ASPIRE™

THE CONCRETE BRIDGE MAGAZINE

WINTER 2011

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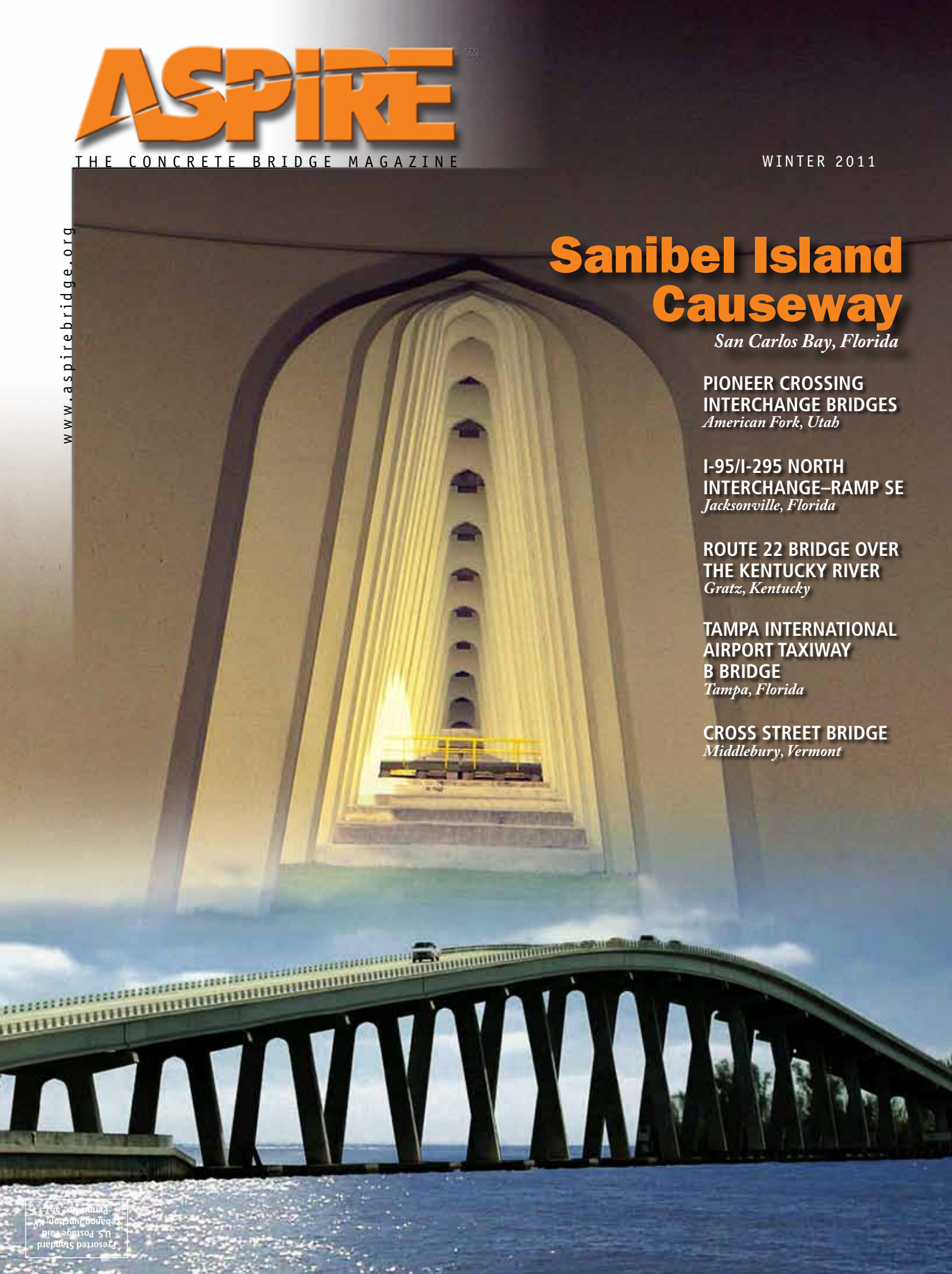

Sanibel Island Causeway

San Carlos Bay, Florida

PIONEER CROSSING INTERCHANGE BRIDGES
American Fork, Utah

I-95/I-295 NORTH INTERCHANGE–RAMP SE
Jacksonville, Florida

ROUTE 22 BRIDGE OVER THE KENTUCKY RIVER
Gratz, Kentucky

TAMPA INTERNATIONAL AIRPORT TAXIWAY B BRIDGE
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Middlebury, Vermont

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Colorado's Longest Highway Span Is Concrete

The **4th Street Bridge in Pueblo** features Colorado's longest highway span at 378'.

The bridge crosses 28 sets of heavy rail tracks in the Pueblo Rail Yard and the Arkansas River. Building from above using concrete segmental balanced cantilever construction allowed for uninterrupted railroad operations during construction. The new bridge accommodates two lanes of traffic in each direction, wide safety shoulders and a multi-use path. Aesthetics selected by the community blend contemporary lines with the natural environment and elements of Pueblo heritage. **The bridge was officially opened to traffic following a ribbon cutting ceremony on December 9, 2010.**

Owner: Colorado Department of Transportation
Designer: FIGG
Contractor: Flatiron

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Social, Economic, and Ecological Benefits of Sustainable Concrete Bridges

Photo: Hardesty & Hanover.

Photo: Kiewit/Clyde, a joint venture, and Parsons.

Photo: Haydon Bridge Co.

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Photo: Ray Stanyard, Photographer.

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EDITORIAL

Photo: Ted Lacey Photography.

Creativity

John S. Dick, *Executive Editor*

Bridge engineers create solutions to safely move traffic over obstacles or to separate intersecting traffic. Most often today, this design process has moved beyond routine. That's when "create" becomes "creativity." Today, design requires imagination, inspiration, ingenuity, innovation, and inventiveness—creativity. The need for creativity results from constraints such as having to accomplish more with less time or money; reducing impacts to the traveling public; extending the lifespans of structures with more durable concrete materials and methods; and working in less space, to name just a few boundaries.

This issue of *ASPIRE*™ offers a host of creative projects and ideas. To bring you more solutions, we developed a new feature called **Creative Concrete Construction**. You'll find these one-page articles on pages 15, 31, and 48. The articles convey creative techniques and methods that may be unique to your area. We think the ideas are worth sharing. We plan to include one or more in each issue. That's where you can help. Have you designed, built, or experienced a unique solution or technique on your project? Can you share it with us? Drop me a note at JDick@PCI.org or select "Contact Us" in the upper right corner at www.aspirebridge.org. We want to hear from you.

Project delivery using design-build methods demands creativity. Even though we didn't plan it, three project profiles in this issue resulted from design-build contracts. Another project article reports on a value-engineering change proposal.

The Federal Highway Administration encourages creativity. The FHWA Highways for LIFE Pilot Program provides incentive funding for states to try innovative approaches. The second part of a two-part article on the program, beginning on page 42, reports on three such approaches.

In the Fall 2010 issue of *ASPIRE*, we featured two creative intersection redesigns. One was the massive relocation of the South Medford interchange on I-5 in Oregon (page 36). The second, a set of six interchanges on the Keystone Parkway in Carmel, Ind., feature the nation's most compact double-teardrop interchanges (page 24).

In this issue, we highlight one of the first diverging diamond interchanges (DDI) in the United States. The DDI causes traffic to cross briefly into opposite lanes to reduce conflict points and increase safety. Traffic flows more smoothly with less time spent waiting at signals. In addition to its unique intersection design, this project had the bridges built at a staging area and moved into place with self-propelled modular transporters. Each bridge needed only an 8-hour traffic closure. The article begins on page 16.

Creativity pays off in administrative offices as well as design offices. If functionally obsolete and structurally deficient bridges are to be replaced and repaired with longer-lasting, state-of-the-art creative concrete designs, adequate funding must be allocated through the agencies' funding mechanisms. Accurate and graphic reports of timely repairs and replacements have been used effectively by the Office of Structures at the Maryland State Highway Administration. The way they do this is reported in the PERSPECTIVE on page 12.

Finally, a note to all who have contacted us seeking the more extensive articles and presentations on Eugène Freyssinet and the Minnesota local bridge scanning tour mentioned in the Fall 2010 issue. Those references are now on the *ASPIRE* website. Go to www.aspirebridge.org and select "Resources."

To all our loyal readers, authors, and advertisers, our very best wishes for a happy and prosperous 2011 from the staff and sponsoring organizations of *ASPIRE* magazine.

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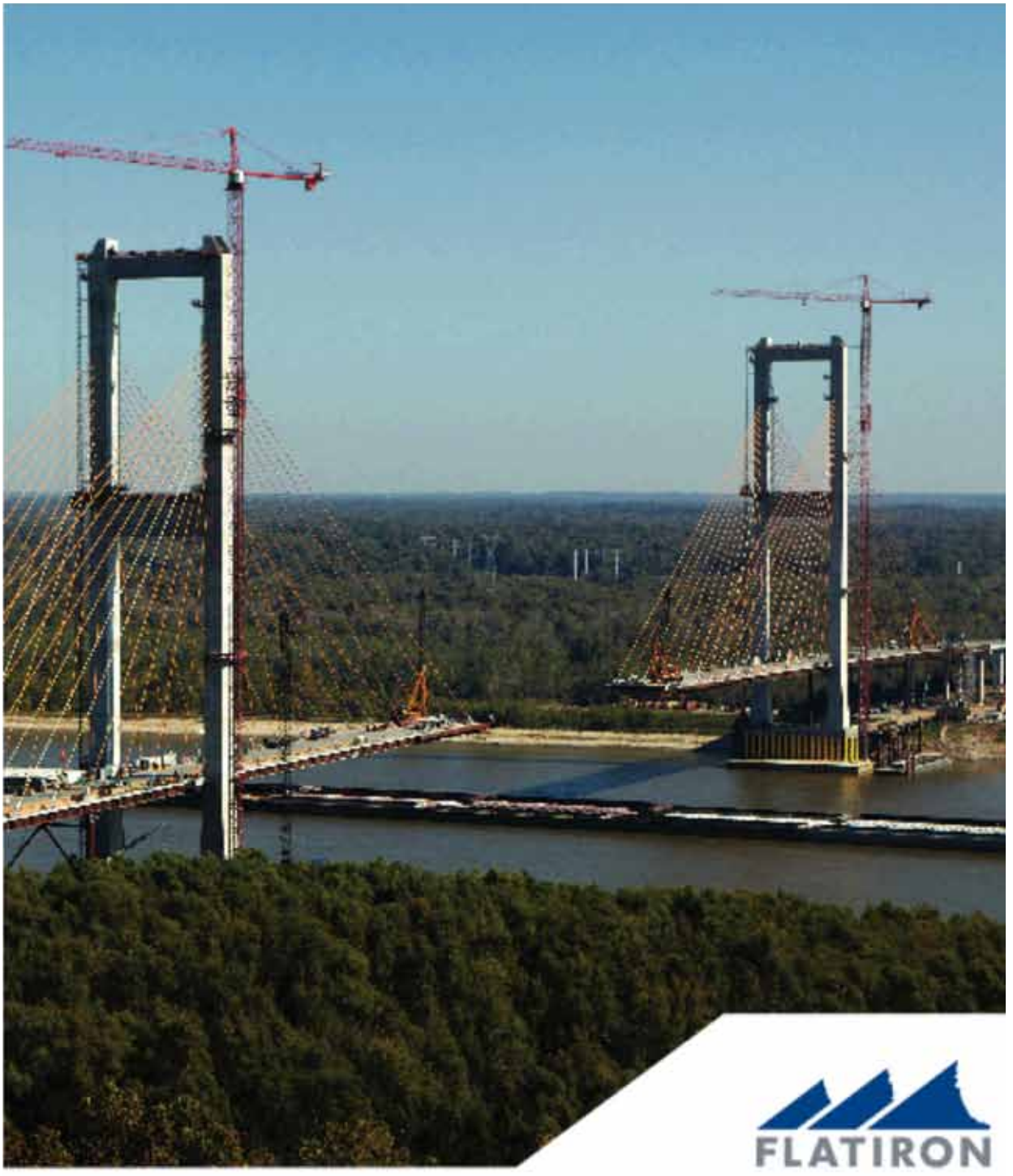
Cover
Sanibel Island Causeway, San Carlos Bay, Florida
Photo: Hardesty & Hanover.



READER RESPONSE

Editor,

In the Fall 2010 issue of ASPIRE,™ *the article on Eugène Freyssinet in the Perspective Section was excellent. The Editor's Note at the end of the article states that the paper by Ken Shushkewich from which the Perspective article came can be downloaded from the* ASPIRE *website. When will that be done?*

Calvin Stripling
Burns & McDonnell
Houston, Tex.

Editor,

I read with great interest the article on Eugène Freyssinet by Ken Shushkewich. At the end of the article there is an editor's note referring to a longer version of the paper, available from the ASPIRE *website. Will it be posted soon?*

Andrew Taylor
KPFF Consulting Engineers
Seattle, Wash.

Editor,

I am absolutely overwhelmed with the production of "The Story of Eugène Freyssinet!" This has made my year. Please thank your layout people for the incredible job they did. It is terrific. Even the font for the title has a French flavor. Everything is perfectly presented on only two pages and shows the five world record span length bridges that Eugène Freyssinet designed and built. The rescue of the Le Havre Maritime Station explains how prestressing came to be accepted by the world (not a lot of people appreciate this story).

The construction of the Luzancy Bridge is presented (not a lot of people know that this was the first precast segmental bridge built). Your edits have made the article enticing for the reader to want to learn more. Now I can appreciate the production process for ASPIRE *which is quite complex and rigorous, and this is what makes it the best magazine in the marketplace today for bridge engineers.*

Ken Shushkewich
KSI Bridge Engineers
San Francisco, Calif.

Editor,

We wanted to thank you for the excellent job in presenting the Minnesota Local Bridge Scanning Tour in the Fall 2010 edition of ASPIRE *Magazine. The layout, pictures, and credits of the article all turned out terrific.*

Also the feature article on the Minnesota Wakota Bridge turned out very nice in my opinion. We're already getting positive feedback from our county engineers on both articles.

At some point in the near future, we would like to communicate these articles to all of our local agencies and Mn/DOT offices through the ASPIRE *website. With that, can you give us an approximate time as to when this edition will be posted on the web?*

We certainly look forward to future opportunities to showcase Minnesota's local concrete bridges and related efforts in the ASPIRE *Magazine.*

Dave Conkel
Minnesota Department of Transportation
Oakdale, Minn.

[Editor's Note]

For all those readers who waited patiently for the Eugène Freyssinet article and the Minnesota Local Bridge Scanning Tour information to be posted on the *ASPIRE* website [www.aspirebridge.org], the files are now there! We invite you to read the fascinating article on Freyssinet and the exciting study undertaken by the state aid bridge office of the Minnesota DOT. On the website, select "Resources" and then "Referenced Papers."

Editor,

You do an excellent job with ASPIRE *magazine! We are proud to be a part of sharing information with the magazine, advertising, and encouraging readership through our reprints of articles and distribution. Thanks for making a difference in our industry.*

Linda Figg
FIGG
Tallahassee, Fla.

Editor,

I always look forward to reading ASPIRE *magazine. As landscape architects, we collaborate with creative structural engineers on the conceptual and detail development of specialty bridges and infrastructure.* ASPIRE *is an incredible asset to the industry with its emphasis on the synthesis of technical innovation and aesthetics. The presentation of the written and graphic information is highly accessible to the layperson. This is important to inform decision makers who value beauty as well as economy in our public works. Your magazine elegantly makes the case that these attributes of concrete are compatible. Congratulations to all at* ASPIRE *on your hard work and success.*

William Collins
Simone Collins Landscape Architects
Norristown, Pa.

Editor,

We would like to reprint your article by Catherine Higgins of Utah DOT on our Utah Transportation Report website [www.utahtransportationreport.com]. We would, of course, attribute your magazine.

David Fierro
H. W. Lochner Inc.
Salt Lake City, Utah

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.

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M. Myint Lwin is director of the FHWA Office of Bridge Technology in Washington, D.C. He is responsible for the National Highway Bridge Program direction, policy, and guidance, including bridge technology development, deployment and education, and the National Bridge Inventory and Inspection Standards.

Kathleen Bergeron is the coordinator of technology transfer within the Highways for LIFE program. She has more than 30 years of experience in transportation programs. Among her numerous accomplishments and awards is the FHWA's highest honor, the Administrator's Award for Superior Achievement.

Dr. Dennis R. Mertz is professor of civil engineering at the University of Delaware. Formerly with Modjeski and Masters Inc. when the *LRFD Specifications* were first written, he has continued to be actively involved in their development.

Robert Healy is the deputy director of the Office of Structures in the Maryland State Highway Administration, where he has worked for 30 years.

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

MANAGING TECHNICAL EDITOR

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

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

January 23-27, 2011
90th Annual Meeting
Transportation Research Board
Marriott Wardman Park, Omni Shoreham, and Hilton Washington, Washington, D.C.

March 24-26, 2011
PCI Committee Days
Wyndham Chicago Hotel, Chicago, Ill.

April 3-7, 2011
ACI Spring Convention
Marriott Tampa Waterside and Westin Harbor Island, Tampa, Fla.

April 18-19, 2011
ASBI 2011 Grouting Certification Training
J.J. Pickle Research Campus, The Commons Center, Austin, Tex.

May 15-19, 2011
AASHTO Subcommittee on Bridges and Structures Annual Meeting
Marriott Norfolk Waterside, Norfolk, Va.

June 5-8, 2011
International Bridge Conference
David L. Lawrence Convention Center, Pittsburgh, Pa.

August 9-12, 2011
Ninth International Symposium on High Performance Concrete
Christchurch Convention Centre, Christchurch, New Zealand

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 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

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

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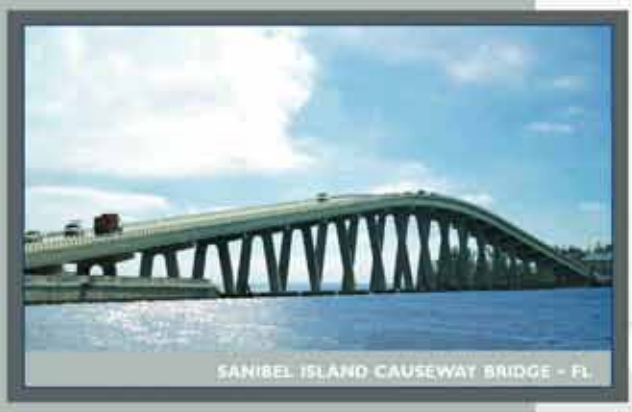
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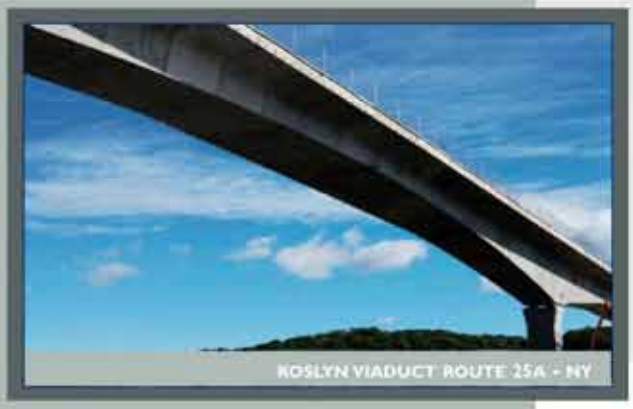
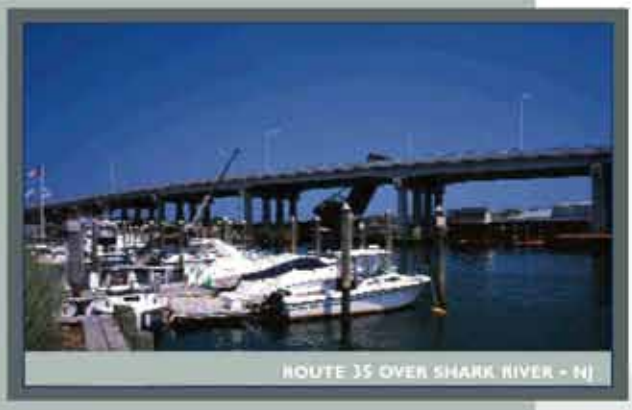

KOSLYN VIADUCT ROUTE 25A - NY


ROUTE 35 OVER SHARK RIVER - NJ


ROUTE 36 BRIDGE OVER SHREWSBURY RIVER- NJ

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CELEBRATING THE PAST, Looking to the Future

by Craig A. Shutt

Completed in December 2009, the $125-million Route 36 Bridge over the Shrewsbury River in Sea Bright, N.J., replaced an existing bascule bridge with a high-level precast concrete segmental box girder design supported on precast, post-tensioned concrete piers. Hardesty & Hanover designed two pedestrian bridges for the project and provided engineering services, including concrete pier design and seismic analysis.
All photos: Hardesty & Hanover.

Hardesty & Hanover enters its 125th year with innovative techniques for designing bridges that are more durable, faster to construct, and more aesthetically pleasing

Bridge engineering has changed drastically since Hardesty & Hanover opened its doors in 1887. Founder Dr. J. A. L. Waddell was a leader in reinforced concrete and steel bridge design and held the patent for the first modern vertical-lift bridge design and other movable-bridge innovations. The firm's work still includes many movable bridges, but expansion into other sectors has enabled its designers to implement new techniques and innovations.

"We are experienced in all types of bridges, both fixed and movable," says Glen Schetelich, a partner in the New York-based engineering firm's Hoboken, N.J., office. The firm's engineers have focused primarily on mid- to short-span bridges, which have involved a range of challenges dealing with terrain, environmental concerns, owners' growing needs, and additional community input.

"Our clients look to us because of the depth of service we provide," adds Keith Griesing, director of engineering. "Many companies are technically capable of creating bridges, but they aren't as attuned to the client's needs as we are. Our goal is to partner with our clients and understand their challenges so we can first deliver a service and ultimately create the best product for them. Our project managers stress communication and teamwork."

Assessing Original Designs

The firm's long history has allowed it to return to some of its original designs. "We have a long history of building durable structures," notes Tim Noles, a partner in the Sunrise, Fla., office. "Having the original plans for a project can be beneficial during rehabilitation work, because it gives us insight into the original intent. Frequently, the owners themselves no longer have copies of the plans."

The firm has extensive history with rehabilitation, often analyzing bridges to determine if they can be preserved. "In some cases, we try to rehabilitate a bridge in kind, with improvements to meet current AASHTO criteria," Noles notes. "But often we replace a movable bridge with a new high-level, fixed bridge." That is happening more

The new $43 million precast concrete bridge along Route 35 over the Shark River in Belmar, N.J., extends 2000 ft using 17 spans of AASHTO girders, including a main span of 170 ft. The bridge, which replaced a bascule bridge that disrupted traffic to beachfront communities, is 84 ft wide and carries four lanes of traffic.

today, Schetelich adds. "The federal government especially is looking to replace movable bridges, if it's feasible."

For instance, the Route 36 Bridge over the Shrewsbury River in Monmouth County, N.J., a 75-year-old double-leaf bascule bridge, was replaced with a high-level structure consisting of precast concrete segmental box girders and precast, post-tensioned concrete piers. The new bridge increases clearance to 65 ft along this main corridor to New Jersey's eastern beaches and the national park at Sandy Hook. Hardesty & Hanover designed two adjoining pedestrian bridges and provided geotechnical engineering, foundation and segmental concrete pier design, scour and seismic analysis, and utility relocation and access. More details of this project are provided in the Summer 2010 issue of *ASPIRE*.™

A similar replacement occurred with the former Route 35 Bridge over Shark River in Belmar, N.J., where a low-level bascule bridge was replaced by a 2000-ft-long, high-level, prestressed concrete bridge with AASHTO girders comprising 17 spans, including a main span of 170 ft.

Community Input Increases

Movable bridges often are replaced due to the growing focus on user costs, which have become a key priority for bridge owners. This concern often leads to more community input on each aspect of the project. "Some projects require a lot of community outreach, and, in those cases, we serve as the owner's partner," explains Griesing. "We can answer the technical questions, but we also understand the owner's goals and can represent those to the community. Today, engineering represents one small part of the puzzle in moving a project from its concept to completion."

That was a key challenge for the new design of the Roslyn Viaduct project along Route 25A over Hempstead Harbor in Roslyn, N.Y. The 29-span, pin-and-hanger steel viaduct was replaced with twin concrete segmental box-girder bridges built using the balanced-cantilever method. The 2200-ft-long viaduct and its 2775-ft-long approach roadway and ramps were replaced in staged construction including innovative design schemes to minimize traffic congestion. More details of this project are provided in the Fall 2009 issue of *ASPIRE*.

The New York State Department of Transportation set up a Bridge Task Force that met monthly with community groups and concerned citizens. "We really got to know the people most involved, and they learned about us," says Griesing. "The repetition created a more relaxed atmosphere so we could discuss concerns more informally."

The meetings included new ideas garnered from the groups and handouts that showed the current plan. "This was a new approach to a project for me, and it required a different set of skills than engineers typically use," he says. "But I expect it will occur more often with bridge owners."

The biggest concerns were the construction process and disruptions, he notes. "It was interesting to me that they were more interested in the 'how' than in the 'what,' " he says. "The construction staging, scheduling, and interaction with the work on a daily basis were key parts of the process."

'We are experienced in all types of bridges, both fixed and movable.'

Aesthetics a Growing Priority

Aesthetics also was a concern on the Roslyn Viaduct, as it often is in such meetings, he adds. "Owners are realizing that aesthetics have a great value to a community, particularly as older, established bridges are replaced. Citizens want a proportionate structure that reflects the community and the surrounding environment. It's going to be there for a long time, and those concerns have to be taken seriously. You have to partner with the community to get it right," says Greising."

That's especially important for many structures in Florida, adds Noles. "It's a national trend, but Florida is a leader in creating aesthetically pleasing bridges. That's because of its tourist industry and the many bridges along the coast, where they are landmarks in the community. The state wants its bridges to make an impression, because they add to the scenic landscape and can have a financial impact."

That was certainly the case when Hardesty & Hanover redesigned the Sanibel Island Causeway over San Carlos Bay in 2006. The firm first conducted an in-depth inspection of the existing double-leaf, Hopkins Trunnion-type bascule bridge with accompanying steel-stringer flanking spans.

Then it developed construction plans and specifications to implement the recommended high-level fixed bridge, consisting of precast, prestressed

'Owners are realizing that aesthetics have a great value to a community.'

'We are always looking for new ideas and working with manufacturers to find new concepts.'

concrete Florida bulb-tee girders spanning a maximum of 144 ft over 21 spans for a total length of 2996 ft. The substructure features canted-leg reinforced concrete piers founded on precast, prestressed concrete piles. The substructure was designed for vessel-collision impacts and a 100-year storm scour. See the related article, "Concrete Bridges in Lee County, Florida," in the Spring 2009 issue of *ASPIRE*.

"The biggest challenge was working with citizen groups to create a design that satisfied their concerns and met the owner's needs," says Noles. Its impact on the skyline was a particular concern, as were aesthetic treatments and colors for railings, MSE walls, and other visible elements. "We invited the community to provide ideas and incorporated many of them into the design during a 3-month process."

Maintenance is Key

Owners also are guarding their long-term budgets more than ever. That often leads to concrete structures. "We've been designing bridges to LFRD standards to last 75 years, but 100 years is becoming more common," says Griesing. "That requires a more robust design, along with key improvements on a case-by-case basis to lower the allowable stresses. Most officials realize that focusing on short-term savings is not a good strategy anymore."

Adds Noles, "Many owners prefer concrete, because they won't have to paint it, even with new painting systems that extend paint life. Concrete bridges can result in lower maintenance costs than steel bridges."

Concrete bridges also are being considered more often due to the speed with which they can be built once the site is available. Precast concrete components in particular can reduce the amount of time needed for road closures, even if they don't speed up the overall design-to-completion time, notes Griesing. "They provide a more intense impact for a shorter duration, which officials like."

Preconstruction activity has increased, he adds, because it keeps the site clear and open for longer. "New York State likes precast concrete projects," he says. "They like the prefabrication aspect, as well as the shop-level quality of the components and the amount that can be done in a short time once the pieces arrive at the site."

Using the NEXT Beam

The firm recently worked with PCI Northeast, a chapter of the Precast/Prestressed Concrete Institute to incorporate a new mid-size girder for span lengths of 50 ft to 80 ft, into one of its projects. The beam, called the Northeast Extreme Tee (NEXT) girder acts as a simple span under dead load and continuous under live load with the use of a cast-in-place closure at the pier.

The firm used the beams as part of its rehabilitation of the Kew Gardens Interchange in Queens, N.Y., which consists of the Van Wyck Expressway, Grand Central Parkway, and the Jackie Robinson Parkway. The Queens Boulevard Bridge in this complex will feature a two-span, NEXT-beam structure, providing a form for a lightweight cast-in-place concrete deck, saving substantial time during construction. Beam lengths will run between 68 ft and 88 ft. The beams and girders utilize concrete with a specified compressive strength of 10,000 psi.

The design of the $127-million precast concrete Roslyn Viaduct project over Hempstead Harbor in Roslyn, N.Y., was developed with input from a Bridge Task Force that included local public officials and appointed representatives of community groups. Those discussions included the replacement bridge and pier types, staged construction, traffic noise concerns, aesthetics, environmental impact, business impact, and other factors.

The $29-million Sanibel Island Causeway over San Carlos Bay in Florida consists of a precast concrete high-level, fixed structure that replaced a bascule bridge. The new design, spanning a maximum of 144 ft over 21 spans for a total length of 2996 ft, features prestressed concrete Florida bulb-tee girders. The substructure consists of canted-leg reinforced concrete piers founded on prestressed concrete piles.

New Concepts Proliferate

Hardesty & Hanover's designers are looking at other innovations in concrete bridge design as well. These include lightweight concrete, especially for decks, as in the Queens Boulevard Bridge, and a variety of concrete additives, such as silica fume, fly ash, and calcium nitrite to add durability by inhibiting moisture penetration and corrosion. They also are using more epoxy-coated reinforcement to increase durability. "There are some new products on the horizon that we expect will help increase durability," says Schetelich. "We are always looking for new ideas and working with manufacturers to find new concepts."

That includes an increased use of self-consolidating concrete (SCC), adds Griesing. New York State in particular has been using more SCC. "They like the flowability," he explains. "As precast concrete shapes become more complex, they require more reinforcement including additional post-tensioning. SCC can ensure there are no voids as the interiors become more crowded. The smooth finish is also very desirable."

Increased seismic forces are leading to more heavily reinforced components, which encourages the use of SCC, says Schetelich. Those requirements are impacting many elements, including piers. "As the codes tighten, I expect we'll see more reinforcement needed, which will lead to increased use of SCC."

The firm's engineers intend to continue to use new technologies, in conjunction with their long history and knowledge of existing bridges, to aid their clients in creating innovative designs. "New segmental concepts are providing new ways to meet challenges, and there are other techniques that are gaining ground now," says Griesing. "They give us more flexibility in meeting challenges and add more tools for us to use."

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

Building on 125 Years

The firm that would one day become Hardesty & Hanover was founded by Dr. J. A. L. Waddell in 1887 in Kansas City, Mo. He believed his firm could succeed only if it was owned and operated by innovative and passionate engineers like himself.

That philosophy continues today, following the announcement in September that the company has formed a strategic alliance with Thornton Tomasetti Inc. in New York to collaborate on the evaluation and engineering of transportation infrastructure and movable structures. The two companies have worked together in the past on an informal basis, notably on the replacement for the drive system for the five retractable roof panels at Miller Park in Milwaukee, Wis.

Waddell's company became Waddell & Hendrick in 1899, followed by Waddell & Harrington in 1907 and Waddell & Son in 1917. It moved to New York City in 1920, and became Waddell & Hardesty in 1927 when Shortridge Hardesty was made a partner. The name changed a final time in 1945 when Clinton D. Hanover joined the firm.

Among the company's signature structures is the South Halsted Street Bridge in Chicago, built in 1894, which became the prototype for vertical-lift bridges. Other early structures included the Arroyo Seco Bridge in Pasadena, Calif. (1913), the Goethals Bridge and Outerbridge Crossing in New York (1928), the Marine Parkway Bridge in New York (1937), and the Rainbow Bridge to Canada from New York (1941).

Hardesty & Hanover today operates 13 offices worldwide with more than 250 employees.

The new Queens Boulevard Bridge in the Kew Gardens interchange in Queens, N.Y., will feature the Northeast Extreme Tee (NEXT) beam developed by PCI Northeast. The beam offers a modified tee shape that creates advantages while utilizing concrete with 10,000 psi compressive strength.

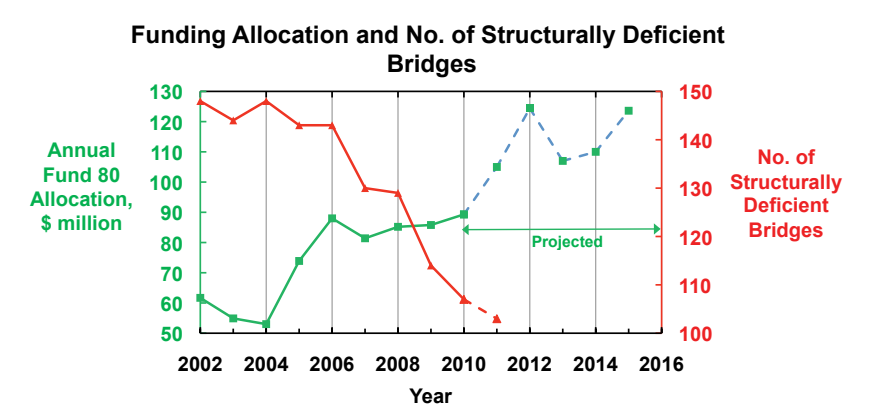
Using Data-Based Bridge Performance Measures

CREATING DETAILED PERFORMANCE MEASURES THAT SHOW THE IMPACT OF BRIDGE FUNDING CAN SWAY STATE ADMINISTRATORS AND ELECTED OFFICIALS

by Robert Healy,
Maryland
State Highway
Administration

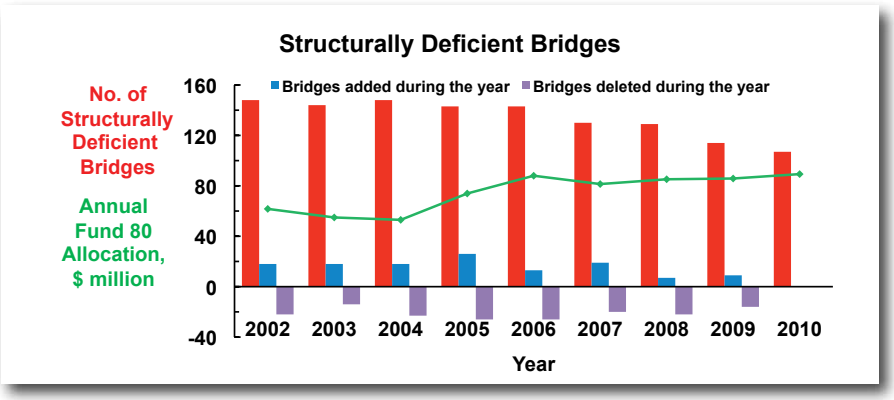
Ask any elected or state official if bridge preservation is important, and they'll agree that it absolutely is. No one wants to face the ultimate disaster of a bridge collapse due to lack of preservation. But when the time comes to allocate funds, the array of competing "important" programs often expands beyond the state's available resources, leaving bridge repairs and replacements underfunded. To ensure that bridge projects receive the money they deserve—and that they can hang onto it as budgets tighten during the year—engineers need to be confident that fund allocators understand the impact the money will have on citizens' lives.

In Maryland, we meet this need with a series of data-based performance measures with illustrative charts that show that funding added to the department's budget will directly impact the number of structurally deficient bridges that we operate. This effort has proven successful, securing even more data points that help show the cause-and-effect relationship that makes a compelling case.



The key chart in Maryland's presentation for funding allocations uses performance data produced for StateStat showing funding allocations each year compared to the number of structurally deficient bridges. The chart visually demonstrates the value that added funding can provide.

As a result of this effort and more focus by state officials in general on bridge rehabilitation, funding for bridge projects in the state has risen significantly, from $53 million in 2004 to $89.3 million in 2010. The total is expected to continue to rise, reaching a projected $124.4 million in 2012. Over the same period, the number of bridges maintained by the State Highway Administration that are "structurally deficient" has dropped from 148 in 2004 to 107 in 2010.



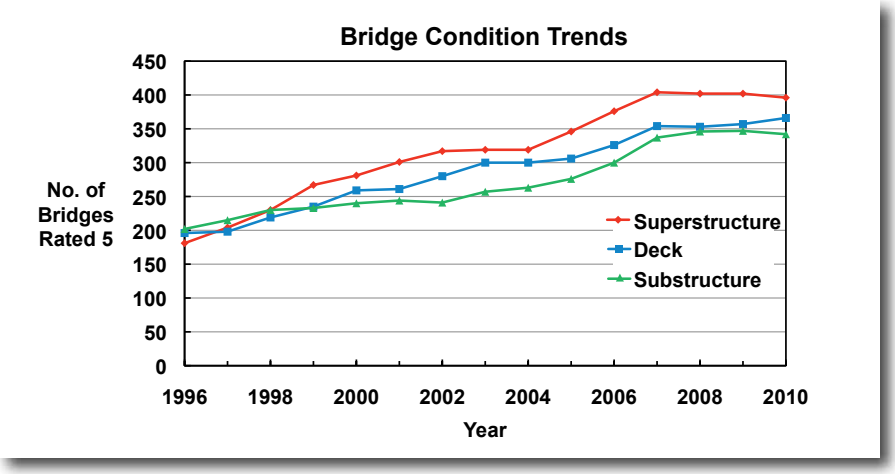
This chart shows the number of structurally deficient bridges on the State Highway Administration system per year, along with the amount of increase or decrease compared to the amount of yearly funding.

Showing the Relationship

The intensive data-tracking and presentation process began in earnest 5 years ago, as we focused more attention on the relationship between the level of funding received and the condition of bridges. The critical element is proving that money spent on projects has a payoff. We focus on that point specifically in our presentation. Intuitively, this cause-and-effect relationship makes sense, but showing quantitative data makes it stand out from other highway programs competing for funds.

The program solidified in 2006 thanks to the direction of Governor Martin O'Malley, the former mayor of Baltimore. As mayor, O'Malley instituted a reporting mechanism for department performance, called CityStat. When he moved into the governor's mansion, he expanded the concept to all of Maryland. The StateStat data gathering process encouraged us to compile as much information as necessary to explain the department's performance accomplishments and goals.

This chart shows the growing number of bridges that are rated 5 and in danger of falling into the structurally deficient category (rating of 4 or less). It also shows the beginning of a trend that preventative maintenance on nondeficient bridges is beginning to pay off. The information can help persuade officials that money allocated for this purpose will help prevent more bridges from falling into the category of structurally deficient.



The information is used to create the presentation on which funding requests to the state Department of Transportation and other funding groups are based. It also forms the basis for presentations given to other bridge groups and association meetings.

As noted, the dramatic cause-and-effect relationship became apparent between 2004 and 2006, when funding rose from $53 million in 2004 to $73 million in 2005 and $88 million in 2006. That growth was charted against the number of structurally deficient, state-operated bridges, which fell from 143 in 2006 to 130 in 2007, 129 in 2008, and 114 in 2009. Maintaining high levels of funding in 2007 through 2009 resulted in the number of structurally deficient bridges to continue falling.

Showing this slightly delayed response (which is expected as the funding is put into use) not only aids in securing necessary funding each year, but it helps retain it as budgets get squeezed for various reasons as the year unfolds. During the recent recession, when funds became scarce as motor-vehicle titling fees and other revenues declined, many departments and programs were cut back. However, the bridge department kept its funding intact, helped by the emphasis placed on bridge preservation by senior officials and because we could demonstrate that the allocated funds produced measurable performance to benefit our citizens.

New Data Added

The performance data, which previously required only a few pages, continues to be expanded as new charts and relationships are found to help explain how well the budget is leveraged. The data now are produced in an annual report that includes historical information and contextual data in addition to the performance statistics.

The next challenge is to convince allocators to continue funding projects so structures can be addressed before they reach the structurally deficient stage. None of the existing bridges are improving on their own, and our goal is to gain enough funding that we can prevent more from falling into this category.

Preventing bridges from falling into the structurally deficient category will require a new type of measurement to show how the money has produced a return on the investment. Our goal is to use performance data to establish sustainable funding levels that support aggressive preventative maintenance and extended bridge life while minimizing life-cycle costs.

All states have access to this basic bridge information because it is required in annual reports to the federal government. The key to gaining the necessary funding is presenting it in a performance-based model to show that bridge expenditures create a significant bang for the buck.

Non-Funded Bridge Projects with Costs in Excess of $5 Million Ranked by Priority Needs

System Preservation Costs and Capacity Improvement Costs

Priority	Project Description	County	System Preservation Cost 2010	Capacity Improvement Cost 2010	Total Improvement Cost 2010
1	MD 272/AMTRAK	Cecil	$6,000,000	$4,000,000	$10,000,000
2	Frederick Road over I-695	Baltimore	$5,000,000	$20,000,000	$25,000,000
Priorities 3-13					
14	I-70/MD 63	Washington	$11,000,000	$3,000,000	$14,000,000
15	Crosby Road over I-695	Baltimore	$3,000,000	$3,000,000	$6,000,000
16	I-81 over Potomac River	Washington	$6,500,000*	$22,500,000*	$29,000,000*
		Totals	$98,700,000	$98,300,000	$197,000,000

*Maryland's share of the costs

To ensure officials understand that problems loom on the horizon, the department produces a list of upcoming nonfunded bridge projects in excess of $5 million to repair, ranked by needs. This chart is also useful in showing that much of the cost associated with large bridge preservation projects is not related to bridge condition, but nevertheless frequently must utilize precious bridge preservation funds in order to proceed.

Precast Concrete Façades in OREGON

by Keith Kaufman, Knife River Corp.

The Columbia River Gorge National Scenic Area includes 79 miles of I-84 that follows the Columbia River in Oregon. The I-84 Corridor Strategy provides guidelines from hundreds of agencies, stakeholders, and citizens related to the long-term vision and design for structures in the corridor. The guidelines emphasize a Cascadian bridge style that includes monuments at bridge abutments, textured formliners, haunched elliptical-girder profiles, and open bridge rail geometry.

To date, four bridges have been designed following these guidelines and three are complete. To achieve the appropriate aesthetics and desired bridge sight lines, the fascia panels are cast with specified formliners, normal weight gray concrete, and are supported from the bridge superstructure. After erection, specified stain combinations are applied to the fascia panels, superstructure, and substructure elements to complete the finish.

Keys to Success

Bridge contractors and engineers rarely deal with fascia panels and related connections. The *AASHTO LRFD Bridge Specifications* provides little guidance related to these important details. Engineers need to consider how to support the panels, whether to cast the deck before or after panel erection, and how to accommodate dead and live load deflections. Translation and vertical construction and erection tolerances need to be incorporated into the connections. Shop drawings must include details of the interface of fascia panels and supporting elements. Preconstruction meetings are critical to ensure tolerances and erection techniques requiring special hardware are understood. Engineers should also consider future inspection and the possible replacement of fascia panels due to damage from over-height vehicles or debris loading. The contractor and precast manufacturer must coordinate the purchase of formliners to ensure that field cast concrete and precast concrete match.

Keith Kaufman is chief engineer at Knife River Corp. in Harrisburg, Ore.

EDITOR'S NOTE

For more information related to the I-84 Corridor Strategy and bridge projects, see www.oregon.gov/ODOT/HWY/REGION1/ColumbiaGorge.

The guidelines in Oregon's I-84 Corridor Strategy emphasize a Cascadian bridge style that features precast concrete panels with a façade cast on textured formliners. Designers must pay close attention to the connections for such panels to ensure they fit in the field. Photos: Knife River Corp.

Completed diverging diamond interchange at Pioneer Crossing and I-15, American Fork, Utah. All photos: Kiewit/Clyde, a joint venture, and Parsons.

PIONEER CROSSING

by Steve Haines, Parsons Corporation

A diverging diamond interchange on the move

The $172 million Pioneer Crossing project in American Fork, Utah, comprises 6 miles of new arterial highway between two major development centers in Utah County and 1 mile of reconstruction of I-15, south of Salt Lake City. The new roadway serves a significantly growing community within the cities of American Fork, Lehi, and Saratoga Springs. The jewel of this new connector is its interchange with I-15—a diverging diamond interchange (DDI).

The interchange was originally conceived by the Utah Department of Transportation (UDOT) as a single-point urban interchange (SPUI). The Request for Proposals, however, provided an Alternate Technical Concept (ATC) process that allowed individual design-build teams to develop, gain UDOT approval, and include innovative concepts in their proposals for the project. The winning team submitted the DDI, including necessary traffic modeling analysis to support the concept.

The DDI concept had two main advantages over a SPUI: reduced right-of-way requirements and increased safety for the traveling public. The DDI requires vehicles to briefly cross to the opposite side of the road at crossover intersections. Vehicles go a limited distance over the interstate before they cross back to the traditional side of the roadway. This layout reduces the number of conflict points by eliminating left turns crossing opposing traffic. The team was awarded the contract for the project in the fall of 2008, providing the cost benefit of the DDI and the time advantages associated with accelerated construction techniques.

The DDI includes twin two-span prestressed concrete girder structures that replaced the existing four-span structure over I-15. Traffic was maintained during construction of the DDI by phasing construction of the twin structures. Additionally, the individual superstructure spans were constructed adjacent to the existing interchange and moved into the final location using self-propelled modular transporters (SPMTs). Once in place, closure pours were placed to achieve continuity of the two-span structure.

Layout and Bridge Design

Once the preliminary alignments of the DDI were established, design of the structures began. The final in-place design for each bridge called for nine precast, prestressed concrete bulb-tee beams, each with a depth of 94½ in. and a maximum single unit length of 191 ft 9½ in. Each beam has a top flange width of 4 ft 6 in. and contains fifty-six 0.6-in.-diameter straight strands and eighteen 0.6-in.-diameter harped strands. Beam spacing was 7 ft 9 in. center to center and the geometric layout required a 53-degree skew at the abutments and center bent. The beam design required a concrete compressive strength of 10,000 psi at 28 days and 7,000 psi at prestress transfer. The beams supported an 8½-in.-thick, cast-in-place composite deck.

During design, a specialist in heavy lifting and transport solutions was

profile

PIONEER CROSSING INTERCHANGE BRIDGES, I-15 TO REDWOOD ROAD / AMERICAN FORK, UTAH

BRIDGE DESIGN ENGINEER: Parsons Corporation, Pasadena, Calif.

PRIME CONTRACTOR: Kiewit/Clyde (A Joint Venture between Kiewit Western Co., American Fork, Utah, and W.W. Clyde, Springville, Utah)

PRECASTER: Hanson Structural Precast, Salt Lake City, Utah, a PCI-certified producer

CAST-IN-PLACE CONCRETE SUPPLIER: Geneva Rock, Orem, Utah

HEAVY LIFT SUBCONTRACTOR: Mammoet, Salt Lake City, Utah

A schematic diagram of the Pioneer Crossing diverging diamond interchange. Drawing: Parsons Corporation

engaged to finalize the location of the SPMTs. The permanent abutments were supported on pipe pile foundations that were enclosed with two-stage mechanically stabilized earth (MSE) walls. Due to this configuration at the abutments, it was necessary to locate the SPMTs at approximately the twentieth points of the spans. This avoided conflicts between the SPMTs and the abutment walls.

Once the SPMT support locations were defined, the superstructure was analyzed for the temporary support conditions during transport from the bridge staging area to its permanent location. The geometric shape of the precast concrete girders was limited by the forms available at the fabricator and the number of prestressing strands was near the upper capacity of the fabricator's bed. The strength of the concrete girders was essentially fixed by the conventional design. If the stresses due to temporary loading during transport exceeded the service limit state, few options other than relocating the SPMTs were available.

The westbound bridge spans are shown in the staging area located approximately 1100 ft southwest of the final bridge location.

The composite behavior of the superstructure allowed the girders to remain in compression during transport. The deck was in tension along the length of the span with the highest tensile stresses over the SPMT support locations. Additional reinforcement was added to the deck to account for these tensile forces and the stress limits in the reinforcement were limited to 30.0 ksi in keeping with the UDOT *Manual for the Moving of Utah Bridges using SPMTs*. To help minimize the tensile stresses in the deck, the concrete end diaphragms were not cast until the spans were in their final locations. Additionally, the concrete deck was not cast over the ends of the girders. This not only reduced tensile stresses in the deck, but facilitated the closure pour at the center-bent to establish live load continuity.

Construction of the Spans

The westbound superstructure spans were constructed in a staging area located southwest of the bridge site and the eastbound superstructure spans were constructed in an area located northwest of the site. The individual spans were constructed on temporary falsework which was supported on large concrete spread footings. Due to existing site conditions, both staging

SPMTs were placed at approximately the twentieth points from the ends of the spans.

TWO PRECAST, PRESTRESSED CONCRETE BULB-TEE GIRDER BRIDGES BUILT WITH CAST-IN-PLACE CONCRETE DECKS IN STAGING AREAS AND MOVED WITH HEAVY LIFTING EQUIPMENT INTO PLACE / UTAH DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: Twin two-span precast, prestressed concrete girder bridges with a cast-in-place composite deck

STRUCTURAL COMPONENTS: Eighteen 94½-in.-deep bulb-tee girders in each bridge with maximum girder length of 191 ft 9½ in.

AWARDS: Mountain States Contractor, *2010 Project of the Year;* Roads & Bridges, *2010 No. 9 Road Project; American Council of Engineering Companies, Utah Chapter, 2011 Transportation Project Grand Award*

areas required extensive geotechnical investigations to determine potential settlement and to provide mitigation.

Once the temporary abutments were in place in the staging areas, the construction of the individual superstructure spans progressed much like a conventional superstructure. The most critical item during the construction steps was monitoring the bearing seat elevations of each individual girder. Potential differential settlement of the bearing seats would result in uneven bearing in the final location and would create additional stresses in the superstructure. Bearing seat elevation adjustments were made at the permanent location to compensate for differential as-built elevations.

Bridge span on the move during 8-hour road closure.

SPMT Move and Monitoring

The weight of each span was approximately 2300 tons, which represents the longest and heaviest documented precast, prestressed girder spans moved using SPMTs in the United States. Each span was supported at each end with dual SPMTs with 20 axles each, which resulted in each span being supported by 320 wheels. The SPMTs carried cribbing and lateral bracing that supported the spans at the required vertical elevation.

Tapered plywood shims were used between the SPMT cribbing and the girders to account for the longitudinal slope of the girders. The shims were centered under the centerline of the girders to concentrate the load on the bottom flange under the girder web.

The twist tolerance for the superstructure was developed using procedures contained in the UDOT *SPMT Manual*. A 3-dimensional analysis was performed to calculate the allowable superstructure twist. The tensile stress in the reinforcement was the limiting factor.

The SPMTs' hydraulic systems were controlled to provide four-point support for each span. Strict monitoring of the superstructure was required to prevent excessive torsion. A simplified string line system was adapted from the UDOT *SPMT Manual* to monitor twisting during transport. This consisted of a base string line set along one diagonal of the bridge at a constant offset from the top of the deck. A dual string was mounted along the opposite diagonal. At one end of the duel diagonal, both strings were set at the same constant offset from the top of the deck. At the opposite end, one string was set at the constant offset plus the twist allowance dimension and the other was set at the constant offset minus the twist allowance dimension. The result was the ability to visually monitor the twist in the center where the strings crossed. The string lines were monitored during transport by personnel on the span and adjustments were made hydraulically to the supports as the move progressed. This resulted in a very efficient and simple method to control twisting.

Final placement of the spans required the precise elevation control obtained during the construction of the spans in the staging areas. As the spans were lowered onto their permanent bearings, 18 points of support had to be at exact elevations to control stresses.

The spans of the westbound bridge were placed on the weekend of October 16, 2009, and the spans of the eastbound bridge were placed on the weekend of June 4, 2010. Each individual span was placed in a single 8-hour traffic closure. This greatly minimized impacts to the traveling public and supported UDOT's Accelerated Bridge Construction goals. Pioneer Crossing was opened to traffic on August 23, 2010, and the DDI became just the third such interchange opened to traffic in the United States.

Steve Haines is project engineer with the Parsons Corporation located in Denver, Colo.

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

A finished single bridge span in the bridge staging area prior to transport to the final location with SPMTs.

THE I-95/I-295 NORTH INTERCHANGE

by Victor Ryzhikov, Antonio Ledesma, and Bob Szatynski, Parsons Brinckerhoff

The bridge nearing completion. This view was taken looking southbound and shows the bridge crossing over the exit to eastbound I-295. Photo: Ray Stanyard Photographer.

Cost, constructability, and aesthetics determine overpass design

The Florida Department of Transportation (FDOT) has completed construction of the initial stage of a three-phased approach for replacing the I-95 and I-295 interchange located 1.5 miles south of the Jacksonville International Airport. The purpose of this project is to improve capacity and operations by replacing the existing partial cloverleaf interchange with an all-directional four-level, system-to-system, high-speed interchange. This initial stage included a new segmental concrete box girder flyover bridge that provides for the southbound I-95 to eastbound I-295 movement along with the widening of an existing beam bridge that supports eastbound I-295 over U.S. 17 and the CSX rail line.

Three types of superstructures were considered during the initial Bridge Development Report (BDR). However, only steel box girders and segmental concrete box girders were ultimately considered feasible after the preliminary analysis was completed. This constraint was primarily based on estimated construction costs and issues related to constructability. Another deciding factor was aesthetics.

The interchange functions as a main access route to the City of Jacksonville. It is the first major feature experienced by most tourists and visitors traveling into Jacksonville from the north, FDOT agreed with city officials that emphasis should be placed on the aesthetic elements of the bridge as the city's northern gateway.

Each alternative was compared for aesthetics, constructability, maintenance costs, and construction cost, with consideration of the present value based on life-cycle analysis. The most influential parameter was construction cost. Construction professionals in Florida generally assume concrete superstructures to be the most economical choice. However, this does not hold true in the case of segmental concrete unless there are peripheral factors such as constructability issues or redundancy in the casting of the segments.

Geometric Requirements

The span arrangement was similar for both superstructure alternatives and was primarily dictated by the existing features of the interchange. The bridge has a maximum span length of 274 ft and the vertical profile was set to satisfy the required minimum vertical clearance of 16 ft 6 in. The new Ramp SE bridge rises above I-95, existing ramps, and I-295 to become the third-level structure in the interchange. The bridge has a horizontal curvature of more than 90 degrees with a radius of 1250 ft.

profile

I-95/I-295 (SR R/SR 9A) NORTH ENTRANCE INTERCHANGE–RAMP SE / JACKSONVILLE, FLORIDA

BRIDGE DESIGN ENGINEER: Parsons Brinckerhoff, Tampa, Fla.

CONSTRUCTION ENGINEER: Corven Engineering Inc., Tallahassee, Fla.

CONSTRUCTION ENGINEERING & INSPECTION: RS&H CS, Jacksonville, Fla.

PRIME CONTRACTOR: Superior Construction Co., Jacksonville, Fla.

POST-TENSIONING CONTRACTOR: Dywidag Systems International-USA Inc., Bolingbrook, Ill.

CONCRETE SUPPLIER: Preferred Materials, Jacksonville, Fla.

PRECASTER, SQUARE PILES: Standard Concrete Products, Tampa, Fla., a PCI-certified producer

The estimated construction cost for the precast segmental alternative was approximately 5% lower than the steel alternative.

While the precast concrete segmental alternative is sometimes considered to be more complicated than the steel alternative, it can offer some significant advantages in other arenas. For example, concrete segments are heavier and the balanced cantilever construction requires a strong back system along with post-tensioning for erection. However, the advantage is that single-column piers can be used that will reduce the cost for materials. In this project, the steel alternative was determined to be more complex, involving hammerhead piers, one integral pier, and one integral pier cap. Even though hammerhead piers are becoming simpler to construct, the two integral components included in the system present a higher degree of difficulty since post-tensioning is required in the caps.

The increased emphasis on aesthetics heavily favored the segmental concrete alternative. Given that this extremely long flyover was going to be a third-level structure, its underside would be highly visible to drivers traveling on I-95 and I-295. With its closed box shape, clean lines, and smooth bottom soffit, the precast segmental concrete box girder was clearly the most aesthetically pleasing choice.

To further enhance the aesthetics of the bridge, octagonal columns were used and the capitals were flared transversely at the top, matching the slope of the webs of the box girder. The tapered shape of the capital provides an elegant transition between the box girder and the supporting column. The columns measured 9 ft transversely and 7 ft longitudinally at their base.

The estimated construction cost for the precast concrete segmental alternative was approximately 5% lower than the steel alternative; consequently, the segmental concrete box girder bridge became the preferred alternative.

Superstructure Design

The bridge is a 10-span continuous structure with a total length of 2256 ft. It is 49 ft 3 in. wide. The span lengths range from 117 ft to 274 ft. The bridge is composed of 234 precast concrete segments with a top flange width of 49 ft 3 in. The typical segment has a depth of 9 ft 6 in. Variable depth segments are used at the piers with the depth increasing to 12 ft 0 in. to accommodate the longer spans. The top slab is transversely post-tensioned.

The design concrete compressive strength is 6500 psi for the segments and cast-in-place concrete closures. The bridge used the balanced cantilever method of construction and was erected using ground-based cranes. The bridge was designed according to the 2004 *AASHTO LRFD Bridge Design Specifications* (3rd Ed.) and the July 2005 FDOT *Structures Manual*. CEB-FIP Model Code 1990 was used for the time-dependent behavior analysis.

The superstructure rests on pot bearings with the superstructure fixed against longitudinal movement at four of the nine interior piers. Hexagonal shaped columns were used to support the bridge while maximizing the strength of the pier. Because the bridge curves over portions

Balanced cantilever construction over the I-95 southbound exit to I-295. Photo: RS&H CS.

PRECAST CONCRETE SEGMENTAL BOX GIRDER FLYOVER RAMP ERECTED IN BALANCED CANTILEVER / FLORIDA DEPARTMENT OF TRANSPORTATION, DISTRICT 2, OWNER

FORMWORK SUPPLIER: EFCO, Orlando, Fla.

POT BEARING AND EXPANSION JOINT SUPPLIER: DS Brown Co., North Baltimore, Ohio

POST-TENSIONING GROUT SUPPLIER: Sika, Lyndhurst, N.J.

BRIDGE DESCRIPTION: 2256-ft-long, precast concrete segmental box girder bridge consisting of 10 spans with a maximum span of 274 ft constructed using the balanced cantilever method

BRIDGE CONSTRUCTION COST: $45 million

AWARDS: *2010 PCI Bridge Design Award, Honorable Mention for Best Bridge with Main Span more than 150 ft*

Above: Construction of the Pier 3 cantilever begins with placement of the pier table. Pier tables were constructed using split segments to reduce the lifting weight. The tapered lines of the column cap create an elegant shape with the slope of the segment webs. Photo: RS&H CS.

Below: Cantilevers are supported using temporary support frames to stabilize the structure and reduce the loads on the pier during segment erection. Photo: RS&H CS.

of I-95, limited horizontal clearance prohibited the use of larger column sizes. To get the most cross-sectional area from the available space, the hexagonal columns offered an ideal shape as the bridge crossed this critical location at a skew.

For the substructure, the use of 24-in. and 30-in.-square precast, prestressed concrete piles and 36-in.- and 42-in.-diameter drilled shafts was evaluated. The relative ease and availability of 30,000-lb hammers made the use of 30-in.-square piles more appealing. As is common in Florida, square precast, prestressed concrete piles were used, since they are economical, offer proven performance, and are made by several precast concrete producers in the state. A resistance factor of 0.65 was applied to the factored design loads before estimating the pile tip elevations.

Designing a cost-competitive precast concrete segmental bridge project with only 234 segments can be a difficult undertaking. By using a variable-depth box to minimize concrete, splitting the pier segments to reduce the maximum lifting weight, and using clean yet simple shapes for the bridge elements, a design solution was devised that enabled the project to be built in a cost-effective manner, while also providing a preferred aesthetic solution.

The construction contract was awarded in April 2007. Construction began in October of 2007 and was completed in September 2010.

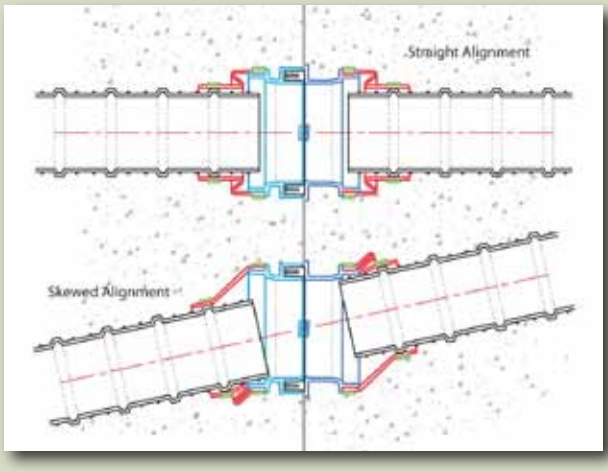
Victor Ryzhikov is senior supervising bridge engineer, Antonio Ledesma is lead bridge engineer, and Bob Szatynski is principal project manager, all with Parsons Brinckerhoff in Tampa, Fla.

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

Improved Tendon Protection Measures Lead to Increased Sustainability

After finding corroded tendons in a few bridges in the state, the Florida Department of Transportation (FDOT) adopted stringent tendon protection requirements to increase the durability and sustainability of post-tensioned segmental concrete bridges.

The I-95/I-295 flyover bridge complies with FDOT's latest requirements for post-tensioning systems. One of the biggest changes to the industry was the introduction of the segment duct coupler used at the interface between precast segments for internal tendons. The segment duct coupler provides a fully protected connection between tendon ducts. This will increase the protection to the prestressing strands leading to an overall improvement in durability of the bridge and provide a longer-lasting structure for maximum sustainability. The GTI duct couplers are shown schematically and in use during segment match casting. Photo and drawing: Parsons Brinckerhoff.



The increased emphasis on aesthetics heavily favored the segmental concrete alternative.

The I-95/I-295 North Interchange flyover bridge in Jacksonville, Fla. Photo: Ray Stanyard Photographer.

AESTHETICS COMMENTARY

by Frederick Gottemoeller

This bridge seems simple, and it is. But the simplicity masks a series of sophisticated choices about proportions, shapes, and materials that make this bridge in fact extremely elegant. If one pays attention to the characteristics that we usually look right past, the elegance emerges.

Start with the geometry, the lines of the structure. All of the main lines of the structure—the edges of the parapet, the intersection of the overhang and the girder, the bottom edge of the girder—exactly follow the curve of the ramp itself. None are interrupted by a pier cap, expansion joint, or other competing line; none are broken into chords. The shadows cast by these elements divide the superstructure into parallel bands of strongly contrasting light and dark that reinforce the main lines of the structure and make it appear thinner. The overhangs are a large enough portion of the total width to make these bands significant. The end result is a bridge that itself reflects the curving, high-speed trajectories of the vehicles that use it.

The piers are thin at their bases so that landscape flows through the bridge without interruption. They widen at their tops just enough to provide room for the two bearings. The bearings hold the girder some distance above the top of the pier, so that you can see daylight between them from many angles. This demonstrates that the bridge is supported on just these two points, and makes it seem lighter than it is. It seems to float over the landscape. It is the like a waiter carrying a heavy tray. By balancing it on his fingertips, he makes the task seem effortless. Because the superstructure is lifted above the pier its lines run right past the pier, and are not interrupted by a pier cap or edge. As a final refinement, the girder depth increases just a bit over the piers, visually expressing the load concentration at that point.

Interchange bridges are mostly seen by people traveling at high speeds, who only have time to recognize the major lines and the largest shapes. This designer concentrated on getting these elements right. Time and money were not wasted on simulated finishes. Such finishes would be simply unrecognizable at highway speeds and the effort would therefore be wasted.

We don't all have the intensity of the Florida sun to play with, but in every area the sunlight has distinctive characteristics that can be used to enhance the appearance of a bridge. It is part of our job to figure how to take full advantage of that.

GOING TO RECORD LENGTHS

by Brian Slagle, Janssen & Spaans Engineering Inc.

Kentucky project's 325-ft-long main span sets record for spliced, precast, prestressed, concrete girders

The Route 22 Bridge over the Kentucky River near Gratz, Ky., was initially planned as a steel structure, but officials at the Kentucky Transportation Cabinet allowed a concrete alternative to be designed. That option resulted in the creation of a spliced, post-tensioned, precast concrete girder bridge that features a 325-ft-long main span, the longest span of this type in the United States. It also produced a cost savings of more than $800,000.

The bridge was designed to replace the existing steel-girder structure, which will be demolished after the new bridge is in place. Upon release of the initial drawings, which featured a steel-plate girder design, engineers at a precasting firm asked if they could provide a precast concrete alternative for consideration.

Long Spans Required

The company realized that to span the river as required would necessitate long spans. But it knew it could produce the segments required, and it had access to special barge-loading facilities that would allow it to deliver the girders via the river.

The 325-ft length was necessary to span the river without changing the pier locations from the original design, which located them along the riverbank. Moving them closer to shorten the span lengths would have required placing a pier in the river, which would have caused encroachment on the waterway and environmental concerns.

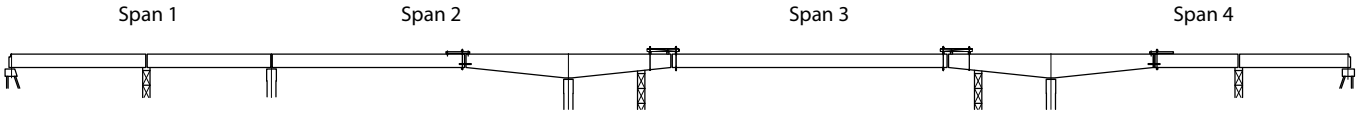
The bridge has four spans and four girder lines were used throughout the bridge. The center span features haunched bulb-tee pier segments varying from 9 ft deep to 16 ft deep. The haunched pier segments were each 138 ft long and weighed 169 tons. Between the two cantilevered pier segments, a 9-ft-deep drop-in girder, 185 ft long completed the 325-ft main span. Segments were joined with 1-ft-wide cast-in-place concrete closure joints.

Spliced Approach Spans

There are two approach spans on the west side with lengths of 175 ft and 200 ft and an approach span on the east side of 200 ft. The precast beams for the three approach spans consist of 9-ft-constant-depth, bulb-tee beams. Span 1 consists of two segments with lengths of 90 ft 9 in. and 84 ft 3 in. that were set on falsework at their splice. Span 2 comprised one end of the haunched pier segment and a drop-in girder segment, 131 ft long. Span 4 comprised two segments, 57 ft 6 in. and 73 ft 6 in. set on falsework with one end bearing on an end bent and the other supported with a strongback from the cantilevered end of the haunched pier segment. In all, eight girder segments were used in each beam line.

Materials Selection

The girder segments used concrete with a specified 28-day compressive strength of 7500 psi. All segments used normal weight concrete except for the main-span, drop-in girders, which used a



Schematic of the framing of the spans on the Route 22 Bridge over the Kentucky River near Gratz, Ky.

profile

ROUTE 22 BRIDGE OVER THE KENTUCKY RIVER / GRATZ, KENTUCKY

ENGINEER: Kentucky Transportation Cabinet, Lexington, Ky.

PRIME CONTRACTOR: Haydon Bridge Co., Springfield, Ky.

PRECASTER: Prestress Services Industries LLC, Lexington, Ky., a PCI-certified producer

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

ERECTION CONTRACTOR: C.J. Mahon Construction Co., Columbus, Ohio

Left: The new spliced precast, prestressed concrete girder bridge along Route 22 over the Kentucky River replaces a deteriorated steel structure that will be demolished once construction is completed. Photo: Aerial Innovations of Tennessee Inc.

Above: The precaster's loading pier allowed the heavy precast girders to be placed on specially designed barges, which delivered the components to the site. The 185-ft-long main-span, drop-in girders were always handled as braced pairs to address stability concerns. Photo: Prestress Services Industries LLC.

A strand jack was used to lift haunched pier segments from the barge to the pier seats. The jacks were later relocated and used to lift the drop-in girders for the main span. Photo: Haydon Bridge Co.

Locks along the waterway had to be repaired and modified to allow the girders to be barged to the site.

semi-lightweight mixture resulting in a unit weight of 125 lb/ft³. This material reduced the weight and made the girders easier to maneuver to and from the barges during loading and erection. Standard grade 60, epoxy-coated reinforcement was used, along with Grade 270 ksi for the pretensioning and post-tensioning strands. Concrete compressive strengths required for the deck and pier concrete were 4000 psi and 3500 psi, respectively.

The three piers ranged from 33 ft to 66 ft in height, with the two piers on the east side set on piles, while the one on the west side, along the river bank, was set on spread footings due to the close proximity of sound bedrock.

Locks Created Challenges

Casting the segments posed no challenges, especially for the shorter spans, which are more typical in length. Transportation to the site proved more challenging than initially anticipated, however. The precaster had planned delivery with special barges, but a system of locks along the waterway created a problem. They were no longer operational, which the precaster knew would require repairs and modifications to at least one lock's entrance to accommodate the barges' widths.

Initially, the precaster speculated that, if delivery was scheduled during high-water in the spring, the water level would be high enough that the barges could float over the locks, saving time and money. The barges then would remain at the site until the next spring, when they could be transported back up the river at the high water mark again. That scenario created a risk factor, as a dry spring would have caused delays or last-minute adjustments.

Upon a closer examination of the locks, the precaster determined that the necessary repairs were not as extensive as originally expected. The repairs were made, and the barges were used to transport the girders. In the end, the river experienced flood-level conditions several times, requiring the contractor to adjust the work sequences and processes to maintain the project's schedule.

FOUR-SPAN, PRECAST, PRESTRESSED CONCRETE SPLICED-GIRDER BRIDGE / KENTUCKY TRANSPORTATION CABINET, OWNER

POST-TENSIONING CONTRACTOR: Dywidag Systems International-USA Inc., Bolingbrook, Ill.

BRIDGE DESCRIPTION: Four-span (175, 200, 325, and 200 ft—center to center of bearings) precast, prestressed concrete spliced-girder structure 909 ft long and 47 ft 4 in. wide, with cast-in-place concrete piers and composite concrete deck

BRIDGE CONSTRUCTION COST: $8.9 million

The new structure features a four-span concrete design that includes a 325-ft main span, the longest span for a precast girder bridge in the United States. The main span and east approach span are shown. Photo: Haydon Bridge Co.

The girders were transported to the site on barges during high-water levels in the spring, after the precaster had modified and repaired several locks along the route. Photo: Haydon Bridge Co.

Construction began with the end bents, piers, and temporary supports. Then the haunched pier segments were erected, followed by the main-span, drop-in segments. Once they were in place, the remaining girder segments were erected and the closures were cast.

No Cranes for Main Span

Because of the difficult riverside site, the biggest construction challenges came with the erection of the center span. The haunched pier segments and main-span, drop-in segments had to be erected without cranes. First, the contractor erected four structural towers around each riverbank pier. They supported two straddle beams above the piers that in turn supported a gantry beam on trolleys. The gantry housed strand jacks that were used to lift the pier segments. Once over the pier, the trolleys moved the segments laterally to their final position.

For erection of the main-span drop-in segments, a reverse strongback was attached to the free end of the cantilevered pier segment. A strand jack was placed at the end of the strongback and was used to lift the drop-in segments into place. Due to the length of the drop-in segments (185 ft), the contractor had to erect these as two braced pairs to address stability concerns. Each pair weighed 258 tons and each jack needed nine strands for the lift.

After removal of the temporary pier segment erection towers, a braced pair of main-span segments was lifted into place by strand jacks from the strongbacks mounted on the pier segments. The haunched bulb-tee pier segments vary from 9 ft deep to 16 ft deep. Photo: Haydon Bridge Co.

After all pieces were erected, the structure was post-tensioned over its full length in two stages. Stage one post-tensioning needed three tendons with fifteen 0.6-in.-diameter strands and was completed prior to the deck placement. Stage two post-tensioning was performed after the deck achieved strength and used one tendon with fifteen 0.6-in.-diameter strands. The final step following the stage two post-tensioning operations was to construct concrete barriers and install expansion joints at the end bents. Construction of the bridge began in early 2009 and was completed in the fall of 2010, on schedule.

A new national record for this type of concrete construction was established by evaluating the original steel plate girder plan, maintaining the pier locations, but otherwise completely value-engineering the substructure and superstructure. The result is a more durable bridge with a significant savings in cost.

Brian Slagle is vice president with Janssen & Spaans Engineering Inc. in Indianapolis, Ind.

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

Temporary towers supported steel beams spanning over the piers that in turn supported a gantry with strand jacks to lift the pier segments and move them laterally into place. Photo: Haydon Bridge Co.

The haunched pier segments and main-span drop-in segments were erected without cranes.

Pier segments were equipped with strongbacks at their main-span ends. The strand jacks were moved to the strongbacks to raise the drop-in girders into final position. Falsework towers under the pier segments provided temporary support of the cantilevers during this operation. Photo: Haydon Bridge Co.

HEAVY-DUTY RUNWAY ACCESS

by Jerry M. Pfuntner and Robert A. Alonso, FINLEY Engineering Group

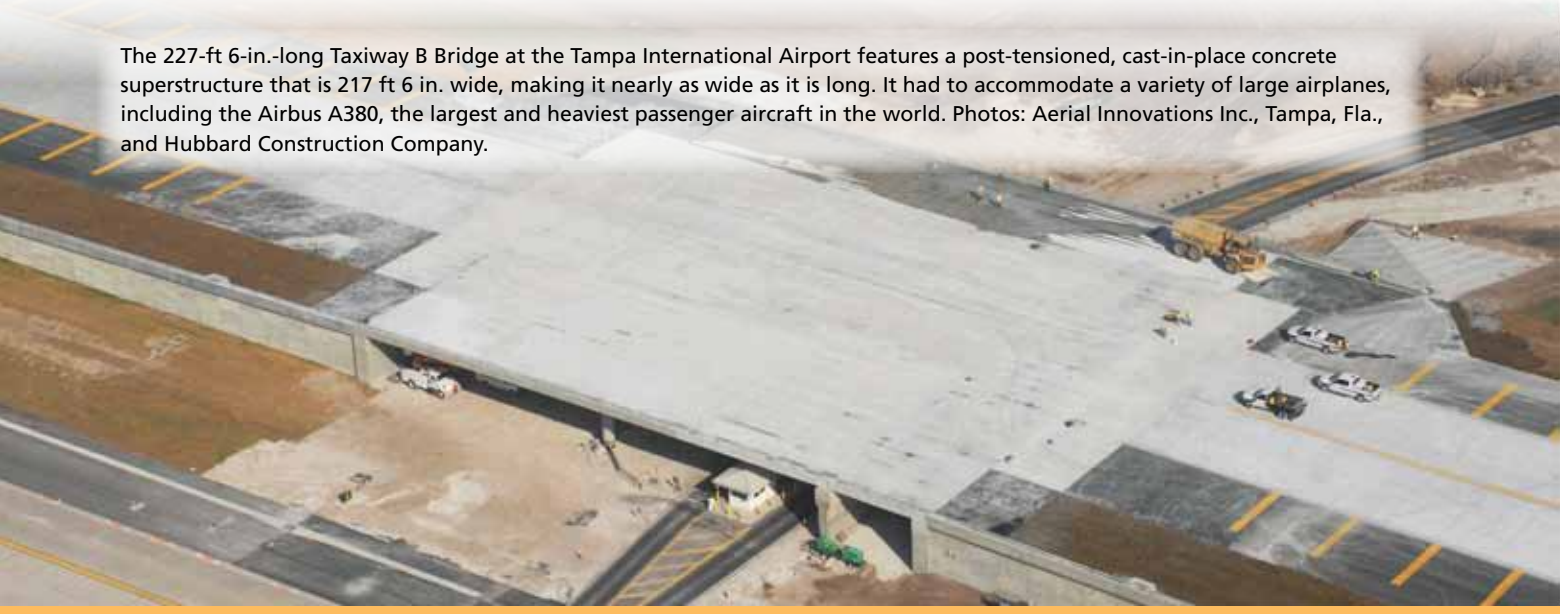
Cast-in-place concrete taxiway at Tampa International Airport creates smoother access for world's largest aircraft

Executives at the Tampa International Airport wanted to provide better access between runways for all types of airport vehicles. Those requirements meant creating a bridge that could accommodate airplanes including the Airbus A380, the largest (and heaviest) passenger aircraft in the world. To meet the variety of goals, the design and construction team created a 227-ft 6-in.-long cast-in-place, post-tensioned concrete bridge. Constraints of time and geometry created a challenging design project.

The Taxiway B Bridge, a fast-track design-build project, is part of a new $950-million terminal complex partially funded by the American Recovery and Reinvestment Act. The bridge allows aircraft to move between the main north-south runways.

Spanning a new access way that includes vehicular traffic as well as a future light rail system and utility corridors, the bridge features three spans that are 97 ft 3 in., 94 ft 3 in., and 36 ft 0 in. in length. To ensure safe movement of the world's largest aircraft, the bridge is nearly as wide as it is long, at 217 ft 6 in. for a single aircraft travel lane. To meet the low taxiway grade requirements as well as underlying roadway profile and vertical-clearance requirements, a shallow superstructure depth varying from 3 ft 3 in. to 5 ft 0 in. was necessary for the main spans.

The bridge was designed using the *AASHTO LRFD Bridge Design Specifications*, supplemented by the Florida Department of Transportation's *Structures Design Guidelines* and aircraft design loads specified by the Hillsborough County Aviation Authority. The structure was designed to carry the Boeing 747, Boeing 777, and the Airbus A380. In addition to the extreme vertical loads produced by these aircraft, the bridge was also designed to resist 70%



The 227-ft 6-in.-long Taxiway B Bridge at the Tampa International Airport features a post-tensioned, cast-in-place concrete superstructure that is 217 ft 6 in. wide, making it nearly as wide as it is long. It had to accommodate a variety of large airplanes, including the Airbus A380, the largest and heaviest passenger aircraft in the world. Photos: Aerial Innovations Inc., Tampa, Fla., and Hubbard Construction Company.

profile

TAMPA INTERNATIONAL AIRPORT TAXIWAY B BRIDGE/ TAMPA, FLORIDA

ENGINEER: FINLEY Engineering Group, Tallahassee, Fla.

PRIME CONTRACTOR: Hubbard Construction Co., Winter Park, Fla.

POST-TENSIONING SUPPLIER: VSL, Hanover, Md.

CONCRETE SUPPLIER: CEMEX, Largo, Fla.

The bridge was the first in Florida to use 31-strand tendons. The total longitudinal stressing force is more than 80,000 kips.

of the vertical load applied longitudinally as a braking force, as well as a 30% vertical impact factor on all live loads.

31-Strand Tendons Used

The cast-in-place concrete voided superstructure for Spans 1 and 2 consists of 25 evenly spaced webs, a 14-in.-thick, transversely post-tensioned top slab, and an 8-in.-thick bottom slab. The bottom slab contains seven 0.6-in.-diameter strand tendons located between each 20-in.-thick web. Each web contains two, thirty-one 0.6-in.-diameter strand tendons. The taxiway bridge was the first in the State of Florida to use the 31-strand tendons. The total longitudinal stressing force in the bridge is more than 80,000 kips.

Pier 2 is integrally connected to the superstructure, and consists of 48-in.-diameter columns, supported by 48-in.-diameter drilled shafts. Pier 3, which has pinned connections to the superstructure, was designed as a continuous 3-ft-wide wall also supported by drilled shafts. The rigid wall allows the longitudinal forces to be distributed to all of the drilled shafts, minimizing the number of shafts required.

The third span, supported by walls at Pier 3 and Abutment 4, was designed to serve as the corridor for a future light-rail track. With a required minimum vertical clearance of 17 ft, the maximum allowable superstructure depth was only 2 ft 6 in. Although the span is only 36 ft, this presented several challenges due to the magnitude of the aircraft design loads. It was decided to integrally connect the superstructure to the abutment. The fixed connection reduced the bending moments in the superstructure, allowing a shallow section to be created that did not require post-tensioning. This created significant cost savings for the general contractor.

Innovative Modeling Techniques

The bridge was a fast-track design-build project from the start. There was less than 3 weeks to prepare the prebid conceptual design. Although the owner provided a preliminary design concept, the designer produced optimized substructure and superstructure designs, estimated quantities, and proposed alternative construction techniques that allowed the contractor to be more competitive with its bid.

To speed this process and ensure the structure could support the required loads, multiple design models were used to accurately reflect the behavior and distribution of loads, as well as to achieve concurrence between models. RM-Bridge and LUSAS 3D were used for the longitudinal and transverse analysis and design of the superstructure.

The results of the two models were superimposed to determine the maximum stresses at all locations during all phases of construction. This 3-D, finite-element modeling, combined with an independent check analysis, allowed the design to be fast-tracked while providing the design-build team with the confidence to proceed with foundation installation while superstructure details were finalized.

In addition to their use in designing the superstructure, these models helped determine the distribution of loads to the substructure. Due to the large longitudinal loads, the abutments and piers were connected to the post-tensioned superstructure, providing the most efficient use of the entire bridge substructure. This produced a better distribution of loads to the columns and drilled shafts. Maximizing the use of the entire structure created significant cost savings, as it reduced the size and number of drilled shafts and columns.

The bridge's bottom slab contains seven 0.6-in.-diameter strand tendons located between each 20-in.-thick web. Each web contains two, thirty-one 0.6-in.-diameter strand tendons. It is the first bridge in Florida to use 31-strand tendons.

Models Provide Fast Start

This extensive modeling and early calculations allowed the design-build team to get a running start once its proposal was accepted. To meet the aggressive construction schedule, final substructure design plans were submitted to the owner within 4 weeks. The contractor began drilled-shaft installation a few weeks later, before the final superstructure design was submitted. The final superstructure design plans were submitted less than 4 weeks after the substructure plans. This rapid process allowed the contractor to fast-track construction and complete construction slightly more than 1 year after it commenced.

227-FT-LONG, THREE-SPAN, CAST-IN-PLACE CONCRETE VOIDED SUPERSTRUCTURE BRIDGE / TAMPA INTERNATIONAL AIRPORT, OWNER

REINFORCEMENT SUPPLIER: Gerdau Ameristeel, Plant City, Fla.

BRIDGE DESCRIPTION: Three-span (97 ft 3 in., 94 ft 3 in., and 36 ft 0 in.) cast-in-place concrete bridge with a superstructure depth varying between 3 ft 3 in. and 5 ft 0 in. and a width of 217 ft 6 in.

BRIDGE CONSTRUCTION COST: $34 million

The main pier, integrally connected to the superstructure, consists of 48-in.-diameter columns, supported by 48-in.-diameter drilled shafts.

The contractor constructed the bridge on shoring, eliminating the need for cranes to lift the superstructure components. The falsework was reused on each phase as the preceding phase was completed.

The shallow superstructure depth varies from 3 ft 3 in. to 5 ft 0 in.

The bridge was designed to be constructed in three phases, with two construction joints running longitudinally down the bridge. The center phase was constructed first, followed by the two adjacent phases.

The post-tensioning forces required to support the live load presented several challenges to the phased-construction method. First, the interface shear between the three faces would be extremely large if all of the post-tensioning tendons in a phase were stressed at once. Additionally, each phase was built on falsework, which then was re-used to construct the next phase.

Since the outer phases were cast directly against the middle phase, the differential deflection due to post-tensioning stressing had to be evaluated to prevent cracking and to ensure the target finish-grade elevations could be achieved. These challenges were addressed by designing the bridge to be self-supporting with only half of the tendons stressed in each phase. After construction of the individual phases was complete, all falsework was removed, and the remaining tendons were stressed.

Why Cast-In-Place Concrete?

Cast-in-place concrete was selected for several reasons. The required minimum vertical clearance was 17 ft, which combined with a shallow roadway profile to limit the superstructure depth. Deflection also had to be minimized, creating a separate challenge because of the cross-sectional requirements. The maximum anticipated deflection of the final design is only 1¼ in. under full aircraft loading.

In addition to the design benefits, there were several construction benefits to specifying cast-in-place concrete. It eliminated the lead time required for prefabricated elements which minimized delays before construction could begin. The contractor also was able to construct the bridge on shoring, eliminating the need for cranes to lift the superstructure components. This was especially important given the location of the project, the volume of air traffic, and height restrictions for construction equipment.

This post-tensioned, cast-in-place concrete bridge will serve the Tampa airport for several decades to come. The fast-track, design-build approach resulted in a successful, functional, and aesthetically pleasing bridge that was completed within the required schedule.

Jerry M. Pfuntner is a principal and assistant technical director, and Robert A. Alonso is a bridge engineer with FINLEY Engineering Group Inc. in Tallahassee, Fla.

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

The taxiway bridge will eliminate the grade crossing of the existing taxiway and road.

Edwin C. Moses Boulevard Bridge

Design allows reuse of existing substructure with shallow precast concrete U-beams

by Seth R. Schickel, RW Armstrong

The first precast, prestressed concrete U-beam bridge in Ohio—Dayton's Edwin C. Moses Boulevard Bridge—was dedicated in May 2010. The bridge crosses Wolf Creek at its confluence with the Great Miami River and replaces the Veterans Memorial Bridge, which was a two-span, earth-filled concrete arch. The bridge is located in the historic Wright-Dunbar District and features parks in three of its quadrants and a bicycle trail along the creek. These elements were the inspiration for the bridge's innovative design and signature aesthetic statement.

RW Armstrong, the design consultant, used a weighted matrix analysis to compare several structure types and treatments. The designers analyzed a range of project factors—not just capital costs alone—such as aesthetics, constructability, durability, environmental effects, life-cycle cost, and maintainability. To maximize resources, the City of Dayton selected conventional structure types with unique aesthetic features for a detailed study. A2SO4 Architecture developed aesthetic concepts and renderings. After reviewing study results and community input, the city selected a streamlined and slender two-span concrete bridge with an aesthetic cable stay tower.

The bridge substructure design blends new and old in innovative ways. Portions of the existing foundation elements were incorporated into the new substructure units. The new bridge is 22 ft wider, so new steel pile footings were constructed on both sides of the existing footings. New pier and abutment walls were then constructed across the combined foundation.

The replacement bridge required a shallow superstructure depth to maintain the existing waterway opening and to keep the low chord above the adjacent levee elevation. Because of roadway constraints, the vertical profile could not be raised. To satisfy these requirements and provide the desired aesthetics, the designers selected a superstructure with a concrete bridge deck on 48-in.-deep precast, prestressed concrete U-beams. This first application of U-beams in Ohio allows wider beam spacing (12 ft 3 in. on center) and has an elegant edge profile—both of which are integral to the structure's aesthetic concept.

Dramatic LED lighting and accent colors selected by the community highlight the bridge's signature elements. Photo: RW Armstrong.

Community input and a weighted analysis of options and priorities helped define the bridge's structure type and features. Photo: RW Armstrong.

The U-beams delivered benefits beyond pleasing aesthetics. They allowed fewer beam lines compared to bulb-tee beams, were inherently more stable during construction, and reduced the thickness of the bridge deck. The U-beams were designed to meet both Ohio Department of Transportation and AASHTO requirements.

The completed Edwin C. Moses Boulevard Bridge is a unique structure that combines form and function with innovative elements to solve a variety of technical and aesthetic challenges.

Seth R. Schickel is project manager with RW Armstrong in Indianapolis, Ind.

The Edwin C. Moses Boulevard Bridge features 48-in.-deep precast, prestressed concrete U-beams, the first U-beams to be used in Ohio. Photo: City of Dayton, Ohio.

MIDDLEBURY'S CROSS STRE

An innovative approach from funding through design

Middlebury is in the heart of Vermont and home to Middlebury College, one of the country's elite liberal arts schools. The college and the quaint town have a rich history. The Cross Street Bridge is an infrastructure wonder. From funding through design, it's a project that can serve as an example to many others desiring to integrate infrastructure improvements into the fabric of the community.

The three-span Cross Street Bridge is the first major design-build transportation project in the state of Vermont, and with a center span of 240 ft, it boasts the longest simple-span precast, post-tensioned, spliced concrete girder bridge known in the United States.

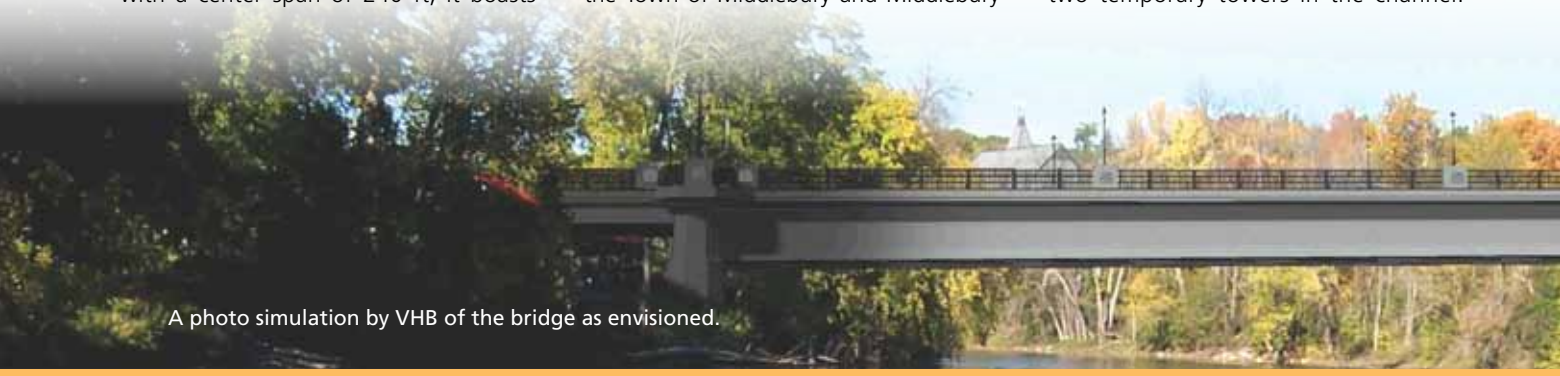
Otter Creek bisects the town, separating the downtown shopping district and the college from emergency services and Route 7, the major north-south highway in the region. The lone existing crossing is a narrow stone arch bridge built in the late 1800s. The need for a second bridge to alleviate traffic for residents and visitors and provide additional pedestrian and bicycle facilities was becoming more and more urgent.

In addition to being the first design-build project in Vermont and the longest simple-span precast, spliced concrete girder in the country, this project is even more unique because the $16 million project received no funding from federal or state sources; it was funded entirely by the Town of Middlebury and Middlebury College. Without the additional federal requirements, the permitting process was streamlined. The fast pace of the project ultimately saved money. Ground breaking was in April 2009 and the bridge opened to the public with great fanfare in October 2010.

Another innovative aspect of the project was the design-build contracting. The town hired a single team for both the construction and design engineering. The decision to use the design-build project delivery method allowed the long-awaited bridge to go from concept to completion quickly upon securing project funding.

Bridge Features

The center span includes five girder lines, 10 ft deep. Each line consists of three individual segments measuring 65 ft, 110 ft, and 65 ft. The span was erected using two temporary towers in the channel.



A photo simulation by VHB of the bridge as envisioned.

profile

CROSS STREET BRIDGE / MIDDLEBURY, VERMONT

BRIDGE DESIGN AND CONSTRUCTION ENGINEER: VHB-Vanasse Hangen Brustlin Inc., North Ferrisburgh, Vt.

SPLICED GIRDER ENGINEER: Corven Engineering Inc., Tallassee, Fla.

GEOTECHNICAL ENGINEER: GeoDesign Inc., Windsor, Vt.

PRIME CONTRACTOR: Kubricky Construction Corp., Glen Falls, N.Y.

PRECASTER AND CONCRETE SUPPLIER: J.P. Carrara & Sons Inc., Middlebury, Vt., a PCI-certified producer

ET BRIDGE

by Christopher D. Baker,
VHB-Vanasse Hangen Brustlin Inc.

A view of Middlebury, Vt., and the new Cross Street Bridge under construction over Otter Creek. All photos: VHB-Vanasse Hangen Brustlin Inc.

The girders were shimmed to the proper elevation, the splices were cast, and the span was post-tensioned and grouted. The post-tensioning needed to span 240 ft required five tendons per girder with each tendon providing approximately 960 kips of jacking force. The precaster was required to produce a 10,000 psi self-consolidating concrete to meet the design demands. Through close coordination with regional admixture representatives and a thorough quality control program, a consistent concrete was produced that met or exceeded the design requirements. The girder segments were erected using a single Manitowoc crane with 160 ft of boom capable of maneuvering the 93-ton segments into place.

The new three-span, 480-ft-long bridge features a 240-ft-long main span that traverses Otter Creek, and is anchored by a pair of 120-ft-long precast, prestressed concrete adjacent box beam spans, crossing over a local road and a railroad. The box beams are 48 in. wide and 42 in. deep and used concrete with a design compressive strength of 8000 psi with 6000 psi required at transfer. The bridge's 44-ft 8-in.-wide superstructure accommodates two lanes of traffic and two sidewalks providing pedestrian access to the bustling downtown shopping district.

The Cross Street Bridge was designed to be low-maintenance. Prestressed concrete is naturally a very durable type of superstructure. In addition, a corrosion inhibitor was used in the precast concrete fabrication. Epoxy-coated reinforcement was used in the deck, along with a membrane and pavement wearing surface. The fascia beams, sidewalk, abutments, and piers were also coated with silane water repellent. The deck is 8-in.-thick with 11-in.-thick, 6-ft-wide sidewalks.

The Cross Street Bridge is the first major design-build transportation project in the state of Vermont.

Environmental Concerns

The innovative approach to the design of the bridge came about as the result of environmental concerns. The Agency of Natural Resources did not approve the original bridge design, which included a pier in the middle of Otter Creek. The design team was then challenged to come up with a way to design the bridge to span the entire channel with no supporting structure in the river. Instead of reverting to a steel structure, Middlebury remained committed to a precast, prestressed concrete bridge. VHB met this challenge by partnering with Corven Engineering Inc. for the new design.

THREE-SPAN, 480-FT-LONG, PRECAST, PRESTRESSED CONCRETE, SPLICED GIRDER BRIDGE / TOWN OF MIDDLEBURY, VERMONT, OWNER

POST-TENSIONING CONTRACTOR: VSL, Springfield, Va.

BRIDGE DESCRIPTION: Precast, prestressed concrete bridge with spans of 120 ft, 240 ft, and 120 ft comprising precast, prestressed concrete adjacent box beams in the end spans and 10-ft-deep, spliced New England bulb-tee girders in the center span. The bridge also used cast-in-place concrete foundations, piers, abutments, deck, curbs, and sidewalks.

BRIDGE CONSTRUCTION COST: $8 million (approximately $360/ft^2)

A 10-ft-deep, 110-ft-long girder segment negotiates city streets in downtown Middlebury. Photo: J. P. Carrara & Sons Inc.

The west abutment consists of a pile cap stub abutment on a single row of H-piles enclosed by a wrap-around mechanically stabilized earth (MSE) wall. The east abutment is a traditional abutment stem supported by a spread footing. Each of the piers is wall-type and is supported by spread footings on H-piles.

The bridge designer collaborated with town officials, a local bridge committee, and the public to develop bridge aesthetics. Maintaining Middlebury's historic, New England charm was a priority for the town. The Cross Street Bridge includes numerous aesthetic features that set it apart from typical highway bridges, such as stepped, hexagonal pier ends with full-height vertical recesses. The bridge also includes decorative street lighting on both fascias, anodized aluminum bridge railings, and pedestrian overlooks at each end of the center span on the ends of the wall piers. Both abutments have an aesthetic finish.

Project Communication

Leadership, teamwork, and a commitment to open communication were keys to this smooth-running design-build project. Given the aggressive schedule and amount of work to be accomplished, due consideration was given early on to defining the process that would guide the project through to completion. The project team agreed upon a hierarchy of communication that would efficiently channel information back to the construction and design project managers as well as other key staff in the office and the field.

The team also worked to establish project timelines and outlined a logical way of packaging the project into manageable "bite-sized" submittals to accommodate contractor and/or fabricator needs. Once the submittal packages were identified, early coordination meetings helped to define anticipated needs during the design and construction process. The team established a plan review process that generally started with periodic fabricator reviews and meetings followed by final reviews by the fabricator and contractor prior to being reviewed by the town and released for construction. Prior to entering each construction phase, the team inspectors and testing specialists were engaged to review the components to prepare for construction.

With cutting-edge engineering and attention to aesthetic detailing, the Town of Middlebury writes a new page in its storied history with an eye on the future and a nod to its past. The Cross Street Bridge is truly one of a kind in its innovative funding and design-build approach, and it has set engineering records. It is a welcomed addition to this unique New England Town.

Christopher D. Baker is principal/national director—structural engineering at VHB-Vanasse Hangen Brustlin Inc. in Bedford, N.H.

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

The Cross Street Bridge incorporates several aesthetic enhancements such as stepped, hexagonal, wall piers with vertical recesses, pedestrian overlooks on each pier end, anodized bridge railings, and decorative street lighting.

Girder segments were set on falsework in Otter Creek where they were spliced and post-tensioned into a 240-ft-long simple span.

CONCRETE BRIDGE PRESERVATION

CBP

State Street Bridge Rehabilitation

Careful planning retains substructures and arches of 83-year-old concrete bridge

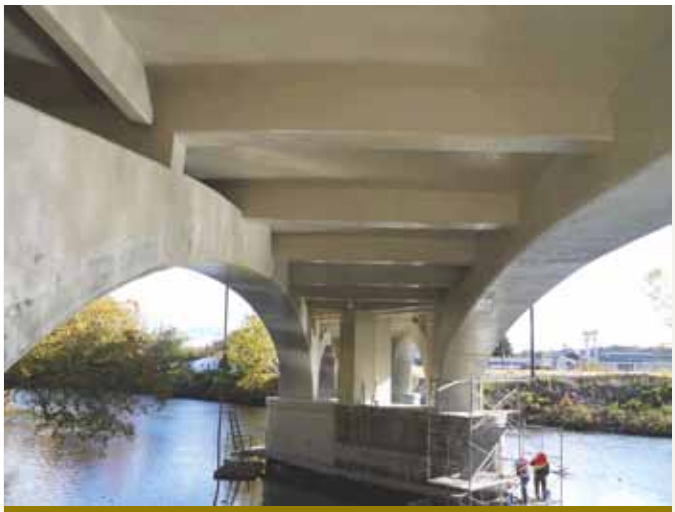
by Manjeet Ahluwalia, TranSystems

With a contracted economy, limited budgets, and continued deterioration of the state's structurally deficient bridges, it is challenging to stretch available funding by applying the latest materials and techniques to bridge rehabilitation. One such project is the rehabilitation of the State Street Bridge carrying State Route 4028 over the Schuylkill River in the Borough of Hamburg, Berks County, Pa. Because of its proximity to I-78 over the Schuylkill River, the State Street Bridge is an important local transportation link. The existing six-span structure, built in 1927, consisted of four main spans of open spandrel reinforced concrete arches and two cellular abutment approach spans supporting a 24-ft-wide roadway over a total length of 529 ft.

The main-span arches each span 86 ft between springlines. The arch ribs are longitudinally offset to match the 48-degree skew of the piers that are uniformly spaced at 95-ft centers. Each pair of arch ribs supports spandrel columns, transverse floor beams and opposing cantilevered sidewalk brackets, spandrel beams, and longitudinal beams. The two approach spans were supported by corresponding four-sided cellular abutments, consisting of U-shaped wingwalls. Transverse floor beams spanned the interior between the wingwalls, and sidewalk brackets were cantilevered from the outer faces of the wingwalls.

Based on the results of TranSystems' bridge inspection findings, concrete testing, and structural analysis and ratings, it was concluded that the bridge required major rehabilitation to maintain its structural integrity and load-carrying capability. It was determined that the arch ribs and the substructures were suitable for reuse in the rehabilitated structure. The selected rehabilitation strategy included rehabilitation of the existing main arches, deck and floor beam replacement, concrete re-

South elevation of the recently rehabilitated State Street Bridge over the Schuylkill River in Berks County, Pa. All photos: TranSystems.



View of the underside of the rehabilitated bridge showing the original arches and the new cast-in-place concrete floor beams and deck.

These were the components of the existing structure that were left in place after removal of the deck and floor beams.

pairs to match the existing architectural features of the bridge, and the partial removal and filling of the cellular abutments to support a standard pavement section. Shotcrete and formed concrete repairs were used for the work. Specified concrete compressive strength for the new deck and floor beams was 4000 psi. The general contractor was Allan A. Myers LP. TranSystems, a subconsultant to Whitney, Bailey, Cox and Magnani LLC, was responsible for the bridge repair design.

Because, the State Street Bridge is a contributing element to the Hamburg Historic District, rehabilitation alternatives needed to minimize impact to the historic fabric of the bridge. The project was completed and the bridge opened to traffic on October 29, 2010.

Manjeet Ahluwalia is senior bridge engineer with TranSystems, Langhorne, Pa.

Methods of Corrosion Prevention and Control in Concrete Bridges

by Matthew Pritzl, Michael Baker Jr. Inc., Habib Tabatabai and Al Ghorbanpoor, University of Wisconsin-Milwaukee

This article summarizes a research study sponsored by the Wisconsin Highway Research Program and conducted at the University of Wisconsin-Milwaukee. The research involved accelerated testing and evaluation of new or promising techniques designed to prevent or control chloride-induced corrosion damage in reinforced concrete bridges.

Laboratory Testing

Thirty reinforced concrete laboratory specimens were subjected to 6 months of accelerated corrosion testing that consisted of wet/dry cycles of exposure to saltwater. The specimens also had the application of a constant electrical potential between their top and bottom mats of uncoated reinforcement. The conditions are used typically to significantly accelerate the corrosion process in reinforced concrete.

The following systems were evaluated:

- tri-silane sealer (alkylalkoxysilane)
- acrylic coating
- epoxy/polyurethane coating
- surface applied galvanic thermal sprayed zinc (with and without epoxy/polyurethane coating)
- embedded galvanic anodes (with or without acrylic coating)
- epoxy repair patch mortar

Sixteen of the specimens received a protective treatment prior to exposure to accelerated corrosion. The remaining 14 specimens were cast with mixed-in chlorides and subjected to patch repair treatments after 3 months of accelerated corrosion. After repairs, the group of 14 specimens was subjected to an additional 3 months of testing. Each treatment was applied to two specimens.

The specimens were evaluated with respect to corrosion currents, chloride ingress, half-cell potential readings, extent of cracking, rust staining, and condition of the reinforcing steel after the conclusion

Thirty laboratory test specimens were subjected to 6 months of accelerated corrosion testing. Photo: University of Wisconsin-Milwaukee.

of testing. The different treatment processes resulted in widely varying performance.

Field Testing

In addition, the effectiveness of some admixtures and sealers was evaluated on nine different bridge decks across Wisconsin through an extensive analysis of chloride ingress. Two of the bridge decks were cast with corrosion inhibiting admixtures, four of the bridge decks were treated with surface applied tri-silane sealers at various times during their service lives, and three of the bridge decks were untreated.

Results

In the laboratory, it was found that the surface applied tri-silane sealer, as well as conjoint use of galvanic thermal sprayed zinc and epoxy/polyurethane coatings, were much more effective in preventing the onset of corrosion than the galvanic anode cathodic protection systems alone or the control.

When used in a patch repair application, the galvanic thermal sprayed zinc, as well as conjoint use of galvanic thermal sprayed zinc and epoxy/polyurethane coatings, were shown to be the most effective in controlling corrosion. In general, corrosion prevention measures taken before chloride contamination were far more effective than the same steps taken after contamination of the concrete.

In the field, it was determined that the application of penetrating sealers at the time of construction, without any reapplication in later years, was not an effective means of reducing chloride ingress. In contrast, periodic reapplication of sealers proved to be an effective means of reducing chloride ingress, even when the initial application was not made at the time of construction. The use of corrosion inhibiting admixtures had varied results based on the type of admixture used.

A complete research report on this study is available online at: http://www.whrp.org/research-areas/structures/downloads/06-06%20Final%20Report.pdf.

Matthew Pritzl is construction engineer at Michael Baker Jr. Inc. in Madison, Wis.; Habib Tabatabai is associate professor; and Al Ghorbanpoor is professor, both in the Department of Civil Engineering & Mechanics at the University of Wisconsin-Milwaukee, Milwaukee, Wis.

Preserving Lincoln's Heritage

Concerns for safety, speed, quality, and money are met in repairs to longest Illinois bridge

The 7122-ft-long Abraham Lincoln Memorial Bridge in La-Salle, Ill., the longest bridge in the state, is supported by 43 pairs of piers. The bridge spans 70 ft above the Illinois River, crossing numerous roads, lakes, wetlands, and railroads. Repairing the piers in areas with limited access required an approach that would maximize safety and quality, while minimizing repair time and costs. To accomplish these goals, shotcrete was applied using platforms hung from above.

The piers range in height from 50 ft to 100 ft and are 6 ft thick at the base and 4 ft thick at the caps. The caps are 4 ft wide and 41 ft long. Bridge spans are between 135 ft and 165 ft. Access on the bridge was limited to a 10-ft-wide area adjacent to live traffic. Ground access was restricted to only a handful of piers, as most were surrounded by the Illinois River, sensitive wetlands, lakes, and the historic Illinois-Michigan canal.

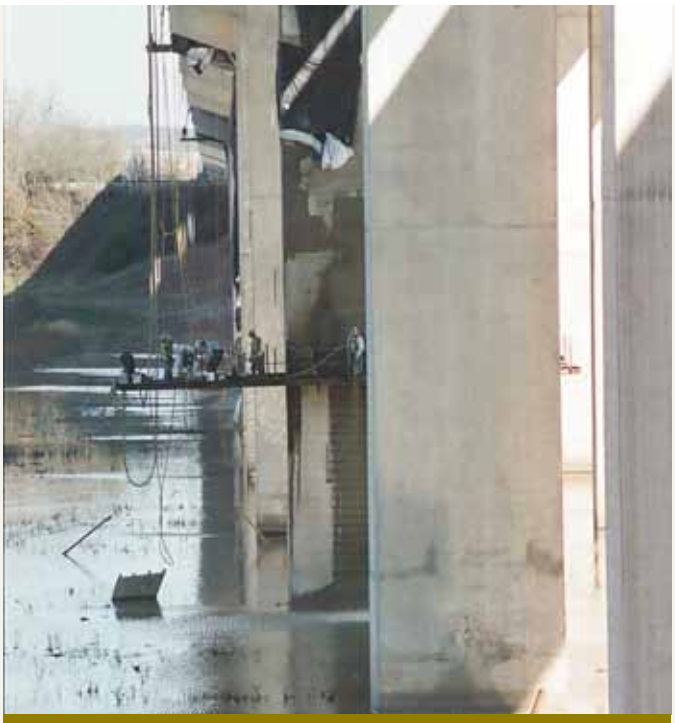
Repairs were completed in two phases, with work on the southbound structure being followed by work on the northbound one. For land-based piers, 70-ft-tall boom-lifts were placed over the bridge's side with cranes. A detailed safety program was created to allow raising and lowering of platforms that were placed just below the deck. They were used at all finger-joint piers over the inaccessible areas. The concrete in the piers was removed past the first mat of reinforcing steel during which saw-cutting the edges and sandblasting with abrasive grit was performed, taking care to blast the saw-cut edges that were polished by the saw. The existing reinforcing bars were supplemented as necessary.

Shotcrete Solution

The shotcrete work was staged from the bridge deck, including delivering prebagged materials. Water was hauled to the site in 250-gal. totes, and the material was monitored to ensure its temperature remained between 70 °F and 78 °F. The shotcrete had a 0.42 water-cement ratio and contained 10% by weight of 3/8-in. river rock.

The project was designed by the Illinois Department of Transportation in Springfield, Ill., with Civil Constructors Inc. in Freeport, Ill., serving as general contractor. American Concrete Restorations Inc. in Lemont, Ill., performed the shotcrete services.

Shotcrete was used to repair the 86 piers on the 7122-ft-long Abraham Lincoln Memorial Bridge in LaSalle, Ill., the longest bridge in the state. Using shotcrete ensured contractors could visually check encapsulation of the reinforcing steel.



All work was completed from overhead, which provided less risk due to the ability to feed air and water hoses over the side rather than handling formwork.

Shotcrete provided a variety of benefits, including the ability to remove and replace concrete in stages. On several severely deteriorated piers, 33% of the pier was repaired and remobilized when the shotcrete reached 70% of the required strength. The procedure was then repeated, eliminating destabilization concerns. The use of prebagged shotcrete also ensured freshly placed, consistent mixtures. Using air and water hoses placed over the side of the bridge also provided a safe procedure.

Construction time was shortened, as the shotcrete placement was completed the next day with sandblasting or high-pressure water blasting of the patch's edge. The shotcreting process also provided a visual encapsulation of the reinforcing steel, eliminating concerns about voids. Shotcrete curing with wet cotton mats also provided a superior finish.

More than 15,000 ft^3 of concrete were replaced. The attention to safety resulted in no accident reports while working 80 ft in the air. The shotcrete solution produced a long-term, affordable repair that proved so remarkable it was named the 2008 Outstanding Shotcrete Project by the American Shotcrete Association.

Concrete placement was eased with the use of shotcrete, which could be smoothed even in unreachable areas without having to maneuver forms. The work was performed by ACI-certified nozzlemen.

This article is an abridged version of an article published in the Winter 2010 issue of Shotcrete *and is published with permission of the American Shotcrete Association. For more information, visit www.shotcrete.org.*

Expanded Shale, Clay and Slate Institute Update

Internal curing is achieved by incorporating prewetted expanded shale, clay or slate (ESCS) aggregate into the concrete mixture to deliver moisture to the hydrating cementitious materials. The absorbed moisture in the ESCS 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 act as internal reservoirs, providing a source of moisture to replace that consumed by hydration. As the cement hydrates, moisture is extracted from the relatively large pores in the ESCS 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 Highways for LIFE Pilot Program

Projects that demonstrate innovation


by Kathleen Bergeron and Myint Lwin,
Federal Highway Administration

The purpose of the Highways for LIFE Pilot Program is to advance **L**onger-lasting highway infrastructure using **I**nnovations to accomplish the **F**ast construction of **E**fficient and safe highways and bridges. Innovation is key to finding our way out of the highway challenge. Innovation is an inclusive term used to convey all of the following: technologies, materials, tools, equipment, procedures, specifications, methodologies, and processes or practices used in the financing, design, or construction of highways.

The first part of this article was published in the Fall 2010 issue of *ASPIRE*.™ It provided the background, objectives, project eligibility requirements, and availability of funding for the Highways for LIFE Pilot Program. In this article, the focus is on projects using accelerated bridge construction (ABC) technology and prefabricated bridge elements and systems. The Federal Highway Administration (FHWA) has sponsored workshops on these technologies in 11 states and more are being planned.

Demonstration Projects

The Highways for LIFE Pilot Program offers incentive funding for states to try innovative approaches. Between 2005 and October 2009, the program awarded approximately $25 million to 25 projects in 21 states, highlighting more than two dozen innovations, such as wider use of ABC techniques and innovative, performance-based contracting.

FHWA encourages the states to work in partnership with the private sector to test and evaluate emerging highway technologies to move them closer to commercialization. The program capitalizes on private sector creativity by funding the best ideas already being developed by industry. The objective is for the states to gain valuable experience in using the innovations and be able to champion deployment of the innovations.

Documentation is a valuable resource for decision makers and practitioners as they adopt innovation. For each demonstration project, FHWA is producing a summary report on success in meeting performance goals. The reports, which also compare the costs and benefits of using the innovation compared to traditional construction, will guide decision makers as they choose the best solutions for their projects.

Information Dissemination

Information dissemination is an essential component of technology deployment, both to help transportation stakeholders use innovations effectively and to expand awareness of the Highways for LIFE mission to improve the American driving experience. The initiative uses a full range of communications tools to tell the innovation story, including workshops, showcases, presentations, brochures, handouts, trade shows, DVDs, videos, reports, and articles in industry publications. The following are examples of completed projects.

Iowa DOT Project

The Iowa Department of Transportation (IowaDOT), the Nebraska Department of Roads, and FHWA, in coordination with the city of Council Bluffs and the Metropolitan Area Planning Agency, proposed improvements to the interstate system around Council Bluffs, Iowa, with improvements extending across the Missouri River on I-80 into Omaha, Neb. The primary component of this project was to replace the existing four-span 24th Street Bridge over I-29/I-80 with a wider and longer two-span bridge.

This project was completed in only one season under an accelerated construction schedule using contract and construction innovations. IowaDOT's approach realized a cost savings of about $1 million or 8% of the total project over conventional construction practices. A significant amount of the cost savings was from reduced construction time. A key feature was the use of full-depth, precast concrete deck panels. Detailed information about this project is provided at http://www.fhwa.dot.gov/hfl/summary/ia/.

Utah DOT Project

The 4500 South Bridge on State Route 266 in Salt Lake City, Utah, was built in 1971. The four-span bridge crossed I-215 and served as an important access point for local businesses and residents. The bridge was in very poor condition. The Utah Department of Transportation (UDOT) needed to expedite the removal and replacement of the bridge. After exploring alternatives and evaluating project and user costs, UDOT selected innovative ABC and project delivery strategies.

The biggest innovation was the removal and replacement of the bridge using self-propelled

Seventy full-depth precast, high-performance concrete deck panels, 8 in. thick, 10 ft long, and 52 ft 4 in. wide, were used on the 24th Street Bridge over I-29/I-80 in Council Bluffs, Iowa. Photos: Iowa Department of Transportation.

The 4500 South Bridge on State Route 266 in Salt Lake City, Utah, was removed and replaced in just 53 hours using self-propelled modular transporters. Photos: Utah Department of Transportation.

One of five crossings on an 11-mile-long stretch of OR 38 included in the Highways for LIFE Pilot Program. Precast concrete columns and piers were used to construct one-half of the bridge at a time. Photo: Oregon Department of Transportation.

modular transporters. The entire operation took a mere 53 hours and has significantly raised customers' future expectations of UDOT on highway project delivery methods and time frames.

The economic analysis revealed a cost savings of about $3.24 million or 36% over conventional construction practices. A significant amount of the cost savings was from reduced delay costs.

Because of the success of this project, UDOT has taken several significant steps toward making ABC an integral part of its bridge construction projects and has set a goal of making ABC standard practice for all bridges by the end of 2010. Detailed information about this project is provided at http://www.fhwa.dot.gov/hfl/summary/ut0409.

Oregon DOT Project

This Oregon Department of Transportation (ODOT) project consisted of removing and replacing five bridges on an 11-mile stretch of OR 38 between the towns of Drain and Elkton. These bridges, built in the late 1920s and early 1930s, were near the end of their useful lives and required immediate attention. After exploring many alternatives and evaluating the project and user costs, ODOT selected the use of the design-build method of project delivery in concert with incentive and disincentive clauses that included innovative staged construction and accelerated bridge removal and replacement techniques. Removal and replacement of the bridges on OR 38 was a great success, and ODOT was able to complete the project more than a year ahead of schedule.

ODOT realized a total cost savings of about $2.4 million over conventional construction practices. These savings stemmed from reduced construction duration, reduced mobilization costs, reduced delay costs, and the use of innovative bridge removal and replacement techniques. Overall, the savings to ODOT represent about 5% of the total project cost. Detailed information about this project is provided at http://www.fhwa.dot.gov/hfl/summary/or/.

Closing Remarks

The Highways for LIFE Pilot Program provides opportunities for stakeholder input and involvement in the development, implementation, and evaluation of the program. The program encourages working together in learning and sharing information on technology developed, deployed, and successfully used under the program. The information is available to the transportation community and the public at http://www.fhwa.dot.gov/hfl.

For Crossing 4 on OR 38, the new precast concrete girder bridge was built next to its final location and slid into place during a weekend closure as the old bridge was slid out of the way. Photo: Slayden Construction Group Inc.

The FHWA Long-Term Bridge Performance Program

by John M. Hooks,
J. M. Hooks & Associates

In 2008, the Federal Highway Administration launched the Long-Term Bridge Performance (LTBP) program, a 20-year-long research program to collect, maintain, and study high-quality, quantitative performance data on bridges. These data will support a better understanding of how and why bridges deteriorate, how to best prevent or mitigate deterioration, how to advance the design and construction of the next generation of bridges, and how to focus the next generation of bridge management tools.

The LTBP program is an undertaking of immense complexity. There are dozens of factors and thousands of combinations of those factors that characterize the bridge population and influence the condition and performance of bridges. Bridges differ greatly by span type, design features, construction materials, dimensions, live load histories, environmental and climatic factors, physical changes that occur on the bridge, and history of maintenance, preservation, and rehabilitation. Each and every bridge represents a unique combination of these factors.

The LTBP Program Roadmap

These differences illustrate the challenges that the LTBP program must address. Because of these complexities and the intended 20-year duration of the program, a well-designed research plan is essential.

The roadmap steps include the following:

1. Defining bridge performance in terms of the specific important issues
2. Identifying critical gaps in knowledge and data
3. Creating a data infrastructure for bridge data from a variety of sources and with different formats
4. Designing experimental studies to answer key performance questions
5. Collecting data on representative samples of bridges, analyzing data, and creating performance models

Starting with What is Known

The National Bridge Inventory (NBI) contains records on every bridge on all public highways in the United States. The NBI provides information on location, age, type of construction and geometry, functional class of the route carried, and up-to-date data on the condition and adequacy of the structure. The NBI is an invaluable resource for matching bridge types and bridge conditions with factors such as age, average daily truck traffic, and environment, and revealing performance relationships and trends that should be studied further. When culverts and tunnels, which will not be studied under the LTBP program, are excluded, over 80% of the bridges in the United States are simple or continuous spans of steel or concrete I-beams, boxes, or slabs. These are the bridge types that will be the initial focus of the LTBP program.

As a part of the development phase, the LTBP program has identified 20 high-priority bridge performance issues in collaboration with 15 state Department of Transportation (DOT) bridge offices. Experts from the DOT offices included those responsible for the design, construction, inspection, management, and maintenance of bridges. These states were selected on the basis of size, geographic location, and climatic conditions to ensure broad national representation. The high-priority performance issues that have been identified are the most common concerns and the most costly activities that the states face in maintaining, repairing, and rehabilitating bridges. These state DOTs also helped identify what data they currently collect and use for their decision-making processes and what gaps they see in their currently available data. These performance issues include performance of cast-in-place (CIP) concrete decks with various protective measures, joints and bearings, coated steel and weathering steel girders, concrete and prestressed concrete girders, substructure members, and mechanically stabilized earth walls, plus foundation elements vulnerable to scour.

One of seven pilot bridges is located near Perry, Utah. Photos and graphic: Federal Highway Administration.

This California pilot bridge is located about 30 miles south of Sacramento.

The Pilot Bridge Phase

The quality and quantity of data collected under the LTBP program must be consistent with the needs of the LTBP experimental studies, and test protocols used for the LTBP inspections must be clear and consistently applied. Because of the complexities of the LTBP program, many uncertainties must be investigated in order to ensure collection of high-quality data while avoiding wasted efforts and costs and minimizing disruption to bridge owners and users. These uncertainties include the amount of time, effort and cost for office preparation, field work, collection and analysis of data; the costs of instrumentation and data collection systems; the time necessary to coordinate with bridge owners and obtain necessary permits; and the costs of maintenance and protection of traffic while field work is underway.

The LTBP Program Roadmap.

A 2-year pilot phase using seven bridges as field laboratories is helping to resolve these uncertainties. The selection criteria for pilot bridges ensure that the pilot bridges represent a cross section of the bridges that will be the focus of the LTBP program. Primary selection criteria are superstructure type, age, type of deck, composite or noncomposite design, deck condition, environmental factors, overall traffic, and percentage of trucks in the traffic stream. The seven pilot bridges are located in California, Florida, Minnesota, New Jersey, New York, Utah, and Virginia, creating a broad geographic distribution. Three concrete bridges are included.

A pilot bridge in Utah carries southbound I-15 over Cannery Road near Perry. The bridge, constructed in 1976, is a single span of AASHTO precast, prestressed concrete beams with integral abutments. The CIP concrete deck has an asphalt overlay and waterproofing membrane.

A pilot bridge in California carries I-5 over Lambert Road about 30 miles south of Sacramento. The bridge, constructed in 1975, is a two-span, post-tensioned, continuous CIP box-girder bridge with a CIP concrete deck.

The New York pilot bridge is the Karr Valley Creek Bridge on Route 21 in Almond, N.Y. The bridge, constructed in 1990, consists of two simple spans of adjacent precast, prestressed concrete box beams made continuous for live load using a continuity diaphragm over the center pier.

The ultimate goal of the pilot study phase is to make certain that all components needed to achieve the long-term objectives of the LTBP program are well tested before beginning the long-term data collection phase.

The pilot bridges were subjected to a comprehensive regimen of finite element modeling, detailed visual inspection, and live load testing and/or dynamic testing to provide a baseline for the condition and structural behavior of the bridges. The deck of each bridge was also inspected using several different nondestructive testing methods, and cores were taken to help characterize the material qualities of the deck and the type and extent of any deterioration. The results of the pilot bridge studies will be evaluated to determine what adjustments in the LTBP protocols are appropriate. The baseline testing of all pilot bridges is expected to be completed by the spring of 2011 and evaluation of all the pilot bridge testing data will be completed by the fall of 2011.

The long-term data collection phase of the program will begin early in 2011. The knowledge gleaned and lessons learned from the pilot phase will provide critical insight into the planning and implementation of the long-term data collection phase.

John M. Hooks is principal at J. M. Hooks & Associates. He is a consultant on several projects including the Long Term Bridge Performance program. He previously worked at the Federal Highway Administration for 37 years.

EDITOR'S NOTE

More details of the Long-Term Bridge Performance program can be found in a paper prepared by John Hooks. The paper can be downloaded from the *ASPIRE*™ website: www.aspirebridge.org, click on "Resources" and select "Referenced Papers.

Wapello County Looks to the Future

by Brian Moore, Wapello County

Wapello County in southeastern Iowa has been aggressive in looking for ways to lengthen the service life of bridges. Although a relatively small county, with 36,000 people in 436 square miles, the county has taken the lead on two recent innovative projects that will aid design techniques across the country.

The county has 180 bridges in all, with about 40 replaced in the past 6 years. New bridges are always made of concrete, either precast, prestressed concrete beams or cast-in-place concrete slabs. This approach is taken due to concrete's longevity, its efficiency in handling heavier live loads, and the economy with which structures can be built in a short time.

County Uses UHPC

The county has taken the lead in finding ways to extend the life span of its bridges through the use of ultra-high-performance concrete (UHPC). The first use was on the Mars Hill Bridge, consisting of three 110-ft-long, precast concrete, modified 45-in.-deep Iowa bulb-tee beams topped with a cast-in-place concrete deck. The UHPC offered a compressive strength of 30,000 psi, which eliminated the need for shear reinforcement in the beams.

Wapello County was familiar with UHPC and saw the potential in using it to improve bridge designs and lower long-term maintenance costs.

Wapello County's first bridge to be built with UHPC was the Mars Hill Bridge. It features three 110-ft-long precast, prestressed concrete, 45-in.-deep Iowa bulb-tee beams topped with a cast-in-place concrete deck.

Designers worked with Iowa State University and the Iowa Department of Transportation to use the Mars Hill Bridge as a prototype. The county received a grant through the Federal Highway Administration's (FHWA's) Innovative Bridge Research and Construction (IBRC) program to fund research and pay the premium created by trying innovative techniques.

The project proved so successful that a second bridge was designed for Little Cedar Creek, with the help of an FHWA Highways for LIFE grant. The project, to be completed in spring 2011, contains 14 UHPC deck waffle panels on a 60-ft-long, 33-ft-wide concrete bridge. The panels are 15 ft long, 8 ft wide, and 8 in. deep at the deepest point, with the shallow portion of the "waffle" squares only 2.5 in. deep.

We believe these waffle panels offer the best application for UHPC for Iowa bridges due to the properties of the material and the design's flexibility and longevity. The design is simple, manufacturing (by Coreslab Structures in Omaha, Neb., using Ductal UHPC from Lafarge North America) is easy and construction moves quickly. The lightweight panels will allow rehabilitation of bridges without needing to strengthen the substructure to handle heavier live loads. It also will be possible to rehabilitate bridges under traffic by replacing one lane at a time. In addition, UHPC is virtually impermeable.

The goal now is to learn from these two projects and expand UHPC's application to a longer bridge, such as a three-span structure. These projects are fairly simple, but they offer great potential to aid future projects around the country, which is our goal.

Brian Moore is Wapello County Engineer in Ottumwa, Iowa.

Wapello County's second bridge to include UHPC is the bridge over Little Cedar Creek, which features 14 precast concrete "waffle" panels for the deck. This offers one of the best uses for UHPC for Iowa bridges due to the properties of the material and the design's adaptability and longevity.

EDITOR'S NOTE

For more information on the Mars Hill project, see the Summer 2007 issue of Aspire.™ *For more on the Little Cedar Creek project, see the FHWA article in the Fall 2010 issue.*

POSEIDON BARGE CORPORATION sells and rents sectional barges to the Heavy Highway, Bridge and Marine Construction Industries. We offer 5' and 7' deep barges which are compatible with our competition. Having distribution centers located in seven states throughout the US and the ability to haul two 40' x 10' x 5' barges on step deck trailers, we can offer you competitive rates with lower mobilization costs then our competition.

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167-ft-long precast concrete beams avoid obstacles along PENNSYLVANIA TURNPIKE

by Troy M. Jenkins, Northeast Prestressed Products LLC

As part of the Pennsylvania Turnpike Northeast extension in Carbon County, twin bridges were designed to span the Lehigh River and Lehigh Canal with one set of 1530-ft-long structures, while a second set of 1020-ft-long bridges spans the adjacent Pohopoco Creek. The geometries of these locations were complex, as a variety of constraints stood in the way. The obstacles included railroad tracks, a state road, the historic canal, and the two waterways.

The original design was conceived as a steel structure, but the Pennsylvania Department of Transportation (PennDOT) allows for a contractor-designed alternate. The engineers at Northeast Prestressed Products LLC (NPP), Cressona, Pa., saw an opportunity to create a precast, prestressed concrete bridge that would offer the benefits of faster construction, greater economy, and lower maintenance costs throughout the structure's life.

To accomplish this required 175 precast concrete PennDOT bulb-tee beams, ranging in length from 100 ft to 167 ft. Many of these needed to be set as chords to achieve the proper radius. Borton-Lawson Inc. in Wilkes-Barre, Pa., consulted on the engineering design for the project.

On the Pohopoco Creek project, 20 of the beams were approximately 163.5 ft long, 20 were 151 ft to 157 ft long, 20 were 137 ft to 141 ft long, and 10 were 100 ft to 102 ft long. On the Lehigh Bridge, 30 beams were 163 ft to 166.8 ft long, 30 beams were 148 ft to 158 ft long, 30 were 129 ft to 138 ft long, and 15 were 100 ft to 108 ft long for a total of 105 beams.

Nothing out of the ordinary was needed to transport the beams to the site. NPP has specialized transportation equipment in its fleet for such deliveries. The beams were tied down and secured to the truck and the vehicle on the trailing end in the normal way. A stability analysis was provided for handling, transportation, and placement of the beams at the site. Only one crane was needed to erect the beams upon their arrival. Walsh Group served as general contractor on the project.

The success of this project indicates that long spans and unusual constraints should not preclude the erection of a precast concrete bridge, which can offer many other advantages in the long run for DOTs nationwide.

Troy M. Jenkins is chief engineer with Northeast Prestressed Products LLC in Cressona, Pa.

Fifty precast, prestressed concrete beams with lengths greater than 163 ft were required for the bridges and delivered to the site and erected without extraordinary provisions.

Careful selection of span lengths was needed to place piers to avoid impacting the river, creek, historic canal, railroad tracks, and access road.

CONCRETE CONNECTIONS

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

IN THIS ISSUE

www.udot.utah.gov/main/f?p=100:pg:0::::T,V:1991
This Utah Department of Transportation website contains more information about Utah's Accelerated Bridge Construction (ABC) program mentioned on page 18.

www.pcine.org/index.cfm/projects/Bridges
Go to this website and click on the photograph of the Cross Street Bridge for more photographs of this unique bridge in Vermont.

www.fhwa.dot.gov/hfl/summary/ia/
www.fhwa.dot.gov/hfl/summary/ut0409/
www.fhwa.dot.gov/hfl/summary/or/

These three FHWA Highways for Life websites contain details about the projects in Iowa, Utah, and Oregon mentioned in the FHWA article on page 42.

http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=1232
This website contains the report titled *Verification and Implementation of Strut-and-Tie Model in LRFD Bridge Design Specifications* referenced in the AASHTO LRFD article on page 52.

http://www.whrp.org/research-areas/structures/downloads/06-06%20Final%20Report.pdf
The complete report titled *Evaluation of Select Methods of Corrosion Control, Corrosion Prevention, and Repair in Reinforced Concrete Bridges* summarized in the Concrete Bridge Preservation Section on page 37 is available at this website.

www.oregon.gov/ODOT/HWY/REGION1/ColumbiaGorge
This Oregon Department of Transportation website contains information related to the I-84 Corridor Strategy and bridge projects mentioned on page 15. The website includes an overview, project site map, schedule, budget, contacts, and information about different projects.

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.

Bridge Technology

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

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

www.hpcbridgeviews.org
This website contains 64 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.

NEW **www.fhwa.dot.gov/everydaycounts/technology/bridges/intro.cfm**
This website contains information about the FHWA Every Day Counts (EDC) initiative as it relates to prefabricated bridges. An EDC Innovation Box is provided where you may share your ideas on how to shorten project delivery or accelerate technology and innovation deployment.

NEW **www.wsdot.wa.gov/eesc/bridge/ABC/**
Visit this Washington State DOT website to learn more about the state's accelerated bridge program and available resources.

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.

www.tsp2.org/bridge
This website was developed to provide highway agencies and bridge preservation practitioners with on-line resources about bridge preservation, maintenance, and inspection.

Bridge Research

www.trb.org/CRP/NCHRP/NCHRPprojects.asp
This website provides a list of all National Cooperative Highway Research Program (NCHRP) projects since 1989 and their current status. Research Field 12—Bridges generally lists projects related to bridges although projects related to concrete materials performance may be listed in Research Field 18—Concrete Materials.

http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_654.pdf
NCHRP Report 654, *Evaluation and Repair Procedures for Precast/Prestressed Concrete Girders with Longitudinal Cracking in the Web*, explores the acceptance, repair, or rejection of precast/prestressed concrete girders with longitudinal web cracking. The report also includes suggested revisions to the AASHTO LRFD Bridge Design Specifications and improved crack control reinforcement details to use in new girders.

Important PCI Events and Deadlines

Call for Papers

The Precast/Prestressed Concrete Institute has issued a Call for Papers for the 2011 National Bridge Conference / PCI Annual Convention and Exhibition, which will be held October 22–25, 2011 at the Salt Lake City Marriott Downtown & Salt Lake Palace Convention Center in Salt Lake City, Utah

Abstracts should be submitted electronically at https://www.softconf.com/b/PCI2011 no later than April 4, 2011. Authors of selected papers will be notified by April 22, 2011. Final papers are due July 15, 2011.

Requirements for papers can be found at www.pci.org.

For more information, contact Alex Morales at (312) 360-3219 or amorales@pci.org.

Committee Days

Save the date for the 2011 PCI Committee Days, March 24–26 at the Wyndham Chicago Hotel in downtown Chicago, Ill. A room rate of $129/night has been secured. Registration will open in January 2011. For more information, visit www.pci.org/cdays.

Design Awards

The 2011 PCI Design Awards program will open for submissions on January 31, 2011. All entries must be submitted electronically by May 23, 2011. There is no entry fee. Project submissions must be completed by May 23, 2011. To make a submission and for more information, visit www.pci.org/2011designawards. Contact Jennifer Peters at jpeters@pci.org or Brian Miller at bmiller@pci.org with any questions.

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The Strut-and-Tie Model:
Visualizing Load Paths

by Dr. Dennis R. Mertz

The strut-and-tie model of Article 5.6.3 of the *AASHTO LRFD Bridge Design Specifications* provides an alternate to traditional models for proportioning reinforcing steel within structural concrete components at strength and extreme event limit states. Traditional sectional models are based on the assumption that the reinforcement required at a particular section depends only on the section force effects of moment, shear, and torsion. These sectional models do not consider the interaction between these force effects. For control of cracking under service loads, the magnitude of principal tensile stresses can be checked using the principles of Mohr's Circle.

According to the *LRFD Specifications*, the strut-and-tie model may be applied to proportioning reinforcement in any component or parts of a component, but must be applied where nonlinear strain distributions exist. Such nonlinear distributions typically exist in deep pile caps and pier caps and, in general, anywhere applied loads or support reactions are less than two member depths apart. In such circumstances, linear strain distributions cannot develop.

In the application of the strut-and-tie model, rather than determine force effects at individual sections along the component, load paths carrying the applied loads to the support reactions are visualized within the component. These load paths are assumed to be straight lines that form a truss within the component. At the limit after significant cracking, the initially curved compressive-stress trajectories do indeed become straight lines, called struts. The straight tension load paths, called ties, represent the steel reinforcement, either prestressed or nonprestressed.

Many different load paths and thus strut-and-tie models are viable for a particular component, just as many solutions exist to any design problem. The more inefficient visualized load paths will require more reinforcement. The most efficient load paths are relatively self evident.

A simple, classical strut-and-tie model of a deep beam is shown in Figure C5.6.3.2-1 of the LRFD Specifications. In the case of the beam shown in the figure, each of the applied loads and nearest support reactions are less than two member depths apart. Many example strut-and-tie models representing more realistic bridge components are included in the final report for National Cooperative Highway Research Program (NCHRP) Project 20-7, Task 217, *Verification and Implementation of Strut-and-Tie Model in LRFD Bridge Design Specifications* by Modjeski & Masters. This valuable resource is available for free download at the Transportation Research Board website, http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=1232. Design examples are also given in the Portland Cement Association publication EB231 titled *AASHTO LRFD Strut-and-Tie Model Design Examples*.

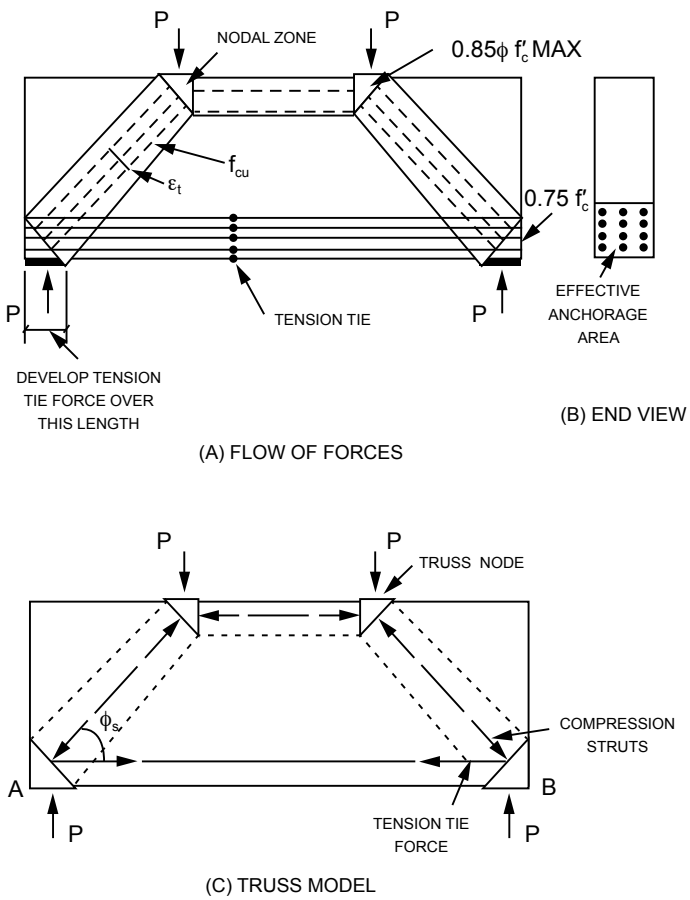

Figure C5.6.3.2-1 from the AASHTO LRFD Bridge Design Specifications.

After the load paths of the applied loads to the support reactions are visualized in the model, the actual load paths must be realized in the component. The size of the compression strut defined in LRFD Article 5.6.3.3.2 must be of sufficient cross-sectional area to carry the compression force without exceeding the limiting compressive stress of LRFD Article 5.6.3.3.3.

Steel reinforcement must be provided within the tension ties to carry tension force when the steel is at yield. Further, the steel must be sufficiently anchored to carry the tie force along its entire length.

The nodes at which the struts and ties meet must also satisfy compression-stress limits specified in LRFD Article 5.6.3.5.

Finally, an orthogonal grid of reinforcement must be provided near the faces of the components to control the significant cracking expected at the limit when the struts and ties are realized.

The strut-and-tie model is a powerful tool for strength load cases when conventional methods of strength of materials are no longer valid. It harkens back to when the structural engineer first learns to analyze a simple truss. By visualizing the members of the truss, the struts and ties, the designer achieves a better understanding of the mechanisms that allow complex structures to safely carry loads.

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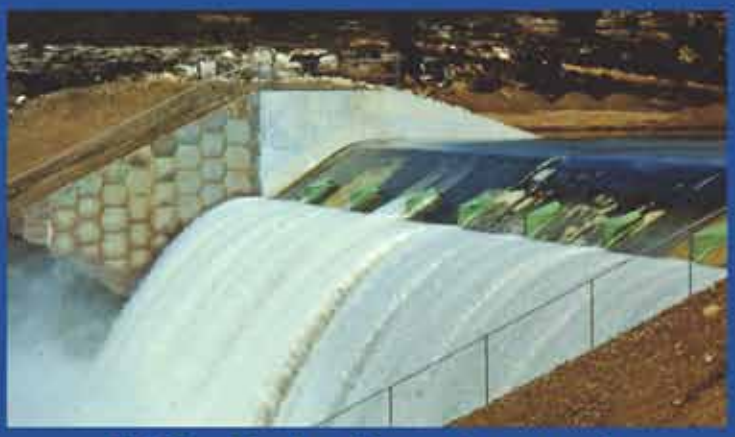

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