cast between adjacent girders during deck placement. These strips had the added benefit of making the top flange reinforcement in the deck bulb tees continuous across the entire deck width. No. 4 reinforcing bars extended 9 in. from the edges of the girder flanges and terminated in 180-degree hooks. The girder flange reinforcement could then be counted on to act as the bottom mat of the deck reinforcement and only the top mat of deck reinforcement needed to be field placed. This allowed for a thinner cast-in-place deck (5.5 in. average), while still providing a total minimum composite deck thickness of 8 in.

All of these challenges, including design, were met in less than a year; from the time the notice to proceed was issued in late 2008 until the bridge opened to traffic in the fall of 2009.

Phil Marsh is a bridge engineer with McNary Bergeron & Associates in Broomfield, Colo.



Typical cross section of temporary eastbound bridge. Drawing: McNary Bergeron & Associates (edited).

The Miami Intermodal Center— Earlington Heights Connector

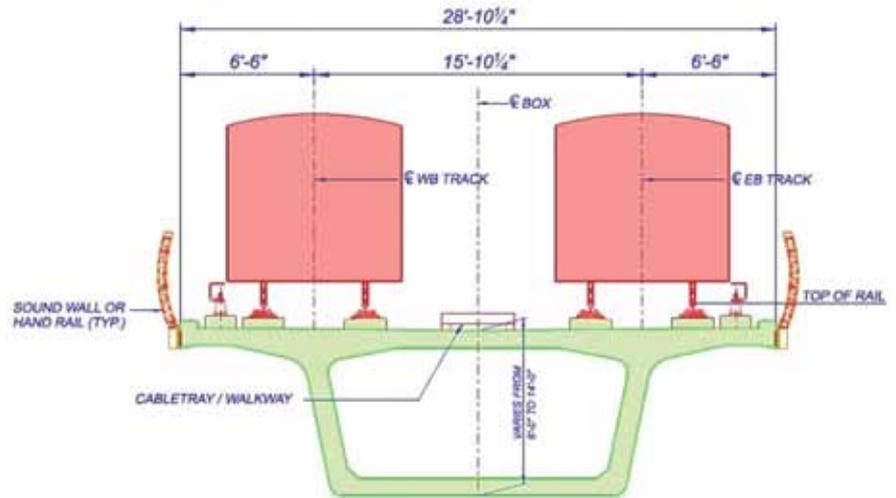
by Velvet Bridges, URS Corporation

CONNECTING THE DOTS

The Miami Intermodal Center—Earlington Heights Connector (MIC-EHC) is located in the Greater Miami area east of the Miami International Airport (MIA). The MIC is a regional transportation hub of the Florida Department of Transportation (FDOT) that is now under construction. The facility will connect local and regional transportation networks to MIA, including Tri-Rail, Amtrak, Intercity bus, Metrobus, taxis, and tour buses to MIA. The MIC will also house the airport's rental car facilities. The MIC-EHC will provide a light rail connection to a new MIC Metrorail Station via a 2.4-mile-long elevated guideway from the existing Earlington Heights Metrorail Station located at State Road (SR) 112 and NW 22nd Avenue. The MIC Metrorail Station and MIA will be linked with an automated people mover owned by MIA. The MIC-EHC will become part of the Metrorail system Orange Line in Dade County and will be owned and maintained by Miami-Dade Transit (MDT).

Project Requirements

The MIC-EHC has a variety of existing and future site conditions that require special span arrangements and structure types along its elevated 2.4-mile alignment. Structures in the vicinity of the MIC Metrorail Station had guideway span lengths limited to 130 ft to match



Typical section through the dual-track segmental box girder. Drawing: URS Corporation.

the bus spacing at ground level. The South Florida Railroad Corridor (SFRC) required a three-span continuous structure with a minimum span length of 180 ft to span over the railroad tracks. At the Miami River, a three-span continuous structure with a minimum vertical clearance of 40 ft from mean high water was required, and with columns and footings of the guideway located clear of the river shoreline. A five-span continuous structure with a main span of 256 ft was required to span over the existing SR 112 eastbound and westbound roadways and the future Miami Dade Expressway

(MDX) SR 112 project. To meet these varied requirements, the MIC-EHC designers utilized several superstructure configurations, including 72-in.-deep precast, prestressed concrete Florida U-beams; precast, post-tensioned segmental concrete box girders; and conventionally reinforced 30-in.-deep, cast-in-place concrete slabs.

Structures Overview

Cast-in-place concrete slab bridges, 30-in.-deep, are used at the connection to the Earlington Heights Station. There are a total of 13 spans or 571 linear ft of guideway. Span lengths vary from 41

profile

MIAMI INTERMODAL CENTER—EARLINGTON HEIGHTS CONNECTOR / MIAMI, FLORIDA

BRIDGE DESIGN ENGINEER: URS Corporation, Tampa, Fla.

PRIME CONTRACTOR: Odebrecht Construction Inc.—Tower-OHL Group—Community Asphalt Corp.-OHL Group, Joint Venture, Miami, Fla.

PRECASTER: U-BEAMS: Standard Concrete Products, Tampa, Fla., a PCI-certified producer

SEGMENT PRECASTER AND ERECTOR: Rizzani de Eccher USA, Bay Harbor Islands, Fla.

PIER SHELL REDESIGN: McNary Bergeron & Associates, Broomfield, Colo.

SEGMENTAL BRIDGES POST-TENSIONING SUPPLIER: DWIDAG Systems International-USA Inc., Bolingbrook, Ill.

SEGMENTAL BRIDGES POST-TENSIONING CONTRACTOR: Rizzani de Eccher USA, Bay Harbor Islands, Fla.

to 50.44 ft for a total of 10,932 ft² of structure.

The 72-in.-deep, precast, prestressed concrete Florida U-beams were used for 79 spans totaling 9589 linear ft of guideway. The typical span is 125 ft but spans vary from 82 to 133 ft. The total area of Florida U-beam guideway structure is 230,266 ft².

The segmental concrete box girder portion of the MIC-EHC features 13 units; with a total length of 1.1 miles of constant and variable depth, single-cell, precast concrete box girders totaling 145,538 ft² of structure. The single-track box girder has a constant depth of 7 ft 8 in., while the dual-track box girder has a variable depth ranging from 8 ft 0 in. at midspan to 14 ft 0 in. at intermediate piers. Typically, the box girder top flange widths match the top width of the Florida U-beam configurations for either single- or dual-track guideways.

The single-track box girder flange width is 15 ft 0 in., except for locations near the airport traction power substation where the width is 17 ft 0 in. in order to accommodate a jumper cable tray and a walkway. The dual-track box girder flange width is 28 ft 10¼ in. The number of spans per unit are either two or three for the single-track guideway, and from two to five for the dual-track guideway. The span lengths vary, with a maximum span of 256 ft at the SR 112 crossing.

The single- and dual-track box-girder segment lengths are 10 ft 9 in. and 10 ft 0 in. respectively. Longitudinally, the bridges are fully post-tensioned including face anchored top cantilever tendons, blister anchored bottom continuity tendons, pier segment anchored external continuity tendons, and blister anchored top continuity tendons. The expansion joint and pier segments are 7 ft 6 in. long, necessary to meet minimum FDOT bridge post-tensioning requirements.

The original design using cast-in-place concrete pier segments was redesigned by the contractor's construction engineer at the beginning of the work to allow the use of precast pier shells with cast-in-place diaphragms. A total of 23 shells were used throughout the project. There were five redesigned precast concrete pier shells, 10 ft 0 in. long for single piers and 18 shells, 27 ft 0 in. long for double piers. For the double piers, the pier shells are stressed together using post-tensioning bars prior to casting the diaphragm. The pier diaphragms are transversely post-tensioned once the cast-in-place concrete secondary placement has reached minimum strength. Pier and expansion joint segments are heavily reinforced to carry the guideway loads into the piers typically using disk bearings or an integral connection to the substructure (For additional information about precast concrete pier shells, see the Creative Concrete Construction article on page 30).



The substructure uses a combination of single and double piers, framed piers, straddle bents, and cantilever piers. The piers are supported by multiple auger-cast piles or drilled shaft footings. Single and double piers are typically used for both single- and dual-track segmental portions of the guideway. Framed piers are used for portions of the guideway at crossovers. Straddle bents and cantilever piers are used where existing or future underlying roadways preclude the use of conventional piers.

The lifting frame at the tip of the balanced cantilever construction over the Miami River required a three-span unit and minimum clearance of 40 ft. Photo: Rizzani de Eccher USA.

2.4-MILE-LONG ELEVATED GUIDEWAY OF SINGLE AND DOUBLE TRACK COMPRISING FLORIDA U-BEAMS, SOLID CONCRETE SLABS, AND PRECAST CONCRETE SINGLE-CELL SEGMENTAL BOX GIRDERS ON SINGLE AND DOUBLE CONCRETE PIERS / MIAMI-DADE TRANSIT, MIAMI, FLORIDA, OWNER

READY MIXED CONCRETE: Cemex USA and Tarmac America LLC, Fort Lauderdale, Fla.

DISK BEARINGS: RJ Watson Inc., Elmhurst, N.Y.

LIFTING FRAME: DEAL, Italy

STRUCTURAL COMPONENTS: 72-in.-deep Florida U-beams in the typical spans, segmental precast concrete box girders for the long-span units of the guideway structures, 30-in.-deep, cast-in-place concrete slabs at the connection to the Earlington Heights station, and precast concrete pier shells on cast-in-place concrete piers

BRIDGE CONSTRUCTION COST: \$136.8 million



Balanced cantilever construction over SR 112 that required a main span of 256 ft. Photo: URS Corporation.



In this section of the Miami Intermodal Center—Earlington Heights Connector, 72-in.-deep Florida U-beams parallel to SR 112 were used. Photo: URS Corporation.

Erection Scheme

All of the segmental units were designed to be erected using the balanced cantilever method. The cantilever stability was achieved by the use of frames around columns supported on permanent foundations and stability towers on one or both sides of piers on temporary foundation pads.

Post-Tensioning Considerations

The FDOT five-part strategy for post-tensioning is intended to create a design, construction, and maintenance environment that will consistently ensure long-term durability of structures with post-tensioned tendons.

Some of the measures incorporated in this project are:

- Center-to-center internal longitudinal duct spacing of two times the duct outside diameter
- A 10-in.-minimum thickness of sections containing internal post-tensioning tendons
- Oversize ducts to accommodate couplers for post-tensioning bars
- A maximum of twelve, 0.6-in.-diameter strands per tendon
- Four, 0.6-in.-diameter strand tendons per web through mid-span and end-span closures
- Use of steel pipe ducts for tendons with anchorages embedded in diaphragms
- A 12-in.-minimum set back from the end of the segment for interior blisters
- A minimum of three bottom tendons per web
- Overlap of midspan continuity tendons by cantilever tendons
- External post-tensioning—in addition to the future strengthening—in the form of draped tendons extending from pier to pier passing through full-height intermediate deviator diaphragms providing an overlap of tendon anchors at the pier segments
- FDOT's standard grouting procedure, with high-performance grout and multiple levels of corrosion protection for the anchorages on interior and exterior surfaces

The guideway corridor is located along some of the most heavily traveled highways in south Florida. Construction had to be carried out with minimum disruption to the existing vehicular traffic and the residents of the neighboring areas. The installation of segments by crane was very difficult or impossible in some cases. Moreover, due to the proximity to MIA, the guideway was located under the airport glide path. A construction plan was developed that would not violate Federal Aviation Authority (FAA) airspace during the erection of bridge segments.

A segment lifting system was developed that consisted of the lifting frame, overhead traveling truss, lifting beam, and a secondary spreader beam. Each segment was lifted and transported to the end of the cantilever where it was moved into place. The segment was epoxied and attached to the previous segment with permanent post-tensioning bars.

A dual-track precast concrete pier shell segment. Photo: URS Corporation.

Project Schedule

Design was completed in October 2007. The project was let for construction in August 2008 with the elevated guideway extension scheduled for completion in June 2011. The first segment was cast at the end of December 2009. The estimated date for the MIC-EHC Orange line to begin revenue operation is April 30, 2012.

Velvet Bridges is senior structural engineer with URS Corporation in Tampa, Fla.

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





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Precast Concrete Pier Shells in Segmental Bridge Design

by Zach Godsell, McNary Bergeron & Associates

In precast concrete segmental balanced cantilever construction, the pier segment is most often produced in a casting yard and erected on bearings and falsework. Alternatively, cast-in-place concrete pier segments have been utilized for longer spans or in areas of high seismicity where a monolithic connection to the column provides a more economical substructure design.

Precast concrete pier shells with cast-in-place diaphragms can be proposed as a substitute for cast-in-place pier segments. Pier shells are a hybrid of fully precast and cast-in-place construction, and combine their typical advantages and disadvantages.

Advantages

- A monolithic connection is provided between the superstructure and column for incorporating seismic design details. The integral pier column connection also provides overturning stability for the partially erected cantilever.
- Typical segment forms can be used to produce the shell segments in the casting yard. These shells are similar in weight to typical segments.
- The cantilever is a single match-cast unit, so no closure pour is required between the pier segment and first typical segments.

Disadvantages

- Reinforcing details are complex and have small tolerances. Coupled and headed reinforcement is utilized to

reduce congestion in the diaphragm.

- Diaphragm concrete and reinforcement are placed in difficult conditions at the top of a column.
- The erection speed falls between that of fully precast piers and cast-in-place concrete construction.

Erection Sequence

With precast pier shells, the fabrication and erection sequence is as follows:

- The pier shell is fabricated in the casting yard using either a unique form or the typical segment form with minor modifications.
- The shell is erected on the column and supported temporarily using falsework. It is positioned for line and grade, and locked into position.
- The diaphragm reinforcing cage is placed in the pier shell. The forms for the diaphragm are secured and the diaphragm cast.

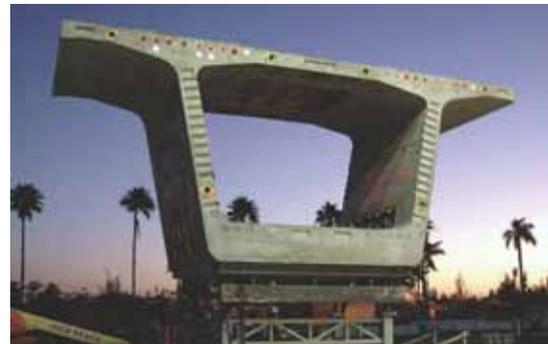
Conclusion

Pier shells can provide advantages over other methods for precast concrete balanced cantilever bridges, particularly in seismically active areas where an integral pier column connection is required for design.

Zach Godsell is senior bridge engineer with McNary Bergeron & Associates in Denver, Colo.

EDITOR'S NOTE

Pier shells were used in two projects featured in this issue. See The Miami Intermodal Center—Earlington Heights Connector on page 26 and The Westbound Nalley Valley Interchange on page 22.



Pier shell segment cast for the MIC-Earlington Heights Connector in Miami, Fla. Photo: McNary Bergeron & Associates.



Diaphragm cage installation for the LBJ "High Five" in Dallas, Tex. Photo: McNary Bergeron & Associates.

Construction of Ramp SW over I-5 in Tacoma, Wash. Photos: Guy F. Atkinson Construction."



Shell segment erection.



Diaphragm cage and column reinforcement.



Completed diaphragm and monolithic pier connection.



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South Maple Street Bridge OVER THE SCANTIC RIVER

Emulation design provides robust structure in just 17 days

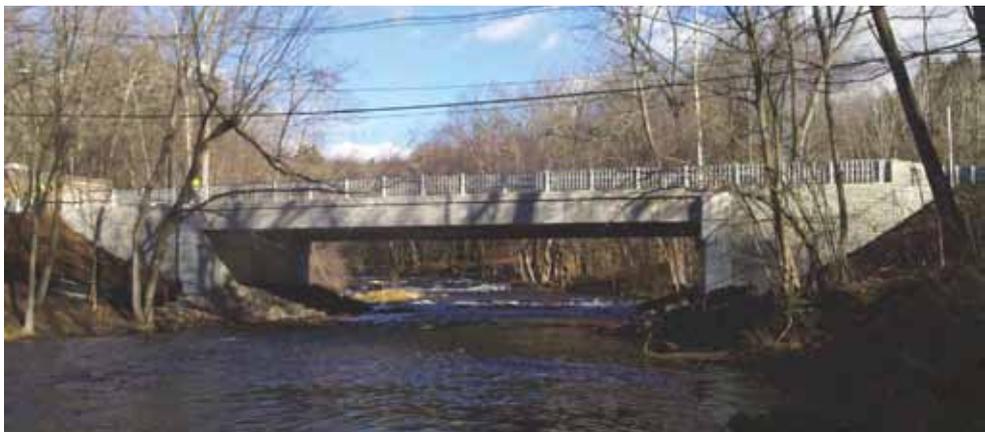
by Charles H. Swanson, Hoyle, Tanner & Associates Inc.



The existing bridge had met its life expectancy. Photo: Ralph Sweet.

The town of Enfield, Conn., completed construction of their first totally precast concrete bridge structure with the South Maple Street Bridge over the Scantic River. The existing bridge was built in 1925 and had been rehabilitated and strengthened several times but had met its life expectancy. It was a 66-ft-long single span. The replacement bridge on the same 10-degree skew alignment is an 82-ft-long, 45-ft-wide, single-span structure that carries two, 11-ft-wide traffic lanes, two 6-ft sidewalks, and two 4-ft-wide bicycle lanes. The detour for the project was relatively cumbersome and the town wanted the bridge closed for the shortest possible duration. The town agreed with its engineering consultant to replace the bridge using an accelerated bridge construction (ABC) concept. The consultant developed a conceptual ABC plan and served as the owner's representative during construction.

On the basis of the conceptual plans, the contractor was selected to finish the design, develop shop drawings for the ABC solution, and plans for the utilities and approach work. The contractor selected the precaster, who in turn selected the precast design engineer to finalize the design and prepare shop drawings for the production of the precast concrete.



The South Maple Street Bridge over the Scantic River at completion. Photo: Arborio Corporation.

The ABC Concept

The new bridge was assembled from 71 precast concrete components comprising 42 unique elements each of which required special detailing. The precast concrete elements included:

- Foundation—19 footing blocks, 3 ft 0 in. thick and typically 13 ft long by 8 to 10 ft wide. Fourteen required skewed edges. The blocks incorporated threaded jacks to level them to grade after setting. Each had three, but up to six, 2-in.-diameter holes through which to inject grout after leveling.
- Abutment Walls—10 abutment panels 3 ft 1 in. thick. Panels were

either 12 ft 9 in. or 14 ft 8 in. tall and varied from 5 ft 10 in. to 10 ft 8 in. wide.

- Wingwalls—13 pieces that varied in thickness from 3 ft 10 in. at the bottom to 1 ft 6 in. at the top. A typical panel was 22 ft tall by 10 ft wide. These panels were cast with an ashlar stone pattern on their exposed face using a formliner. Tops of the panels contained bolts and extended reinforcement for attachment of rail posts and cast-in-place concrete end blocks.
- Bridge Seat Beams—two pieces 47 ft 6 in. long and 3 ft 7 in. wide. One was set on the top of each

profile

SOUTH MAPLE STREET BRIDGE / ENFIELD, CONNECTICUT

PROJECT ENGINEER: Tectonic Engineering & Surveying Consultants P.C., Rocky Hill, Conn.

PRECAST DESIGN ENGINEER: Hoyle, Tanner & Associates Inc., Burlington, Vt.

PRIME CONTRACTOR: Arborio Corporation, Cromwell, Conn.

PRECASTER: William E. Dailey LLC (Dailey Precast), Shaftsbury, Vt., a PCI-certified producer

abutment wall to tie all abutment panels together and provide a seat for the superstructure box beams. The beams tapered in depth from 2 ft 5¾ in. at their centerline to 2 ft 0 in. at the ends. This provided a ¼ in./ft crown slope for the bearings of the box beams and thus the roadway surface. The beams were cast with an added 4-in. high by 5-in. wide continuous length lip that extends down in front of the abutment panels to hide the horizontal joint.

- Precast, prestressed concrete adjacent box beams—11 beams 48 in. wide, 33 in. deep and 83 ft 6 in. long. They were prestressed with 34 straight, ½-in.-diameter strands, eight of which were debonded for a length of 4 ft 0 in. at the ends. The design compressive strength of the concrete was 6500 psi at 28 days and 5000 psi at transfer.
- Cheek walls—four pieces 4 ft 5 in. tall by 3 ft 6 in. by 2 ft 4 in. that closed the space above the bridge seat beams and alongside each edge box beam.
- Pavement approach slabs—12 slabs approximately 6 ft 10¾ in. wide by 16 ft 3 in. long. Each slab is 1 ft 3 in. thick at its approach end and is thickened to 2 ft 11 in. over the last 4 ft 3 in. where it abuts the end of the box beams and sits on the bridge seat beam. All slabs were skewed.

Connections Plan

The connections of the precast concrete components in the substructure were detailed structurally using emulation design. Emulative detailing provides connection systems in a precast concrete structure so that its structural performance is equivalent to that of a conventionally designed, cast-in-place, monolithic concrete structure (ACI 550.1R).

For the abutment panels, bars extended from the footing blocks and were

The precast concrete footings were set and aligned with plywood templates to ensure fit-up of the walls over the dowel bars. Photo: Arborio Corporation.



The wingwalls were 22 ft tall and tapered in thickness from 3 ft 10 in. to 1 ft 6 in. Photo: Arborio Corporation.



Precast abutments and wingwalls were placed and braced. Vertical form boards are shown clamped over the joints in two locations to grout the shear keys full. Next, the bridge seat beam will be placed on the abutment walls. Photo: Arborio Corporation.



The final adjacent box beam was set on the precast concrete beam seat after which the cheek walls were set. Epoxy-coated reinforcement was provided in the tops of the box beams to secure the curbs and sidewalks. Photo: Arborio Corporation.



SINGLE-SPAN, TOTALLY PRECAST CONCRETE REPLACEMENT BRIDGE / TOWN OF ENFIELD, CONNECTICUT, OWNER

BRIDGE DESCRIPTION: A single-span, precast, prestressed concrete adjacent box beam bridge, 82 ft long, 45 ft wide, supported on a precast concrete substructure, erected in 17 days

STRUCTURAL COMPONENTS: Adjacent precast, prestressed concrete box beams, 33 in. deep, precast concrete abutments and wingwalls, precast concrete footings, and precast concrete pavement approach slabs



The underside of the South Maple Street Bridge. Photo: Hoyle, Tanner & Associates Inc.

inserted in dowel bar splice sleeves that were cast in the panels. There were No. 5 bars spaced at 12 in. in the back row and No. 6 at 6 in. in the front row. The abutment panels were set in a 6-in.-deep keyway cast into the top of the footing blocks.

At the top of the abutment panels, the same configuration of dowel bars extended from the tops of the panels

into dowel bar splice sleeves cast into the bottom of the bridge seat beams. These tied the tops of the abutment walls together.

The same kind of connection was made between the footing and wingwalls. There, No. 6 bars spaced at 6 in. were placed in the front row and No. 8 bars spaced at 6 in. in the back row. The

bottoms of these panels were also set into 6-in.-deep keyways.

After bracing the panels, the splice sleeves were injected full with 10,000 psi compressive strength grout through fill tubes cast into the panels for that purpose. A total of 426 dowel bar splices were used in the bridge. Finally, horizontal joints between components were filled with high-strength grout. Vertical joints had keyways cast into their mating surfaces. These were also filled with grout.

The precast concrete approach slabs were set on the bridge seat beams with a 1-in.-wide joint to the ends of the box beams. Holes 2 by 4 in. received dowel bars from the top of the seat beams and were grouted full.

The box beams were set on elastomeric pads. They were connected transversely with two, ½-in.-diameter prestressing strands located at each end and at quarter points along the span.

Construction Sequence

The existing bridge was closed August 1, 2010, with the goal to have the new bridge in service by Thanksgiving. After removal of the bridge and abutments, a considerable amount of utility and approach work needed to be

The handsome new South Maple Street Bridge features an ashlar stone texture cast on the wingwalls. Photo: Hoyle, Tanner & Associates Inc.



completed. In the meantime, the precast manufacturer was casting components for the bridge in their plant.

After the sites for the abutments had been leveled, the contractor cast an unreinforced "mud slab" on which to place the footing blocks. The blocks were adjusted for elevation with embedded leveling screw jacks and verified. Next, the contractor pressure grouted under the precast footings through grout ports provided in the footings. This ensured full bearing contact.

The contractor then set the precast abutment walls and wingwalls over the reinforcing bars projecting from the footing blocks. When the walls and wingwalls were set, plumbed, and braced, the contractor grouted the dowel bar splice sleeves. The next step was to set the precast abutment bridge seat on the projecting reinforcing bars from the abutment walls. This tied the abutment wall pieces together and caused them to act as one unit. Then the precast, prestressed concrete box beams were set on elastomeric bearing pads on the precast bridge seat. Following erection of the box beams, the precast cheek walls and precast approach slabs were erected. A 5-in.-thick composite cast-in-place concrete deck was placed over the box beams and approach slabs completing the entire structure of the bridge.

The structure was erected in just 17 days. The project did not require any replacement or jobsite modification of any precast component. This was considered a testament to what the contractor, the engineer, and precast fabricator were able to accomplish through their team effort.

The project was considered a success by all involved due to the coordination and detailed planning. The town of Enfield was very pleased with the schedule and appearance of their new bridge.

The South Maple Street Bridge project was Connecticut's first totally precast bridge. The project was opened to traffic in November 2010.

Charles H. Swanson is vice president of Hoyle, Tanner & Associates Inc. in Burlington, Vt.



Most of the components of the bridge are shown: box beams, abutment and wingwall panels, cheek walls, and the bridge seat beam with its extended lip covering the horizontal joint with the abutment panels. Photo: Hoyle, Tanner & Associates Inc.

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

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Typical bridge pier with lanterns and overlooks. Photo: C. Hodge, T.Y. Lin International.

Cypress Avenue Bridge Replacement Project

by Michael Fitzpatrick and Chris Hodge, T.Y. Lin International

Redefining the Road to Redding, California

When the city of Redding, Calif., decided to replace two existing, parallel crossings of the Sacramento River in Shasta County, creative engineering solutions and uniquely aesthetic design elements became key priorities for the new iconic bridge that would serve as a gateway to the city. Cypress Avenue is a highly travelled link between Redding and busy I-5. The existing steel girder bridges, built in 1948 and 1968, did not meet traffic demands, pedestrian access width, vertical clearance, foundation scour, and seismic design requirements.

River Environment

The Sacramento River is a major waterway meandering 380 miles through Northern California from its origin near Mount Shasta to its terminus in San Francisco Bay. The bridge crossing location is near the source of the river,

which is an area of sensitive habitat for Chinook salmon and steelhead fish species. This section of the river is also used extensively for recreational fishing and boating, as well as nature hikes, and plays a crucial role in the expansion of a hiking trail and riverfront park. Project improvements needed to consider impacts on these natural and recreational resources.

The Cypress Avenue Bridge replaced the two existing bridges with a six-lane signature bridge, including a bike lane and sidewalk on both sides in compliance with city plans for the Cypress Avenue corridor. In addition to the bridge, the project also included significant widening of approach roadways, construction of conventional retaining walls, modification of two adjacent intersections, and reconstruction and realignment of adjacent connector roads.

Replacement Structure

In order to maintain four lanes of traffic throughout construction, the existing bridges were replaced in three stages,

with each stage requiring approximately 1 year. To accommodate the construction stages, the superstructure consists of three parallel box girders. Two of the girders have three cells and one has four. A 3-ft 6-in.-wide closure placement was used between each of the construction stages.

The six-lane replacement structure consists of a 1025-ft-long, 119-ft 6-in.-wide, five-span, haunched, cast-in-place, post-tensioned concrete box-girder bridge on a 9997-ft-radius curved alignment. The span lengths are 180, 200, 230, 230, and 185 ft. The vertical profile over the river includes an 800-ft-long, -0.25% vertical curve with no superelevation. The deck area provides 9-ft 9-in.-wide areas on each side for sidewalks, lighting, railings, and barriers. There are 8-ft-wide exterior shoulders plus six, 12-ft-wide travel lanes. A 12-ft-wide central area accommodates interior shoulders, a median, and additional lighting.

The haunched box girder depth varies from 8 ft 9 in. at midspan to 14 ft. 9

profile

CYPRESS AVENUE BRIDGE / REDDING, CALIFORNIA

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

PROJECT ARCHITECTS: T.Y. Lin International and MacDonald Architects, San Francisco, Calif.

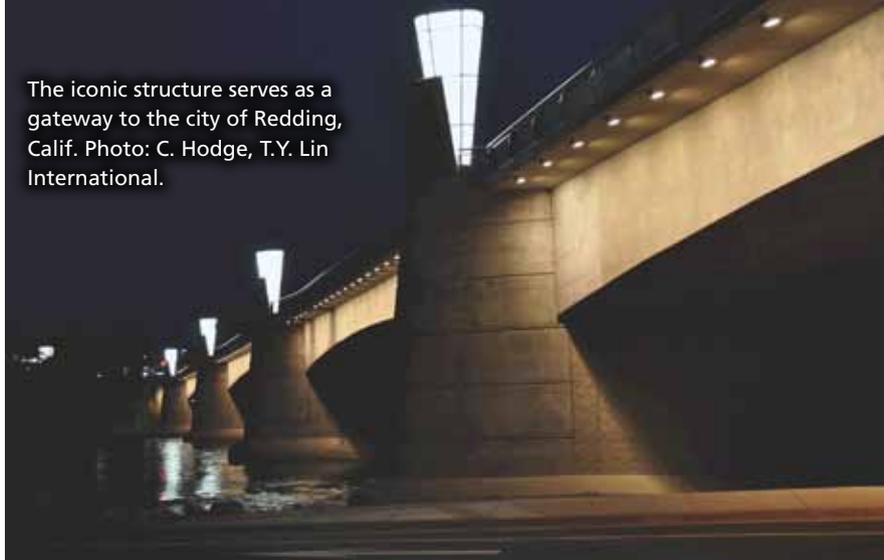
PRIME CONTRACTOR: Kiewit, Fairfield, Calif.

LIGHTING AND ILLUMINATION: Illumination Arts LLC, Bloomfield, N.J.

A series of elegant arches connect the bridge to the landscape.

in. at the piers. The deck slabs are 8 1/8 in. thick. The soffit slabs are 6 1/4 in. thick and generally deepen to 12 in. thick near abutments and pier locations. The box girder webs are 12 in. thick, and the webs of the exterior girders generally flare to either 15 or 18 in. near abutments and piers.

The superstructure, pier walls with overlooks, pile caps, and cast-in-drilled hole (CIDH) piles all required a concrete compressive strength of 4000 psi. The abutments and abutment footings required 3600 psi compressive strength concrete. The concrete comprised typical California Department of Transportation mixtures. All reinforcement was Grade 60. Headed bar reinforcement was used to anchor

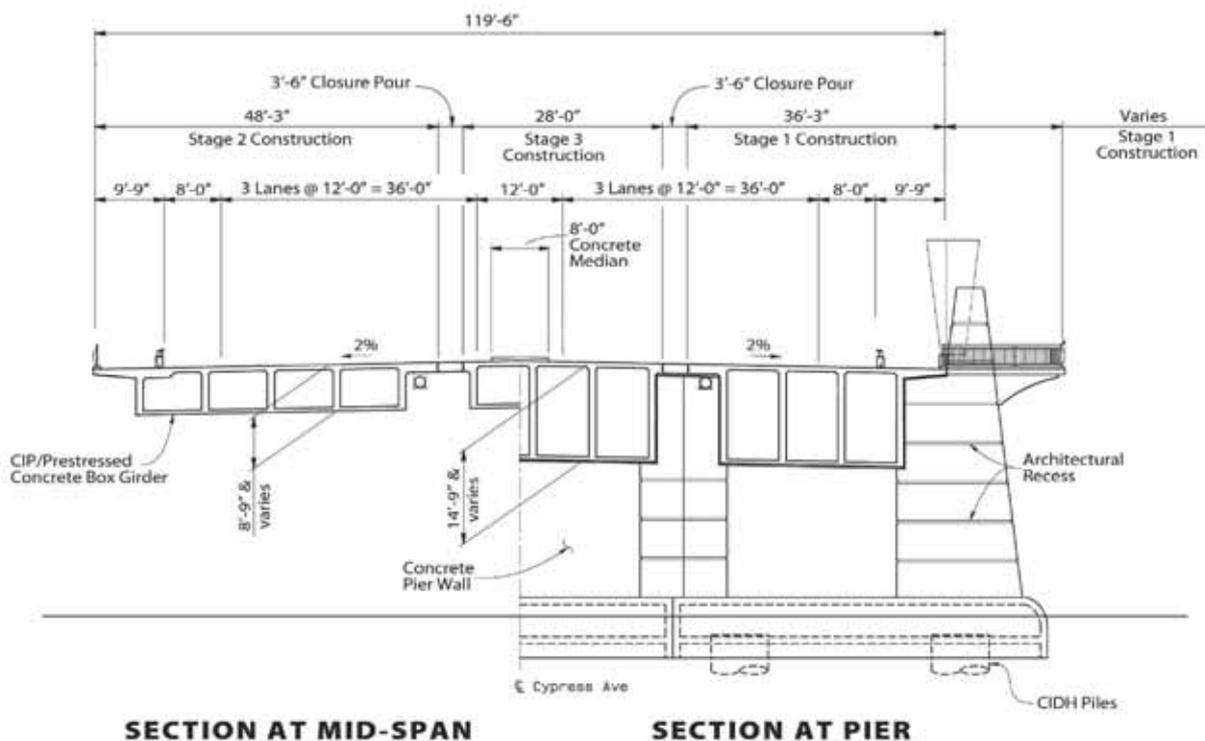


The iconic structure serves as a gateway to the city of Redding, Calif. Photo: C. Hodge, T.Y. Lin International.

the CIDH piles' reinforcing bars in the footing form.

The post-tensioning tendons were continuous over the full length of the bridge. Stressing was performed from both ends. The post-tensioning was done in three stages corresponding to the three stages of construction. Stage 1

post-tensioning included 10 tendons distributed in the four webs of a three-cell box girder. Six tendons contained 25 strands and four contained 21 strands. The total prestress force was 10,210 kips. Stage 2 used eight tendons with 27 strands, one tendon with 26 strands, and two tendons with 22 strands distributed in the five webs of the four-



Typical section at midspan and at pier. Drawing: T.Y. Lin International (edited).

FIVE-SPAN, CAST-IN-PLACE CONCRETE, POST-TENSIONED, HAUNCHED, BOX-GIRDER BRIDGE / CITY OF REDDING, CALIFORNIA, OWNER

BRIDGE DESCRIPTION: A five-span (180, 200, 230, 230, and 185 ft span lengths), 1025-ft-long and 119-ft-wide, cast-in-place concrete, haunched, box-girder bridge with cast-in-place concrete wall piers, abutments, and foundations, constructed in three-major stages over 4 years

BRIDGE CONSTRUCTION COST: \$44 million (\$360/ft²); total project cost, \$62 million



A successful consensus-building process shaped the highly stylized lanterns that appear as an extension of the sloped pier walls. Photo: C. Hodge, T.Y. Lin International.



Stage 1 construction utilizing reusable steel footing form. Photo: K. Pope, T.Y. Lin International.

cell box girder. Total prestress force was 12,560 kips. Stage 3 used eight tendons with 27 strands each in the four webs of the three-cell box girder for a total of 9410 kips of post-tensioning. All strands were 0.6 in. diameter.

Piers were fixed to the superstructure at Piers 3 and 4. Piers 2 and 5 and the abutments used combination sliding and spherical polytetrafluoroethylene (PTFE) bearings. The superstructure is supported by single cast-in-place concrete pier walls, 26 ft tall and 4 ft 10 in. thick. The piers are supported by cast-in-place concrete pile caps, 12 ft wide and 9 ft 6 in. deep with rounded ends and top surfaces located at the waterline. The piers are founded on a single row of 8-ft-diameter, CIDH piles that vary in length from 88.5 to 103.5 ft. The tall cantilever, seat-type

abutments are founded on conventional pile cap footings on driven steel piles.

Gateway to Redding and the Future

The new Cypress Avenue signature bridge, with its unique aesthetics, improves traffic flow and provides safe pedestrian and bicycle lanes with scenic views, in addition to meeting seismic requirements. This iconic structure serves as a gateway to the city of Redding, spanning the Sacramento River, and pointing west to City Hall.

Michael Fitzpatrick is bridge architect with T.Y. Lin International in San Francisco, Calif., and Chris Hodge is bridge services manager at T.Y. Lin International in Sacramento, Calif.

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

Aesthetic Theme through Consensus Building

The bridge was the second phase of the city's master plan to improve Cypress Avenue. It established the route as its main boulevard and home to its cultural centers. The city, therefore, wanted the bridge to enhance the overall plan and to increase pedestrian activity along Cypress Avenue and the new river trail along the Sacramento River.

The project team implemented a four-step process for developing the unique architectural character of the bridge.

- Step 1 – By working with a community advisory panel and hosting workshops for the general public, a variable depth box girder was clearly designated as the preferred structure.
- Step 2 – The project team's architecture group then developed a general list of the architectural elements to be included as part of the project.
- Step 3 – Once the input was compiled from the public workshops and a city-appointed ad hoc committee, the list of special design elements was finalized.
- Step 4 – Selection of final colors and architectural shapes and design of the construction details.

The Cypress Avenue Bridge comprises a series of elegant arches, connecting the bridge to the landscape and illuminated at night to create a soft glow over the length of the superstructure.

The main aesthetic features of the bridge are the eight custom-designed, internally illuminated lanterns. These dramatic lanterns are 16 ft tall and constructed of dichroic glass that changes color based on the viewing position. The dichroic glass is $\frac{3}{4}$ in. thick to reduce the risk of incidental breakage. The lanterns are internally illuminated with cold cathode fixtures and will require re-bulbing only every 20 years. The fixtures can withstand the extreme weather conditions in Redding, which can range from 20 °F in winter to 120 °F in summer. For additional information about the lighting design, see the Creative Concrete Construction article on page 40.

Other architectural elements incorporated into the design add to the distinctive beauty of the new structure. The upstream and downstream edges of the pier wall are rounded and inclined inward from the bottom of the wall to deck level at a 1:8 slope. The sloped wall extends 11 ft 5 in. above the deck to form the housing for the glass lanterns. In addition, the two center piers (Piers 3 and 4) feature reinforced concrete overlooks on each side of the bridge that wrap around the lanterns and provide scenic views of the river at midcrossing. The pier walls and abutments feature a pattern of horizontal banding, with formed reveals divided by large areas of rusticated finish. Three corners of the bridge also include a large, spiral-shaped viewing area. The two abutment viewing areas located at the south edge of the bridge continue this visual theme, with corresponding spiral-shaped stairways from the bridge to the river bank. The bridge sidewalks and overlook areas are paved with a 2½-in.-thick pigmented concrete overlay that features stamped geometric patterns.

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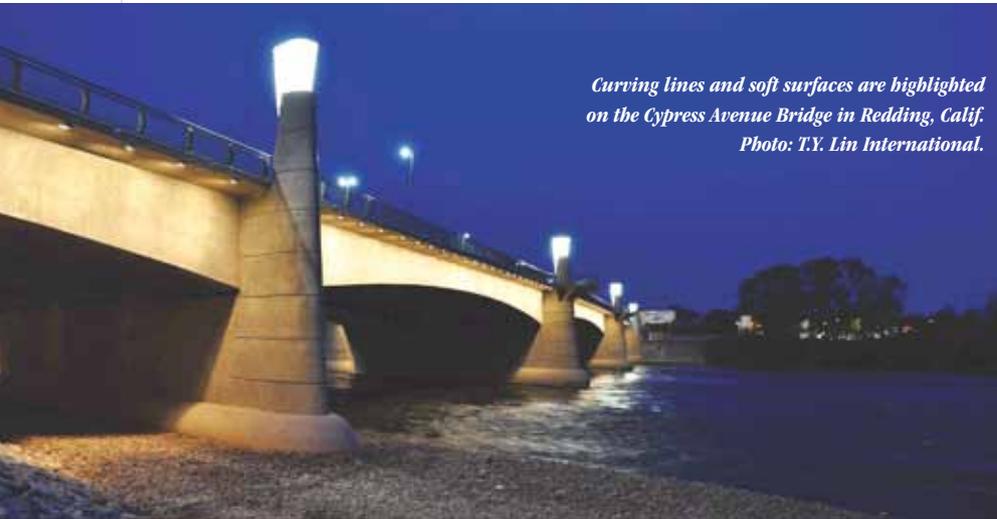
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Photo courtesy of Alamy Africa

Lighting Design

by Michael Fitzpatrick, T.Y. Lin International

for Cypress Avenue and Stewart Street Bridges



Curving lines and soft surfaces are highlighted on the Cypress Avenue Bridge in Redding, Calif. Photo: T.Y. Lin International.

For T.Y. Lin International (TYLI), a successful project is one where structural and safety requirements are met, and the aesthetic performance of the bridge is appropriate to the budget and expresses the values of the community. To ensure the design has visual consistency, the approach to the design process becomes holistic from the beginning of the project, which includes all critical disciplines. One important factor in this integrated design process is the incorporation of aesthetic lighting.

The aesthetic lighting design for the Cypress Avenue Bridge in Redding, Calif., and the Stewart Street Bridge in Dayton, Ohio, employed the same integrated process, but yielded very different final results.

Cypress Avenue Bridge

The Cypress Avenue Bridge form takes its cues from the natural environment, and is conveyed through curving lines and soft surfaces along all the exterior edges (as if softened by the Sacramento River). The city and design team were able to identify two aesthetic lighting goals: first, to demarcate the river and second, to gently wash the edge of girder face with light.

To highlight the river spans, large lanterns were designed to include dichroic glass that changes color based on the viewing position and to be illuminated by cold cathode lamps. The glass was designed and manufactured by

The LED fixtures illuminating the Stewart Street Bridge in Dayton, Ohio, are fully programmable to create unique and seasonal lighting themes. Photo: Woolpert Inc.

Architectural Glass Art, while Illumination Arts executed the lighting plan. In addition, LED fixtures were selected for the roadway and edge girder lighting. The fixture selection resulted in a soft, low-energy illumination. By softly illuminating the girder from abutment to abutment, local residents and park users can now enjoy the overall structure. The lanterns draw attention to the river crossing for travelers along Cypress Avenue.

Stewart Street Bridge

In Dayton, Ohio, the new Stewart Street Bridge is essentially the “front door” to the city and the University of Dayton. The community group wanted to use the bridge to enhance activity along the river, and to make a statement about the ever-growing pride of the community.

The Stewart Street Bridge took on a very modern aesthetic theme through the

development of dramatic Y-shaped piers, which are split both longitudinally and transversely. The aesthetic lighting, developed by TYLI, took full advantage of the form by illuminating the in between the Y-shaped piers at night, which is the opposite of the way the piers are naturally lit during the day.

The LED fixtures are fully programmable to create unique and seasonal lighting themes. The fixtures are also concealed within the superstructure and subsequently not visible to the traveling public. They are also located above high water, keeping the lenses clean and unaffected by rain or snow. By hiding the fixtures, the piers literally glow at night.

Whether used as a soft accent or to make a dramatic statement, aesthetic lighting is an inexpensive way to enhance a bridge’s appearance. TYLI believes that any aesthetic lighting design should be engaged fully into the design process from the beginning in order to ensure seamless integration into the overall project development. The Cypress Avenue Bridge and the Stewart Street Bridge are each a perfect case in point.

Michael Fitzpatrick is bridge architect with T.Y. Lin International in San Francisco, Calif.

EDITOR’S NOTE

To read more about these projects, see the articles on pages 36 and 14.

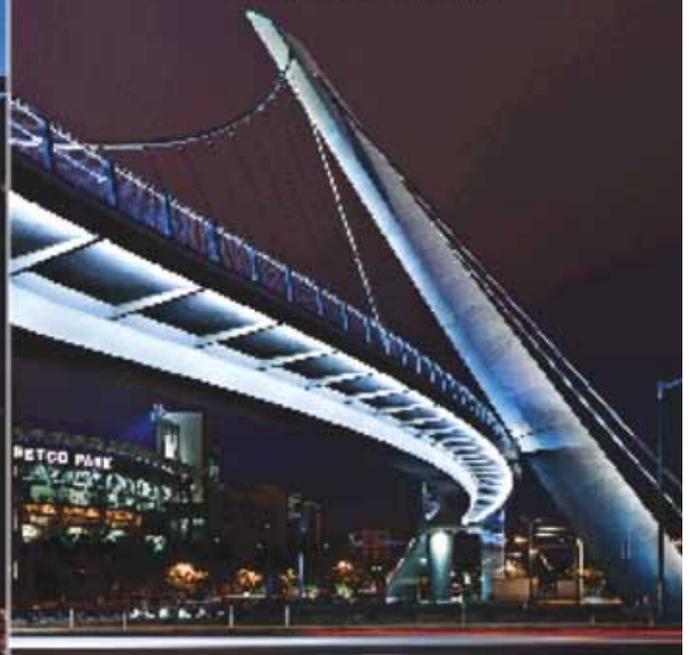


HOOVER DAM BYPASS BRIDGE
CLARK COUNTY, NEVADA AND MOHAVE COUNTY, ARIZONA



Photo courtesy of FHWA

HARBOR DRIVE PEDESTRIAN BRIDGE
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Steel-less in Seattle:

Concrete Solutions for SR 519 Phase 2

by Richard Patterson, AECOM

The Atlantic Ramp and Royal Brougham Bridges

The team that carried out Phase 2 of the State Route 519 (SR 519) Intermodal Access Project managed to please a diverse array of concerned stakeholders by completing a complex, intermodal,

\$84.4 million design-build project 13 months ahead of schedule.

Threading the Space Needle

SR 519 is located in a fully-developed, congested urban and industrial area in downtown Seattle. To complete the connection between the I-5/I-90 interchange and the Seattle waterfront, the project team had to weave its way through numerous stakeholders and

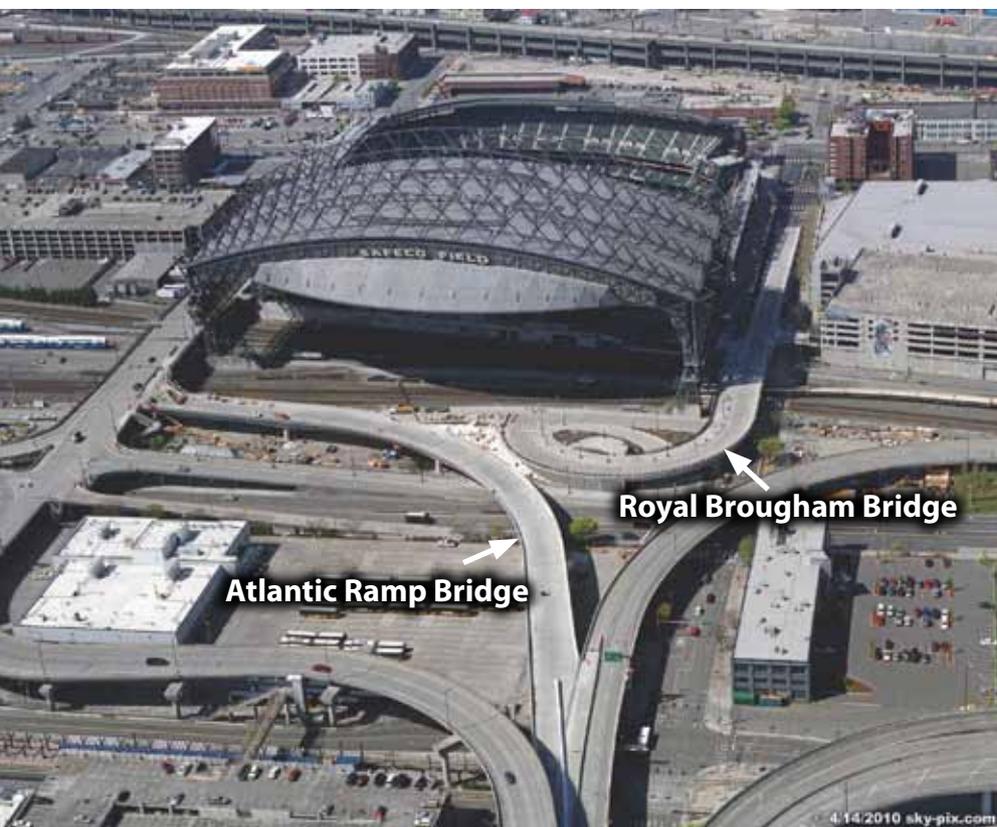
multiple transportation modes. The complications included Seattle's stadium district (SAFECO Field, Qwest Stadium, and the Qwest Event Center); the waterfront district (Port of Seattle and Washington State Ferry at the Colman Dock); light, commuter, and heavy freight rail tracks; and a King County Metro Ryerson bus base. Virtually defining intermodalism, this area epitomizes the challenges that occur whenever modes meet.

When the Seattle Mariners baseball team or the Seattle Seahawks football team play a home game, 50,000–67,000 fans fill either stadium. Before the benefits of the SR 519 project were realized, those fans had to cross five sets of railroad tracks to get to or from the stadium. Add children and excited fans to that mix, in a locale where rain is frequent, and the safety risks grow.

As if pressing safety and traffic concerns weren't enough, another factor weighed heavily on the project team. A solution had to be completed in advance of imminent area megaprojects, especially the \$3.1 billion Alaskan Way Viaduct project.

The SR 519 project required the design and construction of two completely separate structures.

This panoramic view shows the SR 519 Intermodal Access project site curling around Safeco Field. Photo: ©2010 sky-pix.com.



profile

SR 519 INTERMODAL ACCESS PROJECT / SEATTLE, WASHINGTON

BRIDGE DESIGN ENGINEER: AECOM, Seattle, Wash.

PRIME CONTRACTOR: Kiewit Infrastructure West Co., Federal Way, Wash.

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

AWARDS: 2010 PCI Bridge Design Award, Best Bridge with Spans between 76 and 150 ft; 2011 American Council of Engineering Companies National Silver Award in Transportation; 2011 Associated General Contractors Build Washington Award—Construction Excellence; 2011 American Public Works Association National Public Works Project of the Year

The project had to weave its way through multiple transportation modes.

Atlantic Ramp Bridge

The Atlantic Ramp Bridge begins at the I-90/I-5 off-ramp. It slopes in a westbound direction toward the water and curves to the south, where it intersects the east-west Edgar Martinez Way (Phase 1 of the project). It is a five-span, cast-in-place post-tensioned concrete bridge. Though a previous solution called for the use of a steel bridge, that solution presented serious concerns.

Life-cycle costs for steel are much greater than for concrete; concrete bridges require little maintenance. With steel, girders must be painted every 15 years or so. But painting the bridges was not about cost alone. These bridges would have to be painted above live Burlington Northern Santa Fe (BNSF) and Sound Transit rail tracks, where the operating windows create serious time constraints, and over the King County Metro bus base, and across other stakeholders' property. For this project, steel was a poor choice.

In addition, the Washington State Department of Transportation (WSDOT) required a solid connection between the existing I-90 ramp and the bridge. Expansion joints could not be used, since they would create a potential hazard for certain vehicles. Seismic issues complicated this as well. A new, heavier bridge could damage the existing bridge through this connection during an earthquake. So there was a requirement that the new bridge not increase the seismic load on the existing bridge by more than 5%. In response, the project team developed a seismic fuse to connect the bridges.

Functioning in a day-to-day manner as if it were cast with the bridge, the seismic fuse works like a bridge circuit breaker. When a major earthquake strikes, the fuse, a wedge-shaped piece of concrete, pops out and leaves each bridge free to



Work continues even while a BNSF train glides under the new precast bridge. The pedestrians waiting to traverse BNSF's "most dangerous crossing" can now use the much safer sidewalk along the Royal Brougham Bridge. Photo: Washington State Department of Transportation.

move independently. Once the seismic event stops, both bridges are designed to still be standing. The wedge can be removed and steel plates can cover the gap temporarily, keeping the bridges functioning, until the fuse can be replaced.

The seismic design criteria required the implementation of the new *AASHTO Guide Specifications for LRFD Seismic Bridge Design*. The use of these displacement-based criteria was a first for the city of Seattle, and one of the first in Washington State. The project approaches incorporated the use of expanded polystyrene to mitigate effects from poor soil conditions and existing large-diameter utilities—also a first for Seattle.

Royal Brougham Sloping "J"

The other project structure is the Royal Brougham Grade Separation Bridge. It is

designed to separate vehicles (including bicycles) and tens of thousands of pedestrians from the railroad tracks. To fix what has been dubbed their "most dangerous crossing," BNSF even contributed about \$5 million to the project to help facilitate its implementation. In the shape of a J, the bridge carries two roadway lanes, two bicycle lanes, and an 18-ft-wide sidewalk up and over the railroad tracks. The west side of the bridge includes a grand staircase and an elevator for ADA access. This is a highly technical bridge constructed within 2 ft of two large-diameter sewer pipes (one being 100 years old). The bridge horizontal and vertical geometry is very complex.

This bridge had to rise high enough to get over the trains, but stay low enough to allow access into the second level of a parking garage. Beginning far enough to the east on Royal Brougham Way so that

ATLANTIC RAMP BRIDGE, A FIVE-SPAN, CAST-IN-PLACE POST-TENSIONED CONCRETE BOX GIRDER BRIDGE / WASHINGTON STATE DEPARTMENT OF TRANSPORTATION, OWNER

THE ROYAL BROUGHAM BRIDGE, A FIVE-SPAN BRIDGE USING CAST-IN-PLACE, POST-TENSIONED CONCRETE BOX GIRDERS, PRECAST, PRESTRESSED, CONCRETE I-BEAMS, AND CAST-IN-PLACE, CONVENTIONALLY REINFORCED CONCRETE BOX GIRDER / CITY OF SEATTLE, OWNER

BRIDGE DESCRIPTION: Large-diameter drilled shafts, circular columns cast-in-place, post-tensioned concrete box girders, cast-in-place, conventionally reinforced, curved box girders; one span of precast, prestressed, precambered concrete I-beams; and a two-span flat slab ramp bridge to the second floor of an adjoining parking garage

BRIDGE CONSTRUCTION COST: \$84.4 million for design-build

Life-cycle costs for steel are much greater than for concrete.

semi-trucks could still enter the exhibition center building, the roadway had to climb high quickly so that eastbound traffic could go underneath the bridge and into the parking garage at the at-grade entrance. Then the roadway had to level out to allow access to the parking garage at the second level, climb to get over the railroad tracks, and descend rapidly to loop around and return to Royal Brougham Way (the “hook” of the J).

The bridge is a five-span, 667-ft-long structure incorporating a combination of four different types of concrete construction. Starting on the west and working east, the solution features two spans of cast-in-place, post-tensioned concrete box girders, with a reinforced flat-slab bridge serving as the ramp to the second level of the garage.

The single span over the railroad uses precast, prestressed, precambered I-beams. A critical steel-to-concrete conversion, this span posed a unique challenge. In a typical precast, prestressed concrete beam, the bottom of the beam is essentially flat. Unfortunately, that vertical geometry for the bridge would not work; it was off by more than a foot. Building a precamber into the girder made the use of concrete feasible.

The curved portion of the bridge is a two-span, cast-in-place concrete box girder that is conventionally reinforced and not post-tensioned.

Placing the concrete deck on the Royal Brougham structure. Forming for the other structure on the SR 519 project, the Atlantic Ramp Bridge, can be seen in the background. Photo: Washington State Department of Transportation.



Construction continues overhead as a Sounder train glides beneath the newly erected precast beams of the Royal Brougham Bridge. Photo: Washington State Department of Transportation.

It's All in the Delivery

To expedite project delivery, WSDOT and the city of Seattle chose the design-build method for the project. In addition to the two owners, numerous stakeholders contributed to the process, including King County Metro, the Seattle Mariners, the Seattle Seahawks, the Seattle Sounders (soccer), the Qwest Events Center, Sound Transit, BNSF, and the Port of Seattle. But it was the strength of the design-build partnership and the willingness of the owners and stakeholders to implement innovative techniques that set this project apart.

The challenges on SR 519 were considerable. And the clock was ticking. Fortunately, owners, stakeholders, and the design-build project team pulled together to solve these problems with ingenuity and camaraderie. You may

not be able to please all of the people all of the time, but the project team pleased a number of diverse, concerned stakeholders by completing a highly complex intermodal project—ahead of schedule and on budget.

Richard Patterson is a veteran bridge engineer with AECOM in Seattle, Wash.

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

The Royal Brougham Grade Separation Bridge provides safe passage over the BNSF tracks and access to the QWEST Event Center parking garage. Photo: Washington State Department of Transportation.



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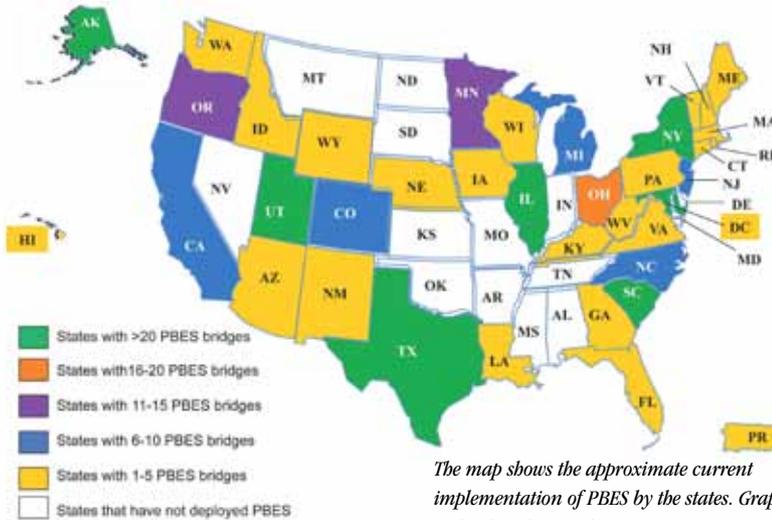
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EVERY DAY COUNTS: The FHWA Technology Deployment Initiative

Part Two—Implementation of Prefabricated Concrete Bridge Elements and Systems



by Claude Napier, Lou Triandafilou, and
M. Myint Lwin, Federal Highway Administration



The map shows the approximate current implementation of PBES by the states. Graphic: Federal Highway Administration.

In Part 1 of this article, published in the Spring 2011 issue of *ASPIRE*,™ we described the FHWA's Every Day Counts (EDC) initiative. Many EDC events have taken place since the initiative was introduced. Ten regional EDC Innovative Summits were completed with 45 states electing to pursue prefabricated bridge elements and systems (PBES) technology in bridge construction, and four PBES online seminars were conducted. The seminars consist of 14 modules covering all aspects of PBES. The concrete industry efforts and capabilities to support PBES deployment were presented by Susan Lane from the Portland Cement Association and Randy Cox from the American Segmental Bridge Institute. The Civil and Environmental Engineering Department of the Florida International University has established a National Center for Accelerated Bridge Construction to support EDC through education, case studies, and training.

Current State of PBES Concrete Technology

With PBES concepts, many time-consuming construction tasks are not done sequentially inside work zones. Components can be manufactured off the bridge alignment to reduce on-site construction time relative to

conventional practice. An old bridge can be demolished while the new bridge elements are built at the same time, off site, under controlled conditions, then brought to the jobsite to install. This form of accelerated bridge construction (ABC) benefits budget-challenged federal, state, and local transportation agencies, by:

- Reducing on-site construction time
- Reducing traffic and environmental impacts
- Improving work zone and worker safety
- Lowering initial and life-cycle costs
- Improving constructability and product quality (controlled production environments and curing procedures; convenient, safer access to assembly processes, etc.)

Primary Concrete PBES

Prefabricated concrete elements and system assemblies may be effectively used in both superstructures and substructures.

For use in superstructures, components include partial- and full-depth precast concrete deck panels, concrete beams with a broad range of shapes and sizes, and composite girders. Superstructure systems and assemblies include large segments of a superstructure, or even an entire superstructure.

For use in substructures and foundations, individual components include piles, pile caps, footings, columns, pier caps, abutment wall panels, wing walls, and precast concrete roadway approach slabs. A systems approach would combine many of these components into a total prefabricated structure.

With the use of high-capacity, self-propelled modular transporters (SPMTs), an entire bridge may be prefabricated adjacent to or off the bridge site, and then moved into final position.

At the Regional EDC Innovation Summits held across the country, many states indicated that they have used one or more of these concrete elements and systems successfully to accelerate construction, reduce disruption to traffic, improve quality and work zone safety, and save costs. The following two examples illustrate PBES concrete systems.

NE 8th Street Bridge

NE 8th Street is the main east-west arterial for Bellevue, Wash., and the primary access route between I-405 and the city's downtown business district. To provide room for a new set of high occupancy vehicle direct connector ramps on I-405, the existing NE 8th Street Bridge over I-405 had to be replaced without causing significant disruption to traffic on either roadway. PBES met the challenge.

The Washington Department of Transportation (WSDOT) chose a totally prefabricated design that allowed it to stage the bridge alongside the existing bridge, and then move it into place. The south half of the new bridge was constructed in a temporary location south of the old bridge. Eastbound traffic was shifted onto the new portion and westbound traffic onto the south half of the old bridge while the north half of the old bridge was removed and rebuilt. Next, westbound traffic was shifted onto the new north half, and the old south portion was demolished. Finally, the new south half was jacked off its temporary piers and rolled into place.

The contractor moved the 2200-ton concrete structure in about 12 hours into its permanent position. The final bridge is 328 ft long and 121 ft wide. PBES techniques allowed WSDOT to avoid taking the bridge out of commission



The NE 8th Street Bridge during its phased construction in Bellevue, Wash. Photo: Guy F. Atkinson Construction LLC.

for up to a year or reducing its capacity by one-half for even longer. The contractor customized techniques to accommodate prefabrication requirements to minimize traffic disruption for downtown Bellevue. The total prefabrication construction caused relatively few disruptions to area drivers, with most closures limited to nights and select weekends and resulted in a wider, safer bridge with more lanes of traffic.

I-85 Project

The Georgia Department of Transportation (GDOT) used PBES to significantly reduce the time and cost of the I-85 Bridge in Troup County, Ga. Using PBES also increased safety and traveler satisfaction.

The I-85 Bridge was planned as a four-span concrete structure with eight columns in each bent. Prefabrication was used for the substructure's columns, pier caps, and deck beams. The bridge components were cast off

site and shipped to the site on conventional semitrailers. The cost savings with PBES were equally compelling. GDOT's approach saved approximately \$1.98 million, or 45% of what the interchange would have cost if it had been built with conventional construction practices.

GDOT's use of PBES expedited construction, reduced cost, improved safety, minimized traveler inconvenience, and provided a high-quality finished bridge.

Closing Remarks

The FHWA deployment goals by December 2012 are to have 100 cumulative bridges designed and/or constructed using PBES techniques, and 25% of single- or multi-span replacement bridges authorized using federal aid to have at least one major prefabricated bridge element that shortens on-site construction time relative to conventional construction. For

FY2011, the Highways for LIFE Pilot Program funding is available to focus heavily on supporting the deployment of EDC initiatives chosen by the states for implementation, and the Innovative Bridge Research and Deployment (IBRD) Program funding is available to support the deployment of EDC bridge-related technologies like PBES and geosynthetic reinforced soil (GRS). The states are encouraged to contact the FHWA division offices for information on these two programs, and for assistance in the deployment of PBES. For additional information on EDC, please visit the FHWA website: <http://www.fhwa.dot.gov/everydaycounts>.

Claude Napier was senior structural engineer with the FHWA Resource Center Structures Technical Service Team in Richmond, Va., now retired; Lou Triandafilou is team leader, Bridge and Foundation Engineering with the FHWA Turner-Fairbank Highway Research Center in McLean, Va.; and M. Myint Luwin is director, Office of Bridge Technology at the FHWA in Washington, D.C.

The I-85 Bridge in Troup County, Ga., used precast concrete substructure elements and beams. Photos: Georgia Department of Transportation.



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- Post-Tensioned Transportation Solutions
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- Pavements, Bridge Decks, Box/Segmental Bridges, and Case Studies

Additionally, the National Bridge Conference Plenary Session will feature Myint Lwin, Director of the Federal Highway Administration's Office of Bridge Technology, who will present an overview and the current state of the authorization of the Federal Highway Bridge Program, and a detailed review of concrete-related legislation. Carmen Swanwick, the state bridge engineer in Utah, our featured state, will share her perspective and vision on the past, present, and future of Utah's concrete bridge applications.

There will be special featured sessions as well, including a report from the New Zealand Earthquake Exploratory Team, as well as overview presentations on the new Third Edition of the *PCI Bridge Design Manual* and the new Strand Bond Quality Assurance Test.

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Using UHPC Connections for Precast Concrete Bridge Decks

by Ben Graybeal,
Federal Highway Administration

The use of precast concrete components has been shown to produce very high-quality and extremely durable bridges. Ultra-high-performance concrete (UHPC), whose mechanical and durability properties far exceed those of conventional concretes, presents an opportunity to significantly enhance the performance of field-cast connections. Of particular interest, UHPCs can exhibit both exceptional bond when cast against hardened concrete and can significantly shorten the development length of embedded steel reinforcement.

Field-Cast Connection Details

Field-cast UHPC connections between prefabricated bridge components have been implemented in nine bridges in Ontario, Canada, and two bridges in the United States. These bridges use a range of details to connect multiple types of precast concrete components, including adjacent box beams, full-depth precast deck panels, and deck bulb-tee girders. The connection designs

used to date have tended to mimic noncontact lap splice connections with a female-female shear key profile. The UHPC concept provides good performance and allows for small, simple connections without requiring the use of post-tensioning or the use of large volumes of field-cast concrete.

Physical Testing Program

The Federal Highway Administration (FHWA) recently completed an experimental study focused on the performance of field-cast UHPC deck-level connections. A summary of the study and results can be found in FHWA-HRT-11-022, available at <https://www.fhwa.dot.gov/publications/research/infrastructure/structures/11022/index.cfm>. The full study results are in NTIS-PB2011-101995, available at www.ntis.gov.

The results of this test program, in combination with the experience gained through field deployments, have demonstrated the viability of the system for precast modular bridge deck

components. The system emulated behaviors that would be expected from a monolithic concrete bridge deck. Noncontact, lap-spliced reinforcement in the transverse and longitudinal UHPC-filled connections was not susceptible to debonding under cyclic and static loadings. The most severe cyclic test concluded with the metal fatigue failure of a series of straight, uncoated No. 5 steel reinforcing bars, which were lapped over a 5.9 in. length in a noncontact lap splice configuration. There was no evidence of the reinforcing bars debonding from the field-cast UHPC, nor water leaking through the UHPC joints during the fatigue testing.

Future Implementation

The concept of using field-cast UHPC to connect precast concrete bridge components is gaining interest. The Ontario Ministry of Transportation and the New York State DOT are continuing to use this technology as appropriate projects arise. The Iowa DOT is planning to construct two projects in 2011. Other states are also considering the benefits of this technology as they move toward increased usage of modular components and other accelerated bridge construction technologies.

Further Information

For further information, readers are encouraged to contact the author at 202-493-3122 or benjamin.graybeal@dot.gov.

Dr. Benjamin A. Graybeal is a research structural engineer at the Federal Highway Administration's Turner-Fairbank Highway Research Center in McLean, Va.

EDITOR'S NOTE

For more information about this concept, see the Route 31 Bridge over Canandaigua Outlet article in the Fall 2009 issue of *ASPIRE*[™], page 28, and the FHWA articles on UHPC in the Spring and Summer 2010 issues, pages 46 and 50, respectively.

Placement of UHPC into the longitudinal connection between deck bulb-tee girders. Photo: New York State Department of Transportation.



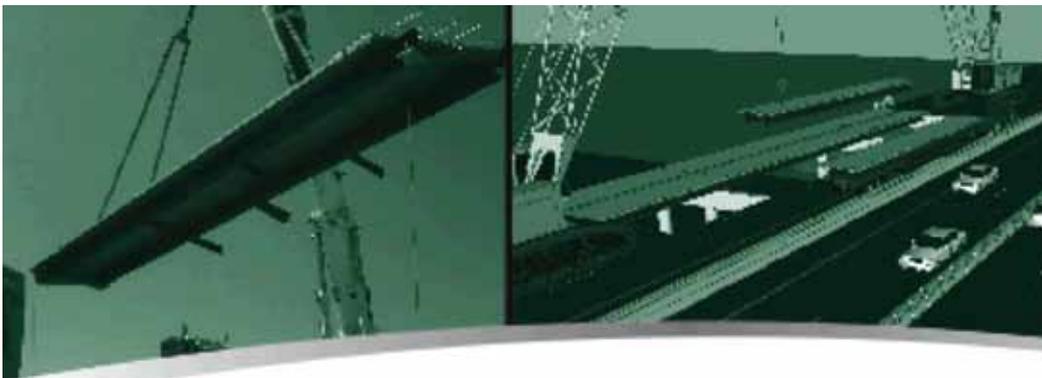
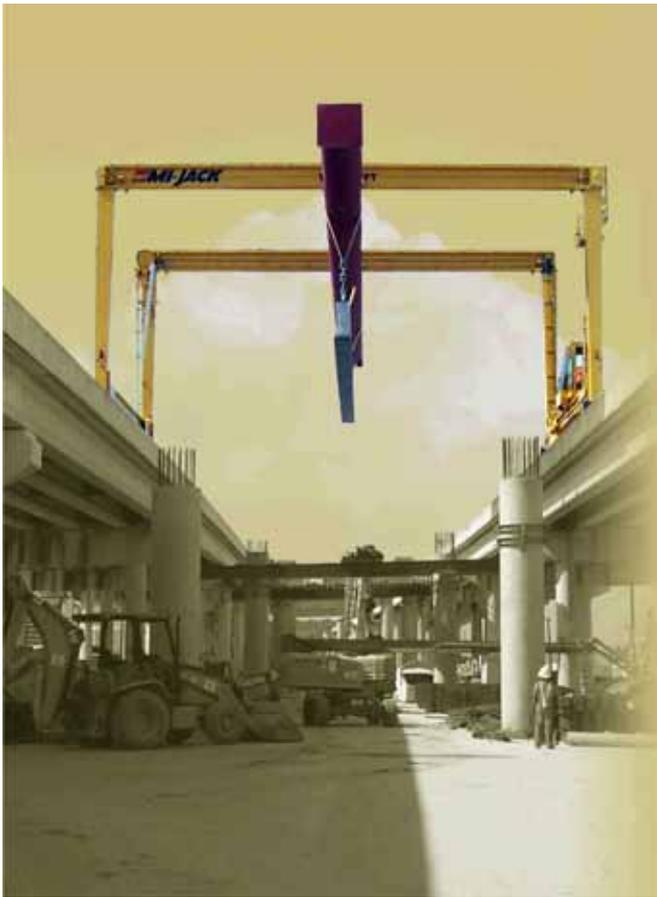
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Burned Bridge Returns in 22 Days

Emphasis on constructability rehabilitates precast concrete bridge quickly

by H. Simon Hagedoorn, FINLEY Engineering Group, and Chris DuBois, Lane Construction Corporation



A fatal accident involving an 8200-gal. gasoline tanker badly damaged the Beachline Expressway/SR 528 overpass in Brevard County, Fla. The bridge was repaired with precast concrete girders in approximately 3 weeks. All photos: Lane Construction Corp.

On January 21, 2011, a fatal accident involving an 8200-gal. gasoline tanker badly damaged the Beachline Expressway/SR 528 overpass at Courtenay Parkway/SR 3 in Brevard County, Fla. Restoring the bridge to service required only 22 days, thanks to close cooperation and a focus on constructability.

Florida Department of Transportation (FDOT) officials concluded that the two easternmost of three spans on each of the side-by-side bridges were beyond repair. Because the overpass provides critical access to the Kennedy Space Center and nearby towns, the bridge had to reopen quickly.

Within 24 hours, FDOT summoned three contractors to a prebid conference at the site. The FDOT emergency-response team developed the project's scope, acquired the original plans, and established a maintenance-of-traffic plan. The job was awarded to Lane Construction Corporation in Maitland, Fla., with a bid of \$2,191,000 and a schedule of 25 days.

“The ability to meet our schedule was the most important factor in our selection of subconsultants and suppliers,” said Gary F. Jera-bek, district manager for Lane Construction Corporation. FINLEY Engineering Group in Orlando was selected to design the repair and reconstruction work.

FINLEY submitted the initial precast, prestressed concrete AASHTO I-beam design to Lane within 12 hours after receiving the contract. The first beam was cast within 24 hours of the notice to proceed by Standard Concrete Products, Tampa, Fla. Final beam designs were complete within 36 hours.

The original design was adhered to as closely as possible while updating to current construction practices. For example, the original AASHTO I-beams had harped strands, but local precast plants were not equipped to fabricate beams that way. Straight strands with end debonding were specified instead.

The bridge features two multi-column piers on driven pile foundations—one on each bridge—including column and cap. The piers were reconstructed to the top of the footing elevation, while the existing footings and piles were reused. Demolition crews took only 2 days to remove the damaged portions. Lane saved 3 days by using monolithic placements for the columns and pier caps, finishing in 4 days. The crew took 1 day to set the beams, which occurred 2 days after they placed the substructure. Seven days after the beams were erected, the bridge deck concrete was cast replacing a total area of 9,628 ft.²

Two days after the decks were placed, barrier walls were slip-formed. Simultaneously, crews milled the pavement. Milling of SR 3 and paving of both roadways followed.

The bridge was completed 3 days ahead of schedule, providing welcome news to a community hit hard by the tragedy. “Fast-track projects require exceptional coordination, cooperation, and understanding,” says FINLEY’s Managing Principal Craig Finley. “Everyone accepted the responsibility to do what it took.”



The repaired bridge was completed 3 days ahead of schedule, restoring critical access to key areas, including the Kennedy Space Center, Port Canaveral, and Cocoa Beach.



High-strength concrete with an 8500 psi design compressive strength was used to facilitate fabrication and delivery of the precast, prestressed concrete AASHTO I-beams, including 16 Type IV beams (12 at 99.5 ft long and four at 36.75 ft long) and four Type II beams (at 36.75 ft long).



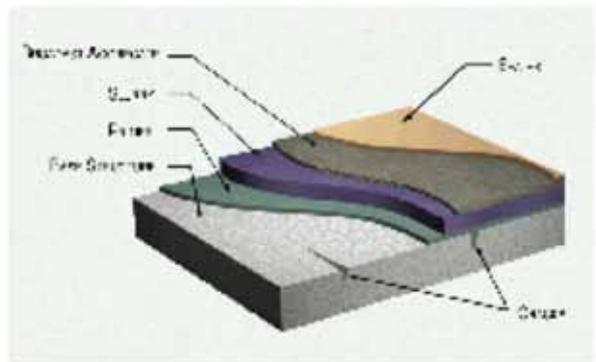
The replacement beams were designed within 12 hours, and the first beam was cast within 24 hours. Final beam designs were complete within 36 hours. Erection continued at night to ensure the deadline was met.

H. Simon Hagedoorn is a regional bridge engineer with FINLEY Engineering Group in Orlando, Fla., and Chris DuBois is the project manager with Lane Construction Corporation in Titusville, Fla.

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Rehabilitation and Re-Use of a 100-year-old Skewed Concrete Arch Bridge

by Michael P. Culmo, CME Associates Inc.

The Massachusetts Department of Transportation (MassDOT) has repaired or replaced many bridges within its “Footprint Bridge Program.” The intent of the program is to replace deteriorated and deficient bridges in the same footprint as the existing bridge, minimizing the amount of approach roadway work. One of these bridges was an historic reinforced concrete arch bridge located on Old State Highway in Chester, Mass. The bridge carries Old State Highway over the west branch of the Westfield River.

The existing 21-ft-wide bridge was a single-span, earth-filled, concrete arch bridge with an overall length of 116 ft measured from the two springlines. An unusual feature is the 30 degree skew of the arch. The bridge crosses a wild and scenic river, therefore impacts to the river and environment needed to be kept to a minimum. The purpose of the project was to increase the width and improve the structural soundness of the bridge, thereby extending its service life.

The bridge was both functionally obsolete and structurally deficient. The bridge was load-posted by MassDOT at 10 tons for two-axle trucks based on an analysis and presumptive materials strength. At first glance, the bridge appeared to be in poor condition. But upon closer examination, the main arch was found to be in very good condition. The fascia of the arch was scaled heavily, but the majority of the structure was sound.

Several options were studied for the project. Concrete core samples were taken and tested, as well as samples of the reinforcing steel. The purpose of the concrete sampling was to determine the compressive strength, chloride ion content, and alkali silica reactivity (ASR). The purpose of the steel sampling was to determine its tensile strength, yield strength, and ductility.

The concrete cores from the arch had compressive strengths of more than 5000 psi. The chloride ion content and ASR levels were low or nondetectable. The reinforcing steel yield strength was over 45 ksi and the ductility was acceptable. With this infor-



This was the condition of the existing north side of the bridge. Photo: CME Associates Inc.



The north side of the completed bridge on Old State Highway over the west branch of the Westfield River in Chester, Mass. It incorporates the standard MassDOT concrete bridge rail. Photo: C. D. Davenport.

mation, the design team determined the arch could safely support modern highway loads. This, combined with the overall condition of the main arch rendered the rehabilitation option feasible. It was also the most cost-effective option. The added benefit to this approach was that the majority of the structural system was retained to serve another century, which demonstrates the sustainable nature of reinforced concrete structures.

The new bridge was widened to accommodate two 10-ft-wide travel lanes and two 3-ft-wide shoulders. This width will provide a safer roadway, while fitting the context of the scenic rural site.

CME Associates Inc. was the engineer of record and C. D. Davenport of Greenfield, Mass., was the general contractor.

Michael P. Culmo is vice president of transportation and structures at CME Associates Inc. in East Hartford, Conn.

Advances in Stress Wave Scanning of Decks and Pavements

Yajai Tinkey, Larry D. Olson, Patrick Miller, and Matthew Hergert, Olson Engineering Inc.

The vehicle-mounted bridge deck scanner (BDS) with rolling sensor wheels was originally funded by the National Cooperative Highway Research Program (NCHRP) Innovations Deserving Exploratory Analysis (IDEA) program. Its applications include comprehensive mapping of top and bottom delamination at the reinforcement, internal cracks, vertical crack depths, thickness profile, and concrete quality/integrity.

The BDS system is equipped with three pairs of transducer wheels. The separation of each wheel can be set to 0.5, 1, or 2 ft. The system was designed to perform either impact echo (IE) testing on all six transducer wheels (typical for the first application) or IE testing on one of the transducer wheels and spectral analysis of surface waves (SASW) on both wheels in each pair (more suitable for detecting debonded asphalt and cracking in decks). Test resolution is up to 0.5 ft along scan lines with a scanning speed of 1 to 1.5 mph. The BDS system has been tested on seven bridge decks to date with very accurate damage mapping results.

The BDS was also researched and developed as part of a Strategic Highway Research Program (SHRP 2) project for detection of delaminated (debonded) asphalt pavement layers.

Yajai Tinkey is associate engineer, Larry D. Olson is principal engineer, Patrick Miller is senior project engineer, and Matthew Hergert is project engineer, all with Olson Engineering Inc. in Wheat Ridge, Colo.

A detailed paper on this topic by the authors was presented at the 2011 Engineering Mechanics Institute Conference. It may be downloaded from the ASPIRE™ website, www.aspirebridge.org, click on "Resources" and select "Referenced Papers."

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CARMEL, INDIANA

by Michael T. McBride, city of Carmel, Ind.

Roundabout Interchange Corridor Complete...Almost.



Carmel, Ind., has dramatically improved east-west connectivity with the use of a series of teardrop interchanges. All photos: American Structurepoint Inc.

In 1998, the city of Carmel, Ind., began its aggressive and innovative efforts to develop the Midwest's first roundabout interchange-dependent, free flowing expressway. The expressway had been 5 miles of congestion-plagued Indiana State Road (SR) 431, a four-lane, 50,000 vehicles per day, limited access highway dividing the community in half. SR 431 through Carmel was producing significant traffic delays at all eight of its at-grade signalized intersections. Making matters worse, Carmel's police department was responding to more than 200 accidents each year at the corridor's intersections, many of which involved injury and several even resulted in deaths.

When Carmel was finally successful in convincing the Indiana Department of Transportation (INDOT) to relinquish SR 431 to the city, the city not only changed the name to Keystone Parkway, it also began a more than \$100 million investment in the corridor. Although improving efficiency of flow through Carmel on Keystone Parkway was important, the city's primary impetus in the proposed project was to improve east-west community connectivity across the Keystone corridor. For years, the signalized intersections had been daunting places for automobiles to pass and downright frightening places for pedestrians.

The teardrop interchanges have greatly reduced traffic congestion and improved safety for motorists and pedestrians.

Carmel's transformation would have to be swift. The agreement, signed in October of 2007, relinquishing control of the roadway to Carmel, required that the city have six of the eight intersection improvements complete prior to 2011 when INDOT planned to begin the reconstruction of a parallel route, U.S. Highway 31. From conception to completion, the city would have only 3 years to transform the Keystone Corridor and have it ready to accept detour traffic during the U.S. 31 construction.

The city's plan for the roadway was to convert seven of the eight signalized intersections to teardrop roundabout interchanges. Keystone would have to be depressed through each intersection, in some cases as much as 20 ft, in

order to avoid building retaining walls above existing grade and creating a visual barrier east to west. The bridges carrying each east-west street would be constructed over the top. The bridges would also accommodate the very compact twin teardrop roundabouts that would control the Keystone ramp terminal traffic.

Construction began in May 2008 on the first two interchanges. Two additional interchanges were completed each year through 2010. By October 1, 2010, all six interchanges were fully operational. The original anticipated project budget of \$112 million resulted with a total final project cost of approximately \$108 million.

The use of concrete was critical to meeting the project purpose, budget, and schedule. Precast, prestressed concrete allowed accelerated, all-weather construction and the aesthetic appeal and long-term durability that the project required.

Michael T. McBride is the city engineer for the city of Carmel, Ind.

EDITOR'S NOTE

In May 2011, nearly 400 engineers from around the world gathered in Carmel, Ind., population 79,000, to attend the seventh annual International Conference on Roundabouts. Carmel has begun work on its 69th roundabout and will build three others this summer. You can read more about the Keystone Parkway interchanges in the Fall 2010 issue of ASPIRE,™ page 24.



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Visit this website to read more about the Miami Intermodal Center located next to Miami International Airport and the MIC-Earlington Heights Metrorail Extension Project described on page 26.

www.wsdot.wa.gov/projects/sr519/sr+519+internodal

This website provides more information about SR 519 Intermodal Access Project described on page 42. Click on Image Gallery for some photographs and a link to photographs on flickr.

www.wsdot.wa.gov/projects/piercecountyhov/sr16_wbnaileyvalley/

This Washington State Department of Transportation website contains information about the SR 16-Westbound Nalley Valley Interchange described on page 22.

www.ci.redding.ca.us/TransEng/cypressbridge.cfm

This city of Redding, Calif., website provides more information about the Cypress Avenue Bridge described on page 36. The site includes a photo album and a time-lapse video.

itd.idaho.gov/projects/garvee/D3/I84_Caldwell_Meridian_Corridor/I84_TenMile_road_interchange.asp

Information about the Ten Mile Road Interchange over I-84 is available from this Idaho Transportation Department website. See page 18.

www.carmellink.org

This website contains information about the Keystone Avenue reconstruction project described on page 56. The site contains a drive-through simulation, written instructions on how to navigate the new roundabouts, and an instructional video for both drivers and pedestrians.

www.fhwa.dot.gov/everydaycounts/

This Federal Highway Administration website provides more information about the Every Day Counts initiative described in the FHWA article on page 46. Click on the Prefabricated Bridge Elements and Systems link and then Case Studies, I-85 Project for more information about the I-85 project.

www.fhwa.dot.gov/hfl/summary/ga/03.cfm

More technical details about the I-85 project are available at this FHWA Highways for Life website.

www.fhwa.dot.gov/publications/research/infrastructure/structures/11022/index.cfm

A summary of a recently completed FHWA experimental study on field-cast UHPC connections is available at this website. (See page 50.)

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.

NEW www.arc-competition.com/welcome.php

This is the official site for ARC—the International Wildlife Crossing Infrastructure Competition. ARC selected five teams to develop concept designs for a wildlife crossing at Colorado's West Vail Pass along I-70. The designs can be viewed at this website.

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.

NEW 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*TM 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 67 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.

<http://international.fhwa.dot.gov/pubs/pl10014/pl10014.pdf>

The U.S. Federal Highway Administration's Office of International Programs has released a report titled *Assuring Bridge Safety and Serviceability in Europe*. The report describes a scanning study of Europe that focused on identifying best practices and processes designed to help assure bridge safety and serviceability. The scan team gathered information on safety and serviceability practices and technologies related to design, construction, and operations of bridges. A summary of the study was provided in *ASPIRE* Winter 2010, page 50.



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Expanded Shale, Clay and Slate Institute Update



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

Once prewetted, the pores in ESCS aggregate act as internal reservoirs, providing a source of moisture to replace that consumed by hydration. As the cement hydrates and moisture is extracted from the relatively large pores in the ESCS aggregate into the much smaller ones in the hydrating cement paste and allows hydration to continue without desiccating the paste. This reduces the development of internal stresses and the tendency for early-age cracking to occur.

Another benefit of internal curing is an improvement in the degree of hydration and the associated mechanical properties for the same mixture proportions, including increased strength and impermeability. This is particularly marked in mixtures containing high dosages of supplementary cementitious materials.

As a consequence of these benefits, it is possible to reduce the amount of cementitious material in a mixture while achieving the same performance, with the associated benefits of longer service life, reduced life cycle cost and lower environmental impact.

Internal curing is the common sense addition to the sustainability of concrete.

For more information about ESCS aggregate, visit www.escsi.org.

The Fatigue Limit States, Part 1



by Dr. Dennis R. Mertz

A recent interim revision to Section 3 of the *AASHTO LRFD Bridge Design Specifications* introduced a second fatigue limit-state load combination. This article discusses the intent of the two fatigue limit states.

The new fatigue limit state is Fatigue I, where the factor on live load is 1.5. Fatigue II is the pre-existing fatigue limit state where the factor on live load remains at 0.75. The concept of two fatigue limit states was introduced so designers would better understand fatigue design. It does not change fatigue designs or the proportions of bridge members.

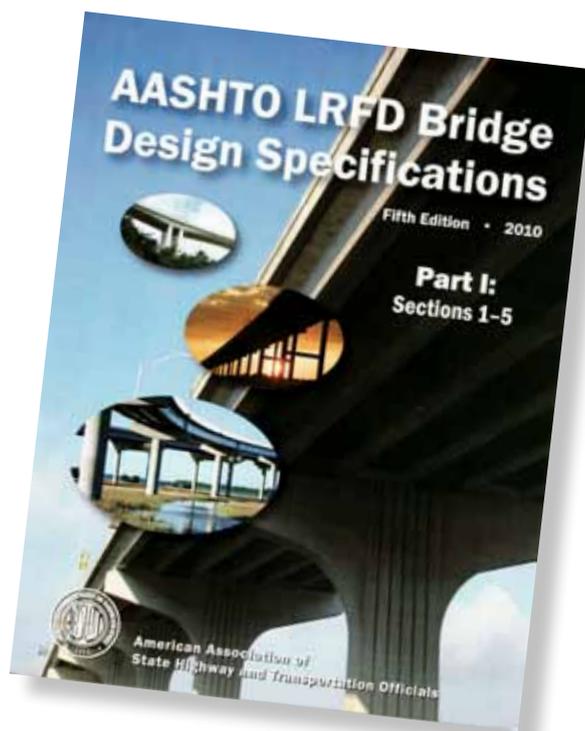
Fatigue damage does not accumulate significantly due to a relatively small number of heavy trucks but more due to the vast number of trucks of more typical weight. Thus, the fatigue limit-state factor on live load included in the *LRFD Specifications* since the first edition was less than one, specifically 0.75. Further, this load factor is not applied to the HL-93 vehicle and lane superposition, but only to the design truck with a fixed rear-axle spacing of 30 ft. The factored stress range from this load factor and truck represents the most typical truck. This factored stress range is used to design bridge details to exhibit a finite fatigue life based upon the average daily truck traffic (ADTT). This pre-existing fatigue load factor has been assigned to the new Fatigue II limit-state load combination. The live-load factor of 0.75 was derived

as the root-mean-cube of the stress ranges experienced by a bridge detail.

Many bridge details exhibit a fatigue threshold such that if all applied stress ranges are kept below this threshold value of stress range, the detail will not crack but will theoretically exhibit

state load combination is not a revelation on fatigue design, but merely a re-writing of the existing fatigue provisions, for both concrete and steel, to explicitly acknowledge infinite-life fatigue design. Previous to the interim revision of adding Fatigue I, the factor of two represented by the Fatigue I load factor divided by the Fatigue II load factor was implicitly included in the fatigue-resistance provisions where appropriate. Thus, fatigue design has not changed, but infinite-life design has become explicit with the designer now knowing when designing for infinite or finite life using the Fatigue I and Fatigue II limit states, respectively.

With the load side of the fatigue limit-state functions discussed above, a future article will investigate the resistance side of the fatigue limit-state functions specifically for concrete bridges.

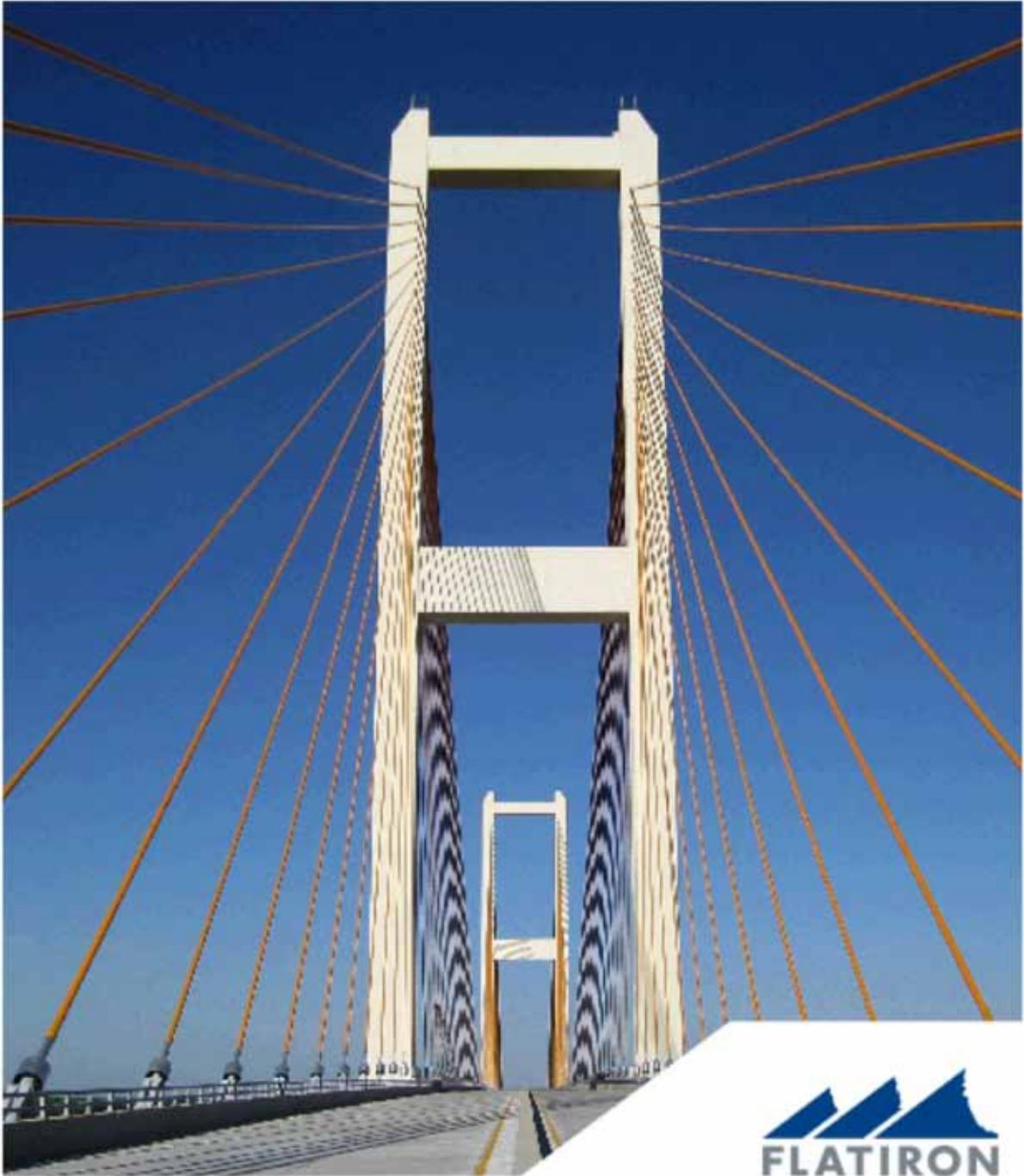


infinite fatigue life. The new Fatigue I limit-state load combination is intended to represent infinite-life fatigue design. The Fatigue I load factor on live load of 1.5 represents the stress range due to the heaviest truck that needs to be considered for fatigue. It is not the absolute heaviest truck. The live-load load factor of 1.5 was derived as the 1 in 10,000 greatest stress range experienced by a bridge detail.

The addition of a second fatigue limit-

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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