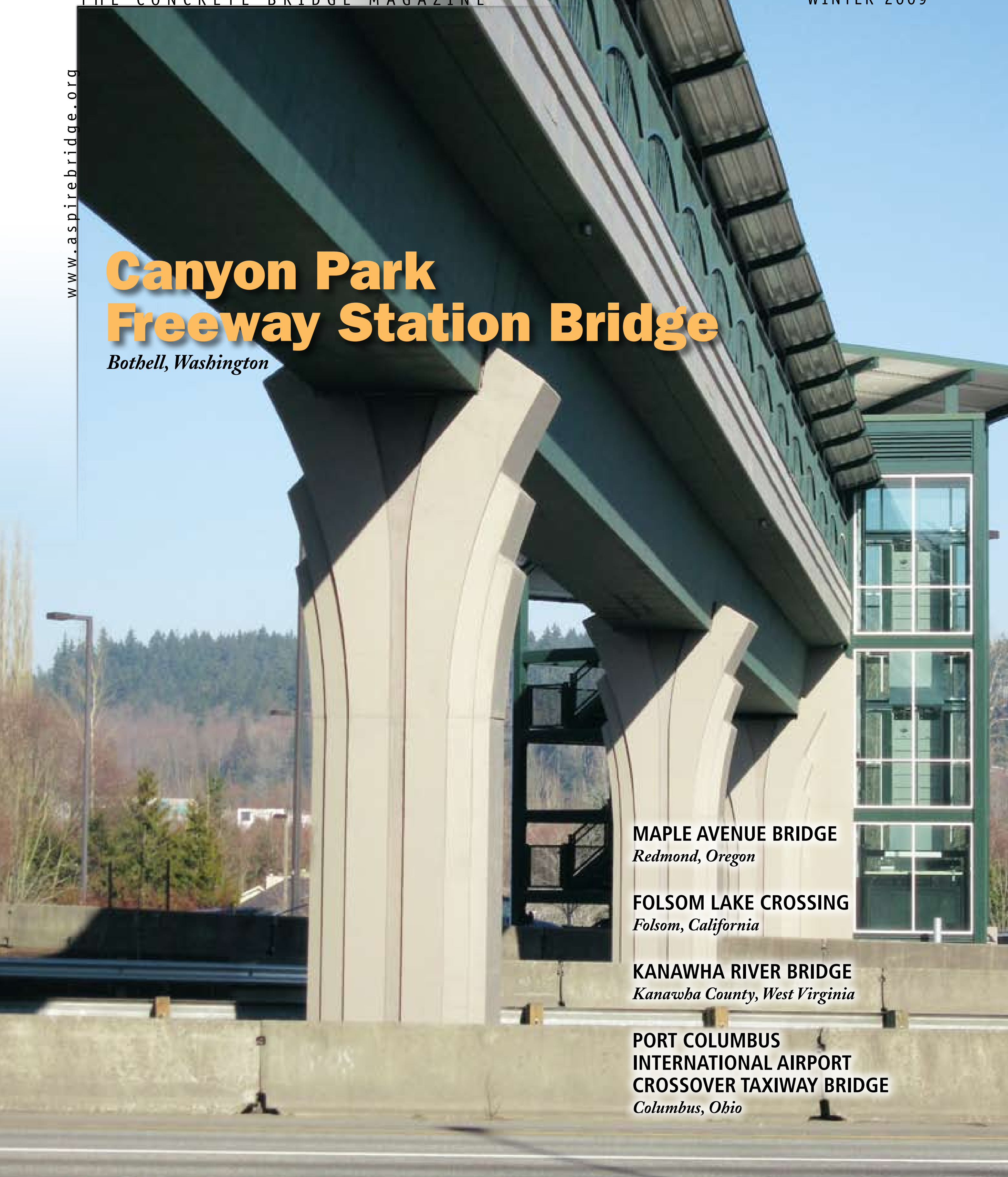
ASPIRE™

THE CONCRETE BRIDGE MAGAZINE

WINTER 2009

www.aspirebridge.org



Canyon Park Freeway Station Bridge

Bothell, Washington

MAPLE AVENUE BRIDGE
Redmond, Oregon

FOLSOM LAKE CROSSING
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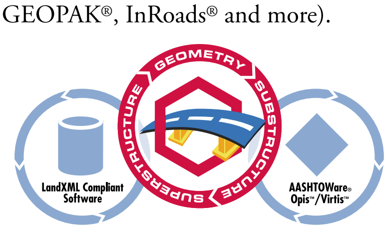

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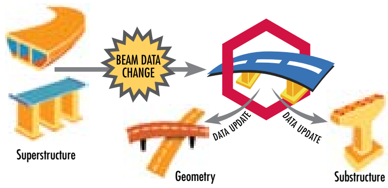

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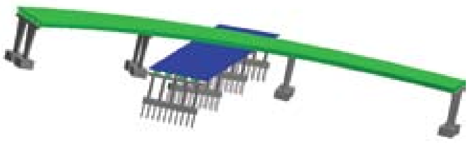

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Social, Economic, and Ecological Benefits of Sustainable Concrete Bridges

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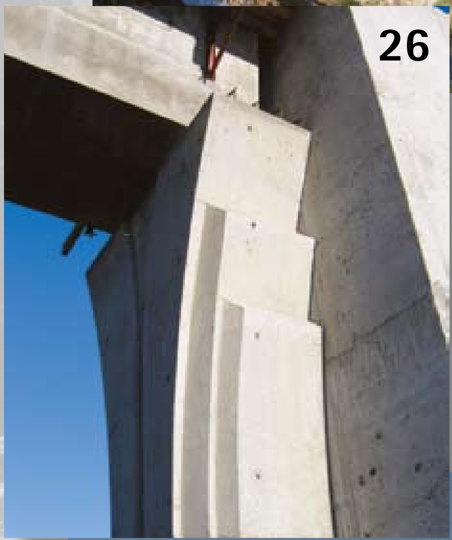

Photo: Washington State Department of Transportation.

Photo: T.Y. Lin International.

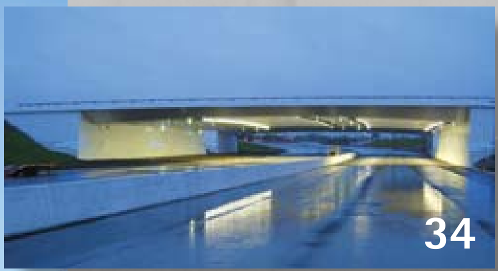

Photo: RW Armstrong.

Canyon Park Freeway Station.

EDITORIAL

Forging a New Generation of Sustainable Bridges

Photo: Ted Lacey Photography.

John S. Dick, *Executive Editor*

With this issue, *ASPIRE*™ begins its third year of delivering information on outstanding bridges, imaginative solutions, and solid, useful techniques for the bridge design and construction community. We appreciate your encouragement and support and we certainly welcome your comments and suggestions.

Sustainability to Remain Focus

Sustainable bridge design will again be our focus in 2009. We introduced and explored it in 2008 and it became the obvious choice for 2009. We discovered that nearly every featured bridge last year had sustainability considerations woven into its design. It became clear that concrete bridges are truly the sustainable solution for our nation's bridges. Every attribute we ascribe to concrete bridges meshes with principles of sustainability. So, we will continue to report your accomplishments in building sustainable concrete bridges and will emphasize those aspects whenever techniques stand out.

Challenges Prevail

As we go to press, the state of the nation's economy is on every mind. In transportation, long-term funding solutions are likely to be a high priority in 2009. Solutions and various economic stimulus ideas have become the topics du jour.

On page 14, John Horsley, executive director of the American Association of State Highway and Transportation Officials offers this observation in his "Perspective: Sustainable Bridges and the Value of Innovation:" "…we have a wealth of talent and techniques to forge a new generation of sustainable bridges that promise greater strength, safety, service, sensitivity, savings, and stability for all who use them. What we lack, however, is a more vigorous national commitment to investment for those structures and other key transportation priorities." We hope that 2009 will see the necessary commitments to transportation infrastructure made by all levels of government.

Project Features

This issue's project reports include three highway bridges, a pedestrian bridge, and a major airport taxiway bridge. Included in the mix is the longest span concrete box girder bridge in the United States, the Kanawha River Bridge, on page 30. A unique pedestrian bridge in Washington State incorporates numerous aesthetic features and required construction over busy I-405 (see page 26). The Port Columbus Taxiway Bridge is designed for Group V aircraft loading while achieving a slender and attractive solution (see page 34). As you can see, there are many applications for concrete bridges.

Industry Advisory

The Safety and Serviceability feature in this issue is an advisory developed by the Precast/Prestressed Concrete Institute (PCI). After experiencing a number of situations involving "sweep" of long slender girders, the industry identified circumstances that could lead to undesirable performance. This discussion begins on page 38.

New Special Section

On page 41, *ASPIRE* begins a new regular feature we call Maintenance, Repair, and Rehabilitation of Concrete Bridges. Until now, we have not explored these subjects, but believe they are critical issues enabling bridge owners and designers to strengthen and prolong their concrete bridge inventories. We look forward to your comments and especially ask for your ideas about projects that deserve recognition. *Let us know!*

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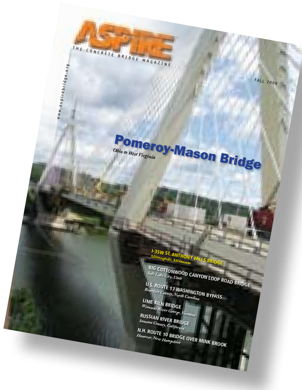
Canyon Park Freeway Station Bridge, Bothell, Wash.
Photo: Washington State Department of Transportation.

READER RESPONSE

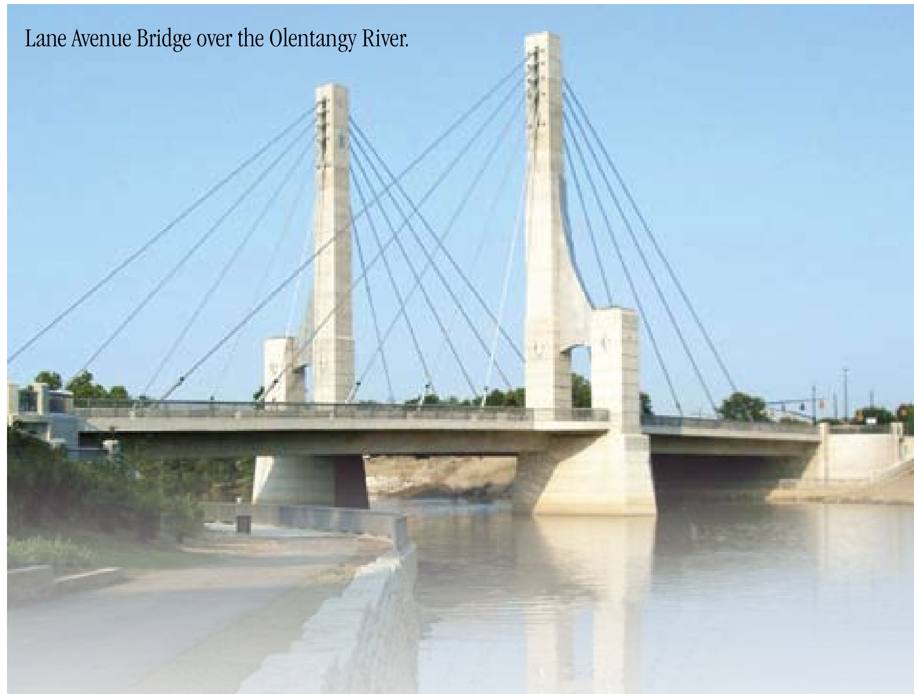


I enjoyed the article on the St. Anthony Falls Bridge in ASPIRE™ (Fall 2008). I admire the effort and achievement in completing this mega project in less then 1/5th the time of a normal construction schedule and I agree it was a monumental accomplishment of all involved.

Sumiden Wire Products Corporation supplied all the prestressing steel strand used in this project and performed flawlessly under extremely difficult circumstances. We were given the contract in January 2008 and originally told we needed to supply the prestressing steel strand over a 12-month period beginning February 2008. Shortly thereafter, we were asked to condense the schedule and supply the entire contract by June 2008.

This accelerated schedule would be difficult in a normal steel market but 2008 was far from normal. Nevertheless, despite steel shortages and sky rocketing steel prices Sumiden Wire Products Corporation met the challenge.

Jeff Feitler
V.P. Sales & Marketing
Sumiden Wire Products Corporation
Stockton, Calif.


Lane Avenue Bridge over the Olentangy River.

I just received my fall issue of ASPIRE magazine and wanted to thank you for considering Franklin County and me to contribute an article.

Keep up the excellent work of your magazine and let us know if we can ever be of assistance in the future.

James A. Pajk
Franklin County Deputy Engineer, Bridges
Columbus, Ohio


I-35W St. Anthony Falls Bridge.
Photo: ©FIGG

The summer issue of *ASPIRE*™ featured one of the world's most unique bridges. The Hood Canal Bridge is a 1.5-mile-long floating structure; the longest in the world over saltwater. The article can be found on pages 16-20. All back issues are available at *www.aspirebridge.org*.

While the article presents an intriguing history of the bridge, its 1982 partial replacement, and work underway now to finish the replacement, we did not recognize those innovative designers who were responsible for both replacement projects. This letter from Mr. Michael Abrahams sets the record straight.

Dear [Editor]:

I am writing to compliment you for the excellent article on the Hood Canal Bridge in the summer 2008 issue and to mention the team responsible for its design.

The original bridge, whose west half sank during a violent storm in 1979, was replaced in a two-phase operation based on plans prepared by the joint venture of Parsons Brinckerhoff and Raymond Technical Facilities (PB/RTF). These plans were prepared in 1980 for Phase 1 and 1981 for Phase 2 and allowed the bridge to be opened to traffic in 1982. Following completion of the plans for the replacement of the west half, PB/RTF then prepared the plans for the replacement of the east half. These were also completed in 1981. Studies at the time by Washington Department of Transportation (WSDOT) predicted that the east half would not have to be replaced for another 20 years so the east half plans remained on the shelf for a number of years.

In 1998, PB (RTF was no longer in business) was retained by WSDOT to update our 1981 east half plans so that WSDOT could proceed with the east half replacement. At the same time, due to growing development in the area, the WSDOT wanted to modify the existing west half bridge and revise the east half roadway width from 30 ft 0 in. to 40 ft 0 in. and to allow for further widening in the future. After a joint study by PB and WSDOT, a preferred widening scheme was adopted and WSDOT, under the direction of Patrick Clarke, proceeded to prepare the plans for the widened east and west half superstructures, to replace the fixed approaches using an innovative slide-in technique and pipe member transition trusses, and to revise the east half gravity anchor plans. One critical issue in the study was to establish the loss of freeboard due to the added weight of the widened superstructure. PB at the same time proceeded to update the plans and specifications for the east and west half movable span control systems, electrical and mechanical systems, and to revise the east and west half buildings. The building work was in association with Streeter and Associates, a local Seattle-based consultant. These plans were completed in 2003, when the construction contract was awarded. The east half replacement continues to be a joint effort by WSDOT and PB, and we continue to be involved in the Hood Canal Bridge project, providing assistance in responding to construction issues.

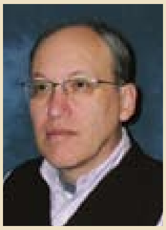
One of the innovations discussed in the article, the use of precast segments for the pontoon construction, was developed by Charles Rejcha, an RTF engineer, who had been trained by Eugene Freyssinet in Paris shortly after World War II. Mr. Rejcha was highly skilled in post-tensioned segmental concrete design and had previously opened Freyssinet's first office in the United States.

Again, my compliments on the excellent article.

Very truly yours,
Michael J. Abrahams, PB AMERICAS INC., New York, N.Y.

CONTRIBUTING AUTHORS

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.



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.

John Horsley is executive director of the American Association of State Highway and Transportation Officials in Washington, D.C. He previously served as county commissioner in Kitsap County, Wash., and as associate deputy secretary at the U.S. Department of Transportation. He is a graduate of Harvard, was a Peace Corps volunteer and congressional aide. He was also past president of the National Association of Counties and founding chairman of the Rebuild America Coalition.

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

Photo: Ted Lacey Photography.

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.

CONCRETE CALENDAR 2009

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

February 3-6
World of Concrete
Las Vegas Convention Center, Las Vegas, Nev.

March 15-19
ACI Spring Convention
Marriott Rivercenter Hotel, San Antonio, Tex.

March 19-20
ASCE Bridge Rehabilitation Seminar
Embassy Suites Hotel Center City, Philadelphia, Pa.

April 15
fib World Congress (hosted by PCI)
Abstracts due April 15, 2009, for this event to be held May 29-June 2, 2010
Gaylord National Resort & Convention Center, National Harbor, Md.

April 20-21
2009 ASBI Grouting Certification Training
J.J. Pickle Research Campus, The Commons Center, Austin, Tex.

April 22-26
PCI Committee Days
Westin Hotel, Chicago, Ill.

May 4-7
World of Coal Ash (WOCA 2009)
Lexington Convention Center, Lexington, Ky.

May 31
The Fifth International Conference on Bridge Maintenance, Safety and Management
Abstracts due May 31, 2009, for IABMAS2010, to be held July 11-15, 2010
Philadelphia, Pa.

June 14-19
International Bridge Conference
David L. Lawrence Convention Center, Pittsburgh, Pa.

July 5-9
AASHTO Subcommittee on Bridges and Structures Annual Meeting
Hilton Riverside Hotel, New Orleans, La.

September 12-15
PCI-FHWA National Bridge Conference
Abstracts due March 1, 2009
Marriott Rivercenter Hotel and Henry B. Gonzales Convention Center, San Antonio, Tex.

September 21-23
Western Bridge Engineer's Seminar
Sacramento Convention Center and Sheraton Grand Hotel, Sacramento, Calif.

October 25-27
2009 ASBI 21st Annual Convention
Hilton Hotel, Minneapolis, Minn.

November 8-12
ACI Fall Convention
Marriott New Orleans, New Orleans, La.

AECOM

THE STRUCTURE *BEHIND* THE STRUCTURE

by Arthur Schurr

How the AECOM bridge practice gets things built

President Franklin Roosevelt said, "There can be little doubt that in many ways the story of bridge building is the story of civilization." And the people who create those bridges are a big part of that story.

Designing and constructing bridges is like no other profession. Though firmly anchored in the earth, bridges can soar skyward like cathedrals. Majestic, grand, inspiring, and iconic, bridges can define a location and transform a region. Yet in addition to their considerable visual, aesthetic, and cultural contributions, bridges also must fulfill a very practical function. At their core, they are a means of getting people and things from Point A to Point B, using the most efficient route possible.

Given that fusion of art and function, anyone who would aspire to design these structures must be part Renaissance thinker, part tinkerer, part linear analyst, and part romantic—but always a full-time team player. It takes a unique blend of individual creativity and selfless teamwork to design and build a successful bridge. Formed to meet that need, the AECOM bridge practice unites a brigade of experts into a global unit that is ready to ply its trade wherever it is most needed.

Illustration: Shutterstock

'We have more than 850 bridge engineers located in 51 offices around the globe.'

"In examining the Brooklyn Bridge right after it was completed, someone described it as a 'durable monument' that would 'convey some knowledge of us to the most remote posterity.' But they also said the Brooklyn Bridge was a 'work of bare utility; not a shrine, not a fortress, not a palace, but a bridge.' And that is exactly how I see what we do," explains Ken Butler, AECOM's national director of bridge services. "Though bridges are a testament to our present sense of aesthetics, culture, and technological achievement, we only build bridges because they are needed to provide passage."

As a 12-year veteran with the firm and almost a quarter century of bridge design expertise, Butler knows how AECOM's bridge practice works. For him, the firm's philosophy and principles are reflected both in the bridges they've built, and in the underlying structure of the bridge practice itself.

"We have more than 850 bridge engineers located in 51 offices around the globe, half of which are located in the United States. As a result, we can offer the full range of bridge services—supporting everything from small overpass structures to major, complex, signature bridges. To deliver on that offer, we rely on a huge reservoir of talent and a three-part technical structure.

"Bridge engineers in each of our local offices represent our first component. They provide a broad array of technical services to a diverse client base that includes departments of transportation, toll authorities, and other public agencies.

"Next, we have a dedicated practice staffed with engineers who have highly specialized technical backgrounds, experience, and expertise in designing and constructing major, complex bridges. Members of this group go anywhere their expertise is needed. They're kind of like a SWAT team of bridge designers. Whether it's the Indian River Inlet cable-stayed bridge in Delaware, the Richmond–San Rafael Bridge in California, the Florida Avenue Bridge in New Orleans, or the East 153rd Street cable-stayed bridge in New York City, they go and get the job done.

"Finally, the third part of our structure is our international component, largely operated by a company unit known as Maunsell. Our international component has lent its expertise to projects throughout the world. They, too, have completed everything from small overpasses to signature bridges that are very dramatic and instantly recognizable. They are currently providing bridge engineering services for the two longest span cable-stayed bridges in the world: Sutong Bridge in China and the Stonecutters Bridge in Hong Kong; and the longest span, cast-in-place concrete box girder bridge, Second Gateway in Australia.

"What gives our structure its real power, though, is that we can transfer expertise fluidly around the world—wherever and whenever it is needed. We can deploy world-class expertise to any locale that requires it. By flexibly integrating our global technical resources, we can meet virtually any client's needs, no matter how small or large, simple or complex."

Boasting more than 43,000 employees globally, and revenues of $5.2 billion in 2008, AECOM serves clients in more than 100 countries. Ranked first in overall transportation design by *Engineering News-Record*, and third in bridge design, the firm prides itself on providing a "blend of global reach, local knowledge, innovation, and technical excellence in delivering solutions that enhance and sustain the world's built, natural, and social environments." Lofty as that may sound, Butler believes it's a very practical, functional blueprint.

"Local expertise is more than sufficient for most projects. But when a project is considerably more complex or unusual, we bring in the requisite expertise from around the country or anywhere in the world. That specialized expertise ensures that our clients get the best technical knowledge, experience, and methods available. That isn't just marketing rhetoric; it's what we do."

This reliance on resource transfers and staff allocations isn't confined to the bridge practice; it is reflected throughout the firm. Many AECOM projects seem like makeshift meetings of the United Nations. According to Butler, though, creating an international mix is never the end goal—but it often is the end result. Rather, it's about deploying the appropriate resources for the task at hand. For example, consider the Delaware Department of Transportation's (DelDOT) Indian River Inlet Bridge.

Indian River Inlet Bridge

Located in Rehoboth Beach, Del., the Indian River Inlet has posed a considerable engineering challenge for nearly a century. The most recently built bridge—dating back to 1965—has a problem: the forceful inlet tides are severely scouring its piers. When the bridge was initially built, inlet depth was measured at 28 ft. Recently the inlet depth was measured at more than 100 ft. A new bridge was needed, one that could overcome the harsh environmental effects that had damaged previous bridges, Butler explains.

"The existing bridge had piers in the water within the inlet. As a result of the shape

The upper and lower trestles with total lengths of 2843 ft and 3643 ft, respectively, were replaced with double tees measuring nearly 44 ft wide and 100 ft long. They were match cast in three segments and post-tensioned together in the precaster's plant. The units were also post-tensioned transversely. Each weighs 425 tons.

of the inlet and the way the tides ebb and flow, scour was a destructive and perennial issue. The inlet had scour holes up to 120 ft deep. Obviously, either the existing bridge piers would be eventually scoured out or major counter-scour measures would be required. The key for the new bridge was to take all the piers and substructure out of the inlet water.

"Given the geometric constraints, we approached it with a form-follows-function mentality; we were really looking for the most economical structure in terms of durability and maintenance for the 100-plus-year service life the client required. So, we created a cable-stayed bridge with a very shallow profile, a 6-ft-deep superstructure. With a combination of precast and cast-in-place concrete, the bridge has single-mast, 240-ft-tall towers that evoke the graceful lines of sailboats. We wanted to make the bridge as slender and unobtrusive as possible, given its pristine coastal environment. We wanted it to blend into the beautiful coastal region and not overpower it."

To be constructed under a design-build partnership with Skanska, the $150 million Indian River Inlet Bridge will stretch 2600 ft, with a 950-ft-long clear span over the inlet. The scour issue is eliminated by placing all supports out of the water; the new foundation consists of 36-in.-square piles. The bridge is scheduled to be open to traffic by the summer of 2011. Heavy construction will begin in early 2009.

The design solution developed for the Indian River Inlet Bridge project demonstrates the flexible effectiveness of AECOM's bridge practice. In addition to partnering with long-time collaborator Skanska and regular subconsultants, AECOM tapped its local Philadelphia office for necessary expertise to get the job done. And AECOM Maunsell is providing erection engineering on the project. AECOM's three-part technical structure once again proved effective for this project.

Precast concrete jackets for the pier shafts used in the retrofit of the Richmond-San Rafael Bridge across San Francisco Bay, are shown in the precaster's yard and installed in place.

Richmond-San Rafael Bridge

The Richmond-San Rafael Bridge provides another illustration of how the firm's bridge practice works. Operated by the California Department of Transportation (Caltrans), the Richmond-San Rafael Bridge carries more than 60,000 vehicles a day. Part of I-580, the bridge is one of four spans crossing San Francisco Bay; it connects the cities of San Rafael in Marin County and Richmond in Contra Costa County. Consisting of two single-deck, reinforced concrete approach trestles with 50-ft-long spans and a combined length of approximately 6500 ft, the bridge also boasts built-up steel-girder spans at both ends, including single-deck and double-deck structures with a combined length of 3600 ft. In addition, two variable-depth, double-deck, cantilever-truss-type structures span the navigational channels with 537.5-ft-long anchor spans and 1070-ft-long center spans that reach a combined length of 10,600 ft. Not a typical bridge by any measure, there were additional significant complications.

Just 4 miles from the Hayward Fault and 10 miles from the infamous San Andreas Fault, the bridge sits between two of the most dangerous and sensitive zones surrounding any elevated structure in the world. Also, because it is one of only four structures crossing San Francisco Bay, closing the bridge to traffic was not an option. Tasked with the role of designing 6500 ft of replacement trestle at the west approach of the bridge in the $735 million project, the AECOM design team had to create a solution that was both effective and efficient.

"We were assigned to perform seismic analysis and retrofit design of the bridge," explains Androush Danielians, associate vice president and manager of the firm's Los Angeles structural engineering department. "Seismic analysis of such a long structure required special techniques. To account for variations in the seismic forces experienced by the structure, multi-support excitation time-history analysis was used to evaluate the structural behavior in a seismic event. Simply put, multi-support excitation exerts different magnitudes of seismic force at each support. Although the other portions of the bridge were retrofitted, we determined that replacement of the trestle portion of the bridge would be more cost-effective than seismically retrofitting it. But the replacement work faced unique conditions; we could not close the bridge completely for any extended period."

"Our solution was to bring in precast, prestressed complete deck sections; these double-tee sections were 100 ft long per span. At night, we would close down the bridge, replace one span, and then open it up for the morning rush. That avoided a lot of construction issues. And aside from wanting traffic to flow to serve the traveling public, we had another serious incentive to make the plan work.

"Any construction delay that caused the bridge to open late incurred a potential penalty of $28,000 for each minute the bridge opened late. That's a pretty serious motivation to make sure that everything goes smoothly and on time. And it did. The penalty was never invoked, not even once. Key to the plan, though, was the precast option. Using precast, prestressed concrete sections for the superstructure made the replacement of the trestle portion possible under these conditions."

Use of the precast, prestressed concrete elements and the design did not go unnoticed. At its 2007 annual national bridge conference in Phoenix, Ariz., the Precast/Prestressed Concrete Institute (PCI) bestowed on AECOM the "Best Bridge Project with Spans Between 75 and 150 Feet" award for its work on the Richmond-San Rafael Bridge. According to the PCI jury, "The project demonstrates the advantages that can be achieved by standardizing sections, even with 64 spans of more than 100 ft. The bridge offered an excellent example of the applications of precast concrete elements in a fairly complex bridge design."

AECOM's internal structure played a vital role in the project's success. Though primarily handled from the Los Angeles office, the project drew in AECOM engineers from around the country—from Oakland and Sacramento to Richmond, Va., and Tallahassee, Fla.

"Our Florida office provided decisive expertise on this project. Precast bridges are very common in Florida, less so in California. Designers from our Florida office helped us create a unique solution, one that impressed Caltrans enough for them to sign off on several 'firsts' in terms of design and execution. Being able to draw on such varied expertise equipped us to create the optimal solution for our client."

Additional U.S. Projects

The firm's technical structure has enhanced AECOM's ability to serve its clients on other projects as well. In New Orleans, La., AECOM is performing detailed design and construction support for the Florida Avenue Bridge project. Part of the $4 billion Transportation Infrastructure for Economic Development (TIMED) program for the Louisiana Department of Transportation and Development, the $220 million Florida Avenue Bridge project is one of three major bridge components of the TIMED program.

Designed to provide reliable access between St. Bernard and Orleans parishes over the Inner Harbor Navigational Canal (IHNC), the project includes a four-lane, 78-ft-wide, high-level bridge over the IHNC. The five-span main unit over the IHNC is 1516 ft long and includes a 470-ft-long center span, which provides 300-ft-horizontal and 156-ft-vertical navigational clearances.

For the Pennsylvania Turnpike Commission, AECOM is providing preliminary and final design engineering for a new 5-mile section of highway that includes more than 19,000 linear ft of elevated, multi-level, curved structure. Located in North Versailles Township near Pittsburgh, Pa., the $240 million Mon-Fayette Expressway (Section 53E) includes a complex, multi-level, system-to-system closed interchange and a system-to-service interchange for this strategic expressway segment. This segment is critical to industrial redevelopment along the Monongahela River.

In Boston, AECOM provided detailed design and construction support for significant elements of the Central Artery/Tunnel project in an $850 million engagement with the Massachusetts Highway Department. Responsible for final design of major structural components and coordination of various design elements and subconsultants for several portions of the Big Dig, AECOM completed considerable bridge work on the project—including approximately 9000 linear ft of auxiliary steel and concrete viaducts and bridges over boat sections, new bridges on Broadway and Dorchester Avenues, and approximately 2000 linear ft of mainline steel and concrete viaducts.

AECOM serves clients in more than 100 countries with more than 43,000 employees globally.

International Component

The core bridge practice has proven to be quite effective for projects both local and national. But the third part of the three-part technical structure described by Butler—the international component—has made significant contributions as well. In New South Wales, Australia, AECOM performed concept and preliminary design, as well as detailed design and documentation for the "Sea Cliff Bridge" (as the Lawrence Harvey

The selection of structure type and erection method for viaducts on the Taiwan High Speed Rail was influenced by the variable terrain and wide river plains; the choice of structural layout played an important part in achieving an economical design. Seismic load effects, although only a part of the entire design process, determined the dimensioning of key elements such as substructure and foundation.

The superstructure of the Taiwan High Speed Rail comprises precast, post-tensioned concrete box girders, 3.25 m (10.7 ft) deep and up to 35 m (115 ft) long, weighing up to 780 tons.

Drive Bridge has come to be known). This dramatic bridge south of Sydney actually consists of two adjoining bridges. The southern bridge section, featuring two 62-m (203-ft)-long end spans and three 108-m (354-ft)-long main spans, was constructed using the cast-in-place balanced cantilever method. The northern section of the bridge is an incrementally launched structure with six 30-m (98-ft)-long main spans and an 18-m (59-ft)-long end span. The two bridges join to form a viaduct that bypasses the southern amphitheater, which is vulnerable to rock falls.

Also in Australia are the Westlink M7 bridges. Located in western Sydney, the $1.1 billion Westlink M7 project is a 40-km (25-mile) motorway that required the construction of 142 bridges including 31 segmental bridges. Timely construction of the bridges was critical to the early opening of the motorway, and bridge standardization was essential. While conventional pretensioned, precast concrete beam designs were used for span lengths up to 35 m (115 ft), precast segmental box girder bridges were chosen for the longer span bridges and motorway overbridges. AECOM provided detailed design and construction support for the Roads and Traffic Authority of New South Wales.

Travel from Taipei to Kaoshiung in Taiwan will soon become much faster with the implementation of the Taiwan High-Speed Rail Link. The $17.5 billion rail project will enable 300,000 people a day to travel at speeds of up to 300 km/hr (186 mph) on a newly constructed 345-km (214-mile)-long high-speed line. Since the line traverses extremely active seismic regions, 38 km (24 miles) of the alignment will consist of high-level viaducts. In providing construction design, the AECOM team faced a number of challenges on the fast-track design/build project—severe seismic concerns, difficult ground conditions, and demanding program and construction constraints.

But wherever they may be located, AECOM bridge projects can benefit from the unique expertise that is available through a network of local, national, and international sources. For Butler and AECOM, the system works. But he cautions that just like designing bridges, designing a practice to create bridge solutions is never a static endeavor. The practice must adapt and reinvent itself continually to meet evolving requirements.

"Clients are very sophisticated; they know their needs better than anyone else. Our job is to provide the best options for satisfying those needs. In the United States, we're facing a particularly difficult time, especially in light of the I-35W collapse in Minnesota. The traveling public is concerned; we must address those concerns, and restore confidence in our infrastructure. Ultimately, though, it comes down to funding. Whether it's through user fees or public-private partnerships or some new funding approach, we must get more creative to help our clients develop new solutions.

"The answers can come from anywhere. That's why we instituted the structure we have. When it comes to expertise, geography should be unimportant. Firms should be able to marshal resources wherever they are needed to achieve the best result for a client. We've learned that the integration of expertise across borders—local, national, or international—facilitates knowledge transfer and exchange. We make ourselves better and learn more by interacting with our fellow designers throughout the company, throughout the world. And in turn, that provides greater value for our clients."

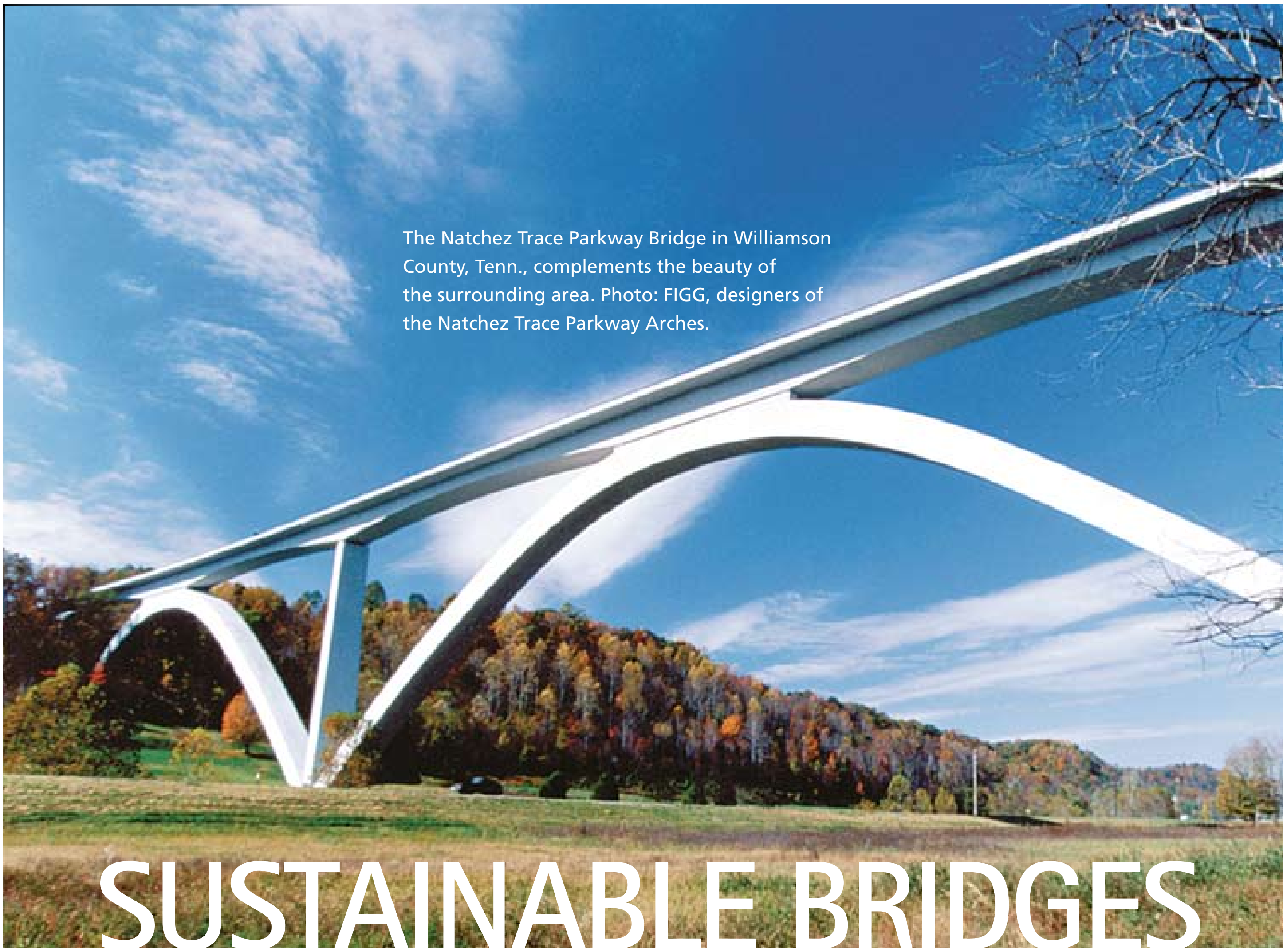
Designing and constructing bridges is like no other profession. As Franklin Roosevelt said, "There can be little doubt that in many ways the story of bridge building is the story of civilization." The women and men of the AECOM bridge practice are part of that story. Their profession helps advance society's progress, creating iconic structures that serve people's needs.

Arthur Schurr is a freelance writer who reports on transportation infrastructure for national and international publications.

Sustainability

"Twenty or 30 years ago, sustainability was hardly even an issue. Now, it's a standard. And it will continue to evolve in ways we can't imagine today. As budgets become tighter and funding becomes more limited, owners are incorporating sustainable elements to make their infrastructure last longer and perform better. They need to lower maintenance costs and minimize future replacement costs. So as bridge professionals, we must constantly seek out innovative materials and methods. But it's equally important to listen" explains Ken Butler, AECOM's national director of bridge services.

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



The Natchez Trace Parkway Bridge in Williamson County, Tenn., complements the beauty of the surrounding area. Photo: FIGG, designers of the Natchez Trace Parkway Arches.

SUSTAINABLE BRIDGES
and the Value of Innovation

by John Horsley,
American Association
of State Highway and
Transportation Officials

At this critical stage in our nation's history, we are faced with myriad challenges when it comes to preserving a viable transportation infrastructure. An especially urgent challenge involves promoting and designing bridges that are sustainable over the long haul.

Sustainability is not a mere buzzword, nor is it a passing fad. It is a thoughtful, wide-ranging approach that weds ongoing practical considerations with far-reaching innovations. Sustainability can be best understood, in the words of the 1987 United Nations World Commission on Environment and Development report *Our Common Future*, as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

In the world of transportation, sustainability includes designing, building, and maintaining bridges that are durable, safe, context-sensitive, and cost-effective. A lot of emphasis is placed on bridge design that imaginatively and seamlessly brings together those various elements. The sustainable bridge is therefore a structure that has been built quickly but efficiently to last a long time with an optimal use of resources, as well as minimal disruption of the surrounding environment and zero tolerance for wasted materials.

That is indeed a tall order, but it is an imperative one in today's socioeconomic climate and amid the sweeping environmental concerns all around us. I can likewise testify, however, that the state departments of transportation have in

…the state departments of transportation have in many key respects already been translating the concepts of sustainability into action.

many key respects already been translating the concepts of sustainability into action.

This can be seen in such practices as the completion of bridge construction projects in the quickest time possible without sacrificing safety and quality, while also keeping down costs and sparing the traveling public the prolonged ordeals of detours and congestion. The states have also exhibited other trademarks of sustainability, including protection of a construction area's ecological integrity and the incorporation of adaptable designs rather than just something in a "one-size-fits-all" mold.

A case in point is the Natchez Trace Parkway Bridge in Williamson County, Tenn. That bridge, which carries the two-lane parkway over Tennessee State Route 96 and a picturesque valley, was constructed with a first-of-its kind concrete design to reduce piers and other impacts. The use of this design enabled the construction impacts on the valley below to be minimized. Specifically, the bridge's arches are able to support the deck without evenly spaced spandrel columns; a major result of this—besides better safeguarding the environment—is providing an aesthetically pleasing appearance that complements rather than clashes with the surrounding postcard-perfect area.

This technologically innovative, on-time project has earned widespread recognition, including a Presidential Award for Excellence and an Award of Merit from the Federal Highway Administration. The structure is among several highlighted in AASHTO's report *Bridging the Gap: Restoring and Rebuilding the Nation's Bridges*.

That report, in addition to describing other specific state bridge enhancement projects, showcases more comprehensive sustainability-oriented initiatives. An example of this involves the Iowa Department of Transportation, which is currently testing fiber-reinforced polymers to use in both replacing deteriorated concrete bridge decks and building new bridges in their entirety. That agency is also utilizing high-performance concrete to build bridges that will be ultimately and carefully monitored for their cost, strength, and durability.

The Oregon Department of Transportation is also assimilating sustainability concepts in its own bridge program. As detailed further in AASHTO's award winning report *Above and Beyond: The Environmental and Social Contributions of America's Highway Program*, that agency has undertaken a $1.3 billion statewide effort for repairing or replacing approximately 300 bridges. This approach includes a streamlined programmatic permit for each bridge, outcome-based environmental standards, and broad stakeholder involvement throughout the process.

In adopting this approach, the Oregon Department of Transportation aims to maintain mobility throughout the state, stimulate the economy, draw on cost-effective delivery practices, stay sensitive to the needs of adjacent communities and the landscape, and make the most of available funding opportunities. This program, incidentally, was named a winner of AASHTO's Best Practices in Context Sensitive Solutions Competition.

These examples and others illustrate what is being done to make sustainable bridges an integral part of our national highways network. We are all working harder than ever before to come up with creative and workable solutions for our bridges that take into account each project's unique and most urgent environmental, economic, and societal demands.

The state departments of transportation are among those in the forefront seeking to meet and master those easier-said-

The optimized "Pi" beam developed for the Federal Highway Administration and first used in Buchanan County, Iowa, has a concrete design strength of 21,500 psi. The full structural depth of the deck is just 4$^{1}/_{8}$ in. Photo: Iowa DOT.

In their quest to maintain mobility, the Oregon DOT designed Elk Creek Crossing No. 4 on OR 38 to be constructed alongside the existing bridge. In one weekend traffic closure, the old bridge was slid aside and the new concrete bridge moved into place with the use of self-propelled modular transporters. Photos: Slayden Construction Group Inc.

…we should all use every possible opportunity to point out how sustainable bridges are making life better in today's world.

than-done challenges. As *Bridging the Gap* underscores, however, we are fighting an uphill battle in this regard.

The future of sufficient funding is uncertain, as government agencies at all levels find themselves increasingly hard-hit financially despite the increasing importance of additional investments in our nation's infrastructure. The National Surface Transportation Policy and Revenue Study Commission confirmed that we should be investing about $225 billion annually over the next 50 years. A significant portion of that projected investment is needed to bring into existence more sustainable bridges.

In short, we have a wealth of talent and techniques to forge a new generation of sustainable bridges that promise greater strength, safety, service, sensitivity, savings, and stability for all who use them. What we lack, however, is a more vigorous national commitment to investment for those structures and other key transportation priorities.

That is why we all must get together, stand forward, speak up, and make the case for that funding. We need to better promote the exemplary work already being done with high-performance sustainable bridges nationwide and their many benefits. In doing so, we should focus on environmental, economic, and social impacts and allocate full and fair consideration to each of these vital driving forces. This "triple bottom line" approach is more than just a winning strategy; it is an indispensable one.

AASHTO, for its part, recently called for increased funding for the nation's transportation infrastructure as Congress considers authorization legislation for federal highway and transit programs in the coming year. The current legislation expires September 30, 2009. The proposed funding includes a $375 billion investment from 2010 through 2015 for highways, with the annual funding level reaching $75 billion by 2015. AASHTO specifically recommends, as a subtotal of that amount, an annual funding level of $8.4 billion by 2015 for bridge preservation. That is double the current funding level for this crucial program.

To further support the need for that increased funding, we should all use every possible opportunity to point out how sustainable bridges are making life better in today's world. That means sharing our stories and statistics on why we need to more extensively move beyond just the blueprint stage for those structures and instead towards their larger-scale development.

"How do you demonstrate the value of innovation?" asserts futurist Durwin Sharp of the Houston-based Virtual Thinking Expedition Company. "By translating ideas into something that even skeptics can understand: results." Those are words that we who care about sustainable bridges and their worth should take to heart.

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CUSTOM ARCHES

by James N. Bollman,
OBEC Consulting Engineers

The NW Maple Avenue Bridge in Redmond, Ore., features three continuous cast-in-place 210-ft-long arch spans, each of which is different to conform to the contours of Dry Canyon below.

Three cast-in-place arches with different shapes conform to Oregon canyon, adding beauty and functionality

The twin arches support bent and spandrel columns and the double-tee deck.

The NW Maple Avenue Bridge provides an east-west link for the city of Redmond, Ore., across Dry Canyon, which bisects the city. The canyon is a scenic natural feature, providing open space and recreation to local citizens. The designers and the construction team were challenged to design and build a bridge that could blend with its natural surroundings while satisfying current and future needs.

City officials desired a bridge that was affordable, functional, aesthetically pleasing, and capable of being efficiently widened in the future as needs required. To meet these needs, the designers created a cast-in-place structure featuring three continuous 210-ft-long arch spans and two 75-ft-long post-tensioned approach spans. Each arch has a distinct contour so the arches together conform perfectly to the sloping topography of the canyon floor.

A very wide range of crossing configurations was considered, from a sag-vertical curve on fill to a single-span arch. The fill was deemed inappropriate and inconsistent with the goals of the canyon, but city officials asked that the design be given at least a cursory investigation to determine a baseline cost.

Design Options

Bridge options that made the final cut for consideration were a five-span bulb-tee girder, a single-span arch bridge with half-arch approaches at each end, and the three-span arch that was selected. It offered the best combination of aesthetics, economy, and scale for the site. City officials were particularly interested in the potential to achieve a "landmark" bridge appearance if they could obtain it for only a modest cost premium.

In terms of materials, steel was considered but was ruled out because it was not competitive from a life-cycle perspective. Precast concrete was determined not to offer the best solution because there would not be many repetitive structural elements.

profile

MAPLE AVENUE BRIDGE / REDMOND, ORE.

ENGINEER: OBEC Consulting Engineers in conjunction with Jiri Strasky, Consulting Engineer, Eugene, Ore.

PRIME CONTRACTOR: Cascade Bridge LLC, Vancouver, Wash.

CONCRETE SUPPLIER: Central Oregon Redi-Mix LLC, Redmond, Ore.

AWARDS: *2008 Portland Cement Association Bridge Award*

Only the arch ribs were identical across the bridge, although they vary from span to span along the ribs. This lack of repetition meant that the production efficiencies offered by precast concrete would not be utilized well.

The columns support a double-tee deck section, with the tee stems matching the spacing of the arch ribs.

Substructure

The arch consists of two side-by-side ribs. Each rib is fixed to the footings at the ends of the three-span series, while pinned to and continuous across the intermediate footings. This arrangement allows the ribs to appear to touch lightly on the canyon floor. All substructure elements are slender in the dimension most visible in an elevation of the bridge.

Bent columns are located at each arch rib support, with spandrel columns placed midway between the arch supports and the composite crown segments. The columns are monolithic with the superstructure tee-beams and arch ribs or footings. The columns were designed as slender members in the direction along the bridge and wide members transverse to the bridge, creating unbraced, rigid transverse frames.

Spandrel columns and bent columns are architecturally similar, with the slender dimensions relative to height nearly constant for both types. At the bents, each column pair appears as one column architecturally but functions as two columns, with one of the pairs located on each side of the transverse deck joint. The twin columns provide little longitudinal restraint as they deflect elastically in response to the thermal length changes of each span.

Superstructure

The columns support a longitudinal cast-in-place double-tee deck section, with the tee stems matching the spacing of the arch ribs. The typical deck section for the arch spans continues across the approaches, where the longer spans of the shallow beams necessitated post-tensioning.

The arch ribs are monolithic with the tee-beams for a 50-ft length at each arch midspan. Seismicity at the site is low, so the transverse frames and composite crowns provide the necessary transverse resistance. Deck expansion joints were placed at each interior bent and at the abutments, where the beams are supported on bearings. Intermediate deck diaphragms, transverse beams, and transverse arch braces were not used, contributing to the structure's openness and clean lines.

At the bents, each column pair appears as one column architecturally but operates as two columns functionally, with one of the pairs located on each side of the transverse deck joint. All photos: OBEC Consulting Engineers.

Construction

Preparing the site for work consisted primarily of scaling loose basalt blocks from the canyon walls and relocating utilities along the bridge corridor. The site presented no particular environmental challenges, alleviating the contractors of those concerns. A staging area in a treeless region next to the bridge was used. Access to the canyon was gained via an existing cut into the canyon's wall face approximately one mile from the bridge site. The staging area was accessed via a temporary road along the canyon floor from the cut.

Stage dead-load sequencing was checked using a finite-element analysis. No temporary ties or longitudinal bracing were necessary to resist transient load conditions from stage loading, other than those for conventional falsework. All transient load conditions were accommodated by construction sequences that cost little in construction efficiency.

The construction used fairly typical falsework and forming, with the obvious exception that unequal concrete levels in the rib halves cast from the base toward the crown of each span introduced unbalanced lateral load into the falsework system.

Transverse temporary x-bracing between the two rib lines was required to reduce the unbraced length for the out-of-plane buckling until the deck was cast and cured. This bracing was planned and detailed in the bid documents, but subsequent superstructure falsework design was not completely coordinated with the bracing design. The bracing was then modified slightly to accommodate the falsework.

THREE-SPAN, CAST-IN-PLACE ARCH BRIDGE / CITY OF REDMOND, OWNER

BRIDGE DESCRIPTION: 780-ft-long cast-in-place bridge featuring three continuous 210-ft-long deck arch spans of different shapes

BRIDGE CONSTRUCTION COST: Superstructure \$76/ft^2; Substructure \$78/ft^2

The series of photos illustrates the construction sequence including arch falsework, arch forms, arch columns, and deck falsework.

The ribs were precompressed with hydraulic jacks placed in jacking frames at openings at the rib crowns. This compensated for the second-order load effects in the arch ribs and longitudinal beams from displacements in the foundations during development of the foundation resistance. Jacking occurred at an optimum step in the construction sequence, with the jacking frames cast into a closure placement at the crowns.

The bridge incorporates several pedestrian-scale features designed for compatibility with the recreational use of the canyon area. Overlooks are located at each abutment, allowing pedestrians to step off the sidewalk to enjoy the canyon's scenery. Similar areas are provided at the interior bents of the arch spans.

Raised cantilever sidewalks on each side have tubular steel rails. The rails meet the strength requirements for both vehicles and pedestrians while allowing freedom of view for all bridge users. Recessed step-lights concealed within the rail bottom tube provide low-level sidewalk lighting.

The open rail also facilitates an accurate perception of the superstructure depth when the bridge is viewed from the side, adding to the slender and graceful appearance. The design offers a majestic presence both from a distance, with its sleek, flowing arches, and from close up, where visitors can admire the canyon and the careful way that the new Maple Avenue Bridge fits into its surroundings.

James N. Bollman is senior bridge engineer, OBEC Consulting Engineers, Eugene, Ore.

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

AESTHETICS COMMENTARY

by Frederick Gottemoeller

In the last issue, I quoted the renowned twentieth century architect Mies van der Rohe's famous dictum, "Less is More." This time I'd like to quote another of his famous sayings, "God is in the Details." On the Maple Avenue Bridge, one has only to look at the proportions of the joint where the arch ribs, bent column, and bearing come together to see what van der Rohe was driving at. The arch ribs appear to narrow to almost a single point as they reach the bearing. The bridge seems to barely touch the ground. That feature alone gives the whole structure an incredible lightness of being.

However, the same kind of attention is applied to the spandrel columns, the bracing, the railings, and all of the other features of the bridge. Each part has an elegant slenderness and simplicity. Each is smoothly and logically connected to the others. Every element appears competent to do its job without wasted effort or materials, giving the whole structure a sense of calm transparency. This bridge really does deserve that often-stated praise: it lies lightly on the land.

Achieving this result required a lot of sophisticated engineering. It is good to see such engineering being done in the service of visual goals, not just cost reduction. Calling the bridge a "signature bridge" creates the impression that only the rare structure deserves this attention to detail and to visual goals. Actually, all bridges deserve that attention. It ought to be a standard part of bridge engineering. Then we wouldn't have to identify "signature bridges," because they would all be signature bridges.

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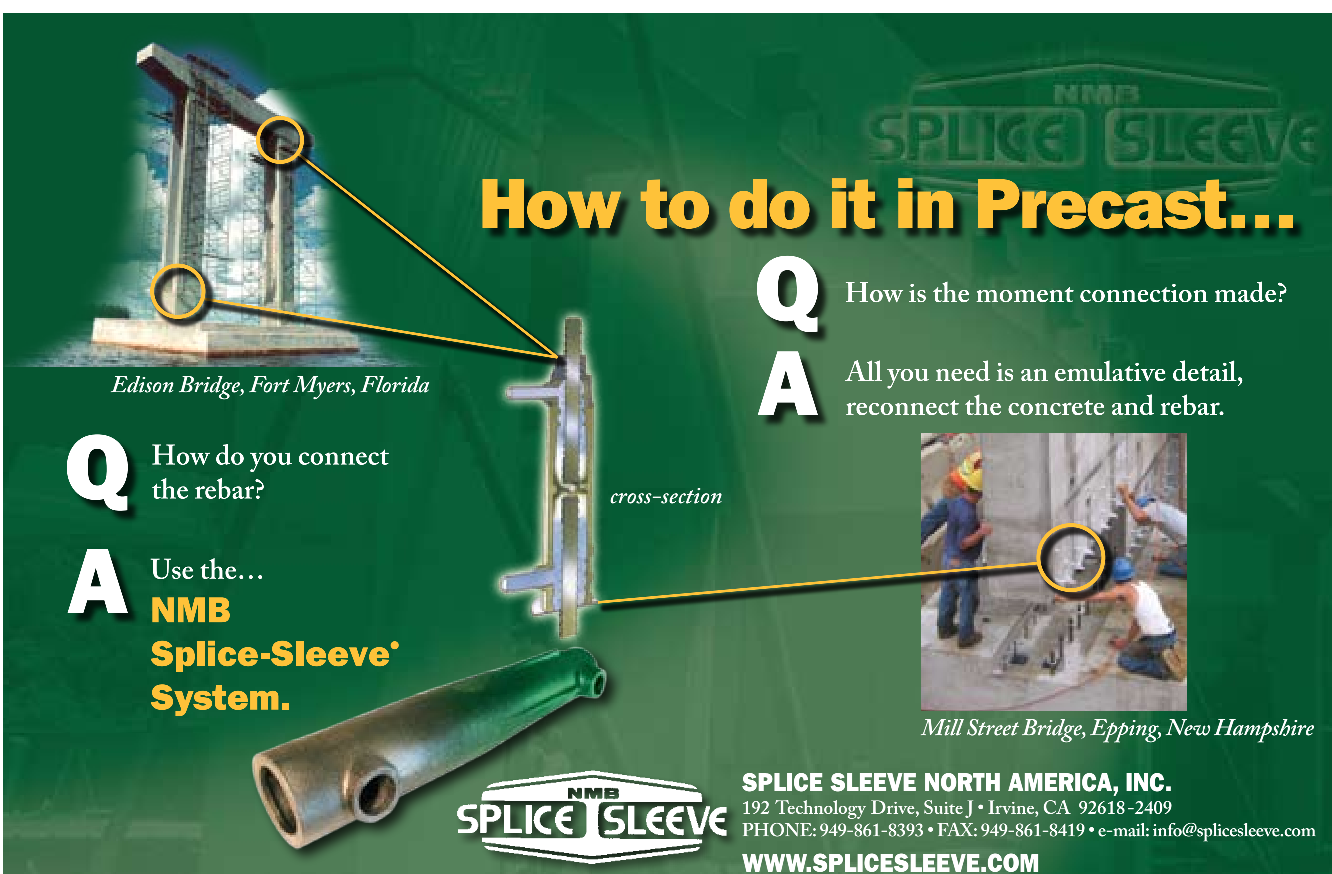
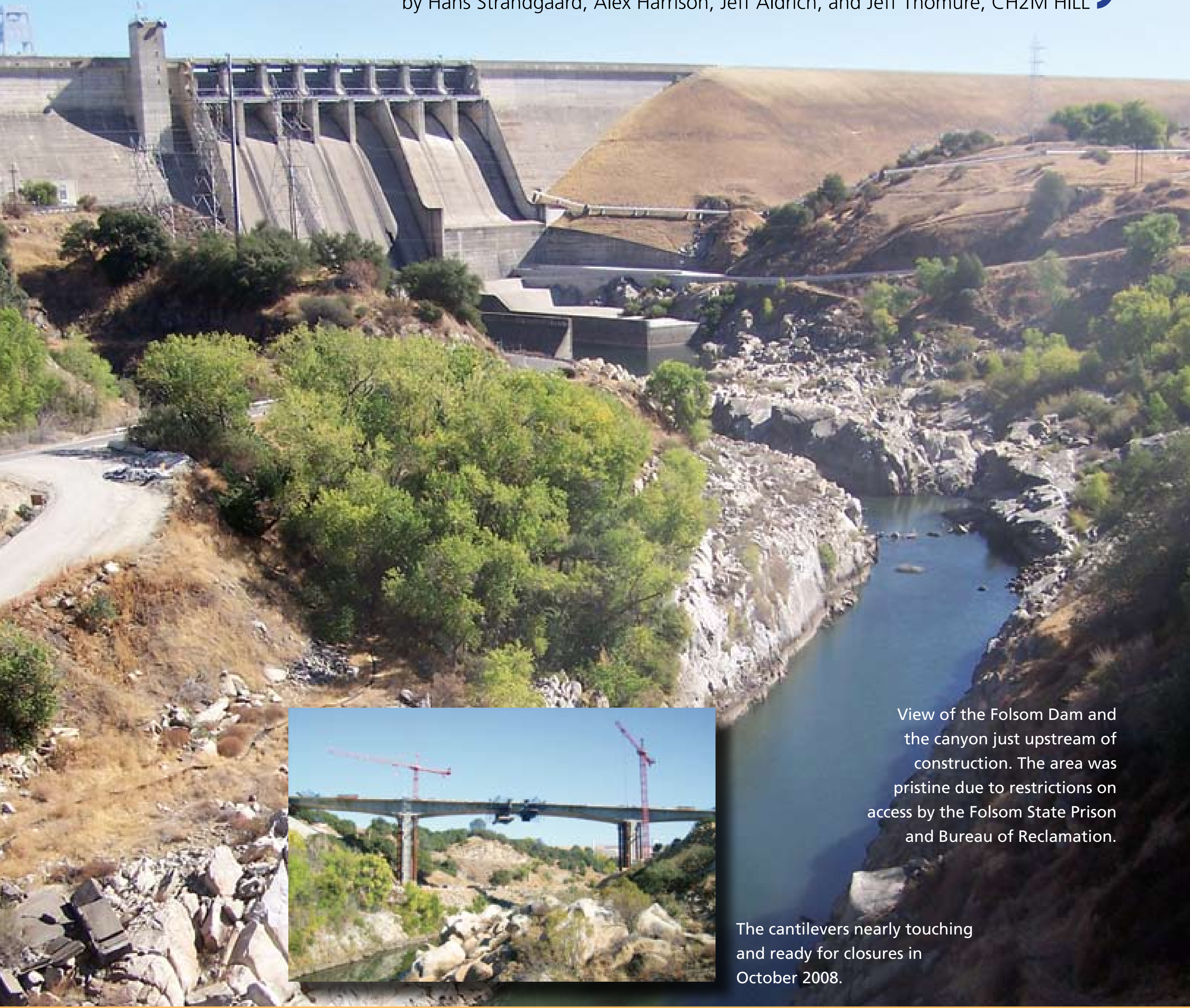


Design and Construction – Folsom Lake Crossing

by Hans Strandgaard, Alex Harrison, Jeff Aldrich, and Jeff Thomure, CH2M HILL



View of the Folsom Dam and the canyon just upstream of construction. The area was pristine due to restrictions on access by the Folsom State Prison and Bureau of Reclamation.

The cantilevers nearly touching and ready for closures in October 2008.

profile

FOLSOM LAKE CROSSING / FOLSOM, CALIF.

CONTRACTING AGENCY: U. S. Army Corps of Engineers, Sacramento District, South Pacific Division

ENGINEER: CH2M HILL/URS Joint Venture, Sacramento and Roseville, Calif.

CONSTRUCTION ENGINEER: McNary Bergeron and Associates, Broomfield, Colo.

PRIME CONTRACTOR: Kiewit Pacific Co., Vancouver, Wash.

CONCRETE SUPPLIER: A & A Ready Mixed Concrete, Inc. Newport Beach, Calif.

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

Folsom Dam Road, located on the crest of Folsom Dam, near the city of Folsom, Calif., was operational from the time of the dam's construction in 1956, until it was closed to public traffic in 2002, as a result of national security concerns. The road was an important regional transportation artery, with 18,000 vehicles using it daily as a link between Sacramento, El Dorado, and Placer counties. Following the 2002 road closure, traffic across the American River was detoured to other downstream bridges, often resulting in gridlock within the city of Folsom. In response to local congestion concerns, plans for a new crossing of the American River near Folsom Dam were fast-tracked by local and state officials. When federal funding for a new crossing was appropriated in 2006, along with additional funding from the city of Folsom and the State of California, the project had adequate resources to begin at once.

In response to the community's desire to open the new crossing to traffic as quickly as possible, the U.S. Army Corps of Engineers (USACE) and the project development team adopted an aggressive design and delivery schedule that included preparing the environmental documentation in parallel with the engineering studies, design, and right-of-way acquisition for the new roadway and bridge.

The USACE selected the CH2M HILL/URS joint venture to prepare designs for the bridge and approach roadways. As the bridge designer, the CH2M HILL project team's mission was to produce a design to be constructed on a fast-track schedule, within a limited budget, while maintaining the required level of quality, constructability, and acceptance from a broad range of stakeholders.

Kiewit made dual use of the struts to act as falsework for the pier table and then to strut the pier tables to reduce rotation and construction stresses as the cantilevers were constructed.

Site Features and Constraints

The selected river crossing site, approximately 1/2-mile downstream of the dam, presented multiple challenges for the bridge design and construction. Limitations on the maximum roadway profile grade resulted in the vertical alignment that crossed the canyon approximately 200 ft above the river. Existing access into the steep inner canyon was very limited. In addition, the California Department of Corrections and Rehabilitation (CDCR) expressed security concerns related to increasing site accessibility next to Folsom State Prison—a high-security facility—located adjacent to the alignment.

Project Coordination Challenges

The tight project schedule and the simultaneous development of the design and the environmental document were identified as being major constraints to the design team; however, weekly meetings and continuous exchange of information expedited project coordination and delivery.

Key concerns among the various stakeholders involved security issues, as well as maintenance of dam operations during and after construction of the new bridge and roadway. Property acquisition was required from the CDCR, the California Department of Parks and Recreation, and the U.S. Bureau of Reclamation, as well as from private land owners. While other alignments may have resulted in a more favorable bridge layout, it could not accommodate the required schedule. In addition, relocating the existing Folsom Dam powerhouse access road was unacceptable, as it would potentially disrupt the only access to this critical facility.

A cast-in-place concrete segmental box girder was the most appropriate structure type.

CAST-IN-PLACE SEGMENTAL BOX GIRDER BRIDGE / CITY OF FOLSOM, OWNER

SPHERICAL BEARINGS: Lubron Bearing Systems, Huntington Beach, Calif.

ROCK ANCHOR HOLES: Drilltech Systems Drilling and Shoring Inc., Antioch, Calif.

BRIDGE DESCRIPTION: Three-span, cast-in-place, segmental box girder, 970 ft long with 430-ft main span and 270-ft approach spans

BRIDGE COST: $38,378,000 (as bid)

PROJECT COST: $73,294,000 (as bid)

Bridge Type Selection

The bridge type selection study conducted during the preliminary design phase investigated a range of bridge types and span arrangements, as well as alternative bridge construction materials. It was determined that a minimum main span length of approximately 350 to 400 ft was required to span the inner portion of the canyon and keep the pier foundations above the flood elevation.

The design team identified a cast-in-place concrete box girder as the most appropriate structure type for this crossing. Box girder bridges are the most widely constructed highway bridge type in California. Local contractors have a long record of successfully constructing this bridge type, and the design team understood that competitive bids could be obtained and potential schedule delays reduced as a result of the familiarity of the local construction market with this structure type. From the owner's perspective, concrete box girder bridges have a solid record of long-term performance and low maintenance in the Sacramento environment. Further, the seismic behavior and design features of this structure type are relatively well defined in California.

One project issue related to concrete box girder construction was the feasibility of using falsework for construction. While falsework has been used in California for construction of tall three- and four-level freeway interchanges, the 200-ft height above the river canyon posed significant problems. Further, the use of falsework required supports to be placed in the American River, which introduced a high level of risk in the event of flooding, and long-span steel truss falsework was cost prohibitive. The design team identified cast-in-place segmental construction as being the only practical method of box girder bridge construction for this site. Several alternative bridge structure types were considered including arch, extradosed, steel plate girder, and spliced precast concrete girder bridges.

Following consultation with constructability resources and preparation of cost estimates for these alternatives, the design team recommended a cast-in-place concrete segmental box girder with integral piers.

Span Arrangement and Bridge Layout

The selected three-span bridge has a main span of 430 ft with equal side spans of 270 ft. Given site geology and topography, this span arrangement accommodates a feasible foundation configuration, and allowed construction to proceed in four simultaneous headings from two pier tables, which shortened the schedule. The symmetrical span arrangement simplified both design and construction details, and provided for maximum repetition. The overall bridge length was well suited to the site topography, which resulted in minimal abutment heights or fills.

A variable-depth box girder was selected with a total depth that varied between 10 ft at midspan to 26 ft at the piers. Exterior webs were sloped to minimize the piers' cross-sectional width, and to provide for improved aesthetics. The 82-ft-wide bridge deck will accommodate four traffic lanes with a 4-ft-wide median. In addition, a 12-ft-wide regional trail located on the north side of the roadway will provide for an unprecedented and dramatic view of the dam.

Superstructure Design

The box girder cross section has two cells with a deck slab that spans approximately 28 ft between web centerlines and has 12-ft-long deck cantilevers. This arrangement optimizes the deck slab thickness while providing for an adequate cross section at the tops of the webs to locate cantilever post-tensioning ducts and anchorages. The deck slab is transversely post-tensioned to minimize slab thickness and control cracking. The design team selected the segment arrangement to be within the capacity of available traveling forms while minimizing the number of segments to be cast on each cantilever. A segment length of 12 ft adjacent to the piers and 15.5 ft away from the piers was selected.

Design of the Folsom Lake Crossing utilized three-dimensional analytical modeling. While traditional practice for transverse design of segmental bridges has been to use an elastic plate analysis in conjunction with two-dimensional frame models, this approach has practical limitations on variable depth girders. Sections with shorter webs have a greater bending stiffness and develop larger live-load web moments than sections with deeper webs. While this effect can be accounted for in two-dimensional models, development of a three-dimensional model allowed for more accurate determination of internal cross-section forces. In addition, the three-dimensional model was used to study shear lag effects over the length of the cantilevers.

Kiewit lifted concrete from the pier bases in 4 yd^3 buckets to a remixer/pumper located at the top of the pier table. Segments were cast full depth in a single placement.

The cantilevers progressing in September 2008.

Form traveler for cast-in-place segmental construction advancing from the pier table. Portions of the travelers were last used on the nearby Benicia-Martinez Bridge project.

Substructure Design

The pier configuration consisted of a "dogbone" cross section column extending from the spread footings to a transition element at the top of the column. This prismatic column cross section provided sufficient ductility under transverse seismic loadings, and allowed the use of repetitive details and maximum reuse of column forms. One aesthetic feature incorporated into the substructure design was a truncated pyramid transition element that provided for a smooth visual and structural transition from the columns to the superstructure soffit. Spread footings were used on top of the granite bed rock.

Seismic Design Considerations

Seismic design is a major consideration for any bridge built in California, and particularly for a long-span, relatively heavy concrete bridge with tall columns. With an estimated peak horizontal ground acceleration of 0.4 times gravity, the site is considered a moderate seismic zone. Finite element analysis was used to determine elastic acceleration response spectrum (ARS) analysis forces and structure displacements.

The structure was designed in accordance with California Department of Transportation (Caltrans) design standards to manage the formation of plastic hinging in the piers in a completed configuration. These plastic hinging forces are resisted by "joint" regions in the pier table and footing. These are designed to remain essentially elastic, as are the superstructure and the footings. The pier table joint region required particular attention due to the steel required to sustain the joint forces in combination with the heavy reinforcement and tendon density driven by segmental construction. Caltrans' design criteria were verified with complex cracked concrete three-dimensional block finite element analysis to verify the design reinforcement configuration. Integrated drawings were developed for this region to eliminate potential interference and enhance detailing of the reinforcement. Similarly, the footings were designed to transfer the pier plastic moments through the footing and into the rock foundation using post-tensioned tie-downs.

A horizontal construction seismic load of 10% of gravity was considered for the balanced cantilever construction configuration, prior to completion of closure pours and before the spans were connected. Both the pier and spread footings were evaluated in this analysis to ensure that there is not a collapse if a moderate earthquake occurs during construction.

The bridge is expected to open in spring 2009.

Hans Strandgaard is senior technologist and regional quality manager, Alex Harrison is senior technologist and regional bridge practice lead, Jeff Aldrich is senior technologist, and Jeff Thomure is bridge engineer with CH2M HILL, Sacramento, Calif.

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

QUICK AND COLORFUL

by Brian Aldrich,
Washington State Department
of Transportation

Precast concrete helps first bridge on interstate corridor meet state's context-sensitive design and speed construction

Administrators at Sound Transit (Central Puget Sound Regional Transit Authority) wanted to connect their new interstate bus transit station to an existing park-and-ride lot across the interstate highway. Their goal was to improve bus transit speed and reliability by eliminating the circuitous route previously required to access the lot.

The connection required a 607-ft-long bridge over the interstate, along with an elevator and stairs down to the surface parking. The bridge had to be built while keeping traffic flowing as smoothly as possible during the construction. In addition, the park-and-ride lot had to remain open with minimal disruption or reduced capacity. To accomplish these goals, designers used precast concrete trapezoidal tub girders that also allowed for the incorporation of context-sensitive features that will serve as an inspiration for other bridges on the interstate corridor.

The bridge is the first on the interstate to use the state's new Context-Sensitive Solution guidelines, which resulted in flared columns and other embellishments. All photos: Washington State Department of Transportation.

profile

CANYON PARK FREEWAY STATION / BOTHELL, WASH.

ENGINEER: Washington State Department of Transportation, Olympia, Wash.

PRELIMINARY ARCHITECT: Streeter Associates, Seattle, Wash.

CONTEXT-SENSITIVE SOLUTION ARCHITECT: HNTB, Bellevue, Wash.

AWARDS: *Best Non-Highway Bridge co-winner, Precast/Prestressed Concrete Institute's 2008 Design Awards*

> Precasting the girders increased the public's safety and convenience during construction.

The bridge consists of six spans varying in length from 70 ft to 124 ft, with a width of 12 ft 6 in. and a usable walkway width of 10 ft 7 in. An inclined ramp is provided at one end and an elevator/stair tower at the other. The walkway is enclosed under a structural steel roof supported by concrete pedestals integrated into the concrete barriers. Throw-screens installed on both sides provide safety for bridge users and travelers on the highway below. A roof is not typical for freeway pedestrian bridges in the state, but it was necessary to encourage transit use by providing protection from inclement weather.

Transit-Government Partnership

The project was a joint production of Sound Transit, which owns the bridge, and the Washington State Department of Transportation (WSDOT), in whose right of way the bridge would be built. Transit officials essentially hired WSDOT to manage the program, and WSDOT's project manager contracted with the WSDOT Bridge and Structures Office to provide the structural design.

It was an easy choice to use precast concrete for the superstructure design, as most of the bridge superstructures in Washington use precast. It offers good durability and extremely low maintenance over its lifetime. Cast-in-place concrete superstructures require falsework over the roadway, creating a hazard to the travelling public.

Steel structures often require more regular maintenance and inspections, especially when they have little redundancy and are fracture-critical. We avoid building a structure that is fracture-critical, which steers us toward concrete designs when there are only one or two girders per span. Steel also has been more expensive and volatile in its pricing, making it more difficult to estimate construction costs.

Traffic on the adjacent freeway ramp had to be stopped while the long ramp up to the bridge crossing was completed.

The ultimate choice was between trapezoidal tub girders and traditional I-beams. The decision for the tub girders was based on aesthetics. These girders are new for our state, with few projects having been completed to recoup costs on the forms. So, these early projects are more expensive than we anticipate for later ones. However, tub girder bottom flanges are wider than for typical I-beams, and they have two webs, allowing one tub girder to replace two I-beams on this project. This saved both casting and erecting time.

The cost for the tub girder superstructure was higher than a typical I-beam superstructure, but it was chosen by Sound Transit due to the aesthetic appeal. The shape complements and enhances the aesthetic elements, including the columns, barriers, and throw-screen panels. The shape also provides an efficient way to resist additional lateral loads from the pedestrian-bridge roof and throw-screen panels.

Precasting the girders increased the public's safety and convenience during construction by minimizing interstate closures and eliminating falsework over the traveled lanes. The concrete superstructure also provides some protection for pedestrians against the harsh freeway environment.

Foundations

Foundations for the bridge columns and elevator/stair tower consist of 2-ft-diameter cast-in-place concrete piles with cast-in-place concrete pile caps, typical for a WSDOT design. The abutment adjacent to the new bus transit station and the connected entry structure were built on concrete spread footings.

Designers on the Canyon Park Freeway Station in Bothell, Wash., used precast concrete trapezoidal tub girders to provide quick erection of the pedestrian bridge that crosses the interstate, connecting a new bus terminal with an existing parking lot.

PRECAST, PRESTRESSED CONCRETE PEDESTRIAN BRIDGE / SOUND TRANSIT, OWNER

CIVIL DESIGN: INCA Engineers Inc., Bellevue, Wash.

PRIME CONTRACTOR: Granite Construction (formerly Wilder Construction), Everett, Wash.

PRECASTER: Central Pre-Mix Prestress Co., Spokane, Wash., a PCI-certified producer

BRIDGE DESCRIPTION: A 607-ft-long pedestrian bridge consisting of six spans of single precast, prestressed concrete trapezoidal tub girders

BRIDGE CONSTRUCTION COST: $5.5 million

The stair tower was constructed simultaneously with the bridge construction, as the end span rested on the tower wall.

Cast-in-place columns were built for the intermediate piers, using designs influenced by the state's new Context-Sensitive Solution guidelines.

Piers and Tower Core

The piers were erected first, along with the core of the elevator/stair tower, since the end span girder sits on the tower. The core of the elevator/stair tower consists of cast-in-place concrete shear walls, which enclose an electrical room and an elevator machine room. The walls form the abutment, which was shaped to match the flare of the bridge columns.

AESTHETICS AND CONTEXT SENSITIVITY

Consideration of aesthetics was a critical element of the design process. The project was designated to be the first on the I-405 corridor to be designed using the new Context-Sensitive Solution guidelines produced for the state. The guidelines were developed by landscape architects, who considered suggestions garnered from public-outreach programs to create architectural elements to be included in bridge designs. This structure was the first in the pipeline that designers felt comfortable producing in this style, and Sound Transit officials agreed to follow the guidelines to create a distinctive appearance that could serve as an influence on later projects.

The result of the careful design and use of the context-sensitive solutions is a structure that was quickly erected to achieve a dramatic appearance. It features flared columns inspired by rhododendrons, horizontal ridges on the outside face of the barrier, and an arched pattern for the throw-screen panels.

To accent the design further, three colors of pigmented sealer were used on different components. "Cascade Green" was used for the precast trapezoidal tub girders, spanning the highway, as well as for the underside of the deck overhangs and structural steel. "Mt. Baker Grey" was used for the central recess of the flared columns. "Mt. St. Helens Grey" was used for all other concrete surfaces.

Girders

The girders were each cast and delivered as single-span units, and all were 5 ft deep, with a 5-ft-wide and 6-in.-thick bottom flange. The out-to-out web dimension at the top is 6 ft 5.14 in., with 7-in.-thick webs sloped at 7:1. Each end of each girder has a 1-ft-thick diaphragm.

Delivery of the precast concrete girders to meet the project's schedule was a challenge. This required the girders to arrive in December, traveling over the Cascade Mountain Range. The large girders had to be parked on the roadway's shoulder overnight in the pass during a snowstorm. Upon arrival, they were unloaded to a staging area and then delivered for the crane to erect as needed.

Erection of the key spans over the roadway was completed in only two nights.

Erection of the key spans over the freeway and ramps was completed in only two nights. Spans one and two with lengths of 70 ft and 86 ft were set on the first night over the northbound lanes and off-ramp. Span three with a length of 124 ft was set on another night over the southbound lanes and on-ramp. A cast-in-place deck was used to provide the walkway. Overall, the erection went smoothly. Construction of the entire project took approximately 11 months.

Both WSDOT and Sound Transit officials were pleased with the resulting design, especially as it met the context-sensitive solution requirements while minimizing road closures. Precasting the girders increased the public's safety and convenience during construction by minimizing interstate closures and eliminating falsework over the traveled lanes.

Brian Aldrich is a bridge engineer specializing in concrete structural systems with the Washington State Department of Transportation.

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

A RECORD SEGMENTAL SPAN
KANAWHA RIVER BRIDGE

by Santiago Rodriguez, T.Y. Lin International

A 760-ft-long main span is the longest concrete box girder span in the United States.

A record concrete box girder span over the Kanawha River will soon complete the widening of a 4.3-mile section of I-64 located in Kanawha County, West Virginia. T. Y. Lin International's bridge designers, working with the West Virginia Department of Transportation, Division of Highways (WVDOH), were confronted with the challenge of creating a low-cost, durable, and aesthetically pleasing structure that would alleviate traffic congestion for commuters in the Charleston area. The resulting eight-span segmental bridge design is the first long-span segmental box girder structure built by the balanced cantilever method in West Virginia.

The existing I-64 bridge over the Kanawha River between Dunbar and South Charleston is a steel plate girder structure with a 440-ft-long main span that was completed in 1974 to carry four lanes of traffic. The preliminary design studies evaluated several alternatives for increasing the capacity of the existing Kanawha River Bridge to six lanes, including widening the existing bridge, complete bridge replacement, and construction of a new eastbound bridge. The alternative selected was the construction of a new eastbound structure on an improved nonparallel alignment carrying three travel lanes and one auxiliary lane. The existing bridge will be modified to maintain four lanes of westbound traffic.

The Kanawha River Bridge shown in this rendering has the record span in the United States for a concrete box girder at 760 ft. All photos and renderings: T.Y. Lin International.

profile

KANAWHA RIVER BRIDGE / KANAWHA COUNTY, WEST VIRGINIA

ENGINEER: T.Y. Lin International, Alexandria, Va.

GEOTECHNICAL ENGINEER: Triad Engineering Inc., St. Albans, W. Va.

PRIME CONTRACTOR: Brayman Construction Corporation, Saxonburg, Pa.

CONSTRUCTION ENGINEERS: Finley Engineering Group Inc., Tallahassee, Fla., and Michael Baker Corporation, Charleston, W. Va.

CONCRETE SUPPLIER: Arrow Concrete, Winfield, W. Va.

FORMWORK SUPPLIER: DOKA, USA Ltd., Baltimore, Md.

AWARDS: *2007 West Virginia Division of Highways Engineering Excellence Award in the Large Bridge Category*

The twin-walled piers support the main span. While strong enough to support the cantilevered construction, they are adequately flexible to accommodate longitudinal deformations.

The bridge types evaluated for the new eastbound structure included a segmental concrete box girder, steel tied arch, steel box girder, concrete cable-stayed bridge, and a steel truss. The segmental concrete box girder and steel arch alternatives were selected for the type, size, and location study. After evaluating construction costs, maintenance requirements, and constructability, final plans were developed for a segmental concrete box girder bridge.

Bridge Layout

With a total length of 2975 ft, the Kanawha River Bridge will span a railroad track operated by Norfolk Southern, Dunbar Avenue, the Kanawha River back channel, Wilson Island, the Kanawha River main channel, Riverside Drive, and MacCorkle Avenue. A 760-ft-long main span—the longest concrete box girder span in the United States—resulted from the need to locate the main piers outside the main channel of the Kanawha River in order to avoid interference with barge traffic.

The eight-span structure has span lengths of 144, 247, 295, 295, 460, 760, 540, and 209 ft for a total length between centerlines of abutment bearings of 2950 ft. Spans 1, 2, 3, 4, 5, 7, and 8 have a curved alignment including a circular curve with a 1910 ft radius and a spiral transition. The main span has a tangent alignment.

A continuous concrete box girder superstructure, using cantilever construction, was chosen for the full length of the bridge. This allowed for longer approach spans, which reduced the bridge's environmental impact.

Given the size and urban setting of the project, bridge aesthetics were an important design consideration. The bridge concept was developed to be compatible with both the existing steel plate girder bridge that will carry westbound traffic and a future twin parallel westbound bridge.

Superstructure

The bridge cross-section accommodates three travel lanes, one auxiliary lane, and shoulders for a total roadway width of 64 ft. The cross section of the superstructure consists of a single cell box with inclined webs. The structural depth varies along the main span from 38 ft at the piers to 16 ft at midspan. The bottom slab thickness is variable with a maximum thickness of 5 ft at the main span piers and a minimum of 9 in. at midspan. The approach spans have a constant depth of 16 ft and a constant bottom slab thickness of 9 in., with the exception of the pier tables where the bottom slab thickness transitions to 1 ft 9 in. The webs have a constant thickness of 1 ft 6 in.

The top slab has constant dimensions for the full length of the bridge. Its thickness varies transversely from a minimum of 9 in. to a maximum of 2 ft at the intersection with the webs. The maximum 2-ft depth of the top slab is required to accommodate the cantilever tendons needed for the main span. The box girder cross section has variable superelevation from plus to minus 8%. The specified concrete compressive strength is 6500 psi at 28 days. For mass concrete, the acceptance age was extended to 56 days.

The concrete box section is post-tensioned longitudinally, transversely, and vertically. The longitudinal post-

CAST-IN-PLACE SEGMENTAL BOX GIRDER BRIDGE / WEST VIRGINIA DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: 2975-ft-long box girder bridge

STRUCTURAL COMPONENTS: 66-ft-wide single-cell box girder in eight spans ranging from 144 to 760 ft built by balanced cantilever. Five single shaft approach piers and two twin-walled main span piers. Drilled shaft foundations.

FORM TRAVELERS: STRUKTURAS, Langesund, Norway

BEARINGS: R. J. Watson Inc., Amhurst, N.Y.

EXPANSION JOINTS: Watson Bowman Acme Corporation, Amhurst, N.Y.

POST-TENSIONING: VSL, Dallas, Tex.

GROUTS: BASF, Shakopee, Minn.

BRIDGE CONSTRUCTION COST: $75 Million ($379/ft^2)

In addition to the Kanawha River, the bridge crosses three roads and a railroad. Photo: Ahmed Mongi, WVDOT.

tensioning consists of two sets of tendons. The cantilever tendons, located in the top slab, are stressed during cantilever construction shortly after a new segment is added. The span tendons, located in the bottom slab, are used in the central part of the spans to provide continuity between adjacent cantilevers. Transverse post-tensioning is utilized in the top slab. Vertical post-tensioning consisting of high strength $1^{3}/_{8}$-in.-diameter bars is required in the webs, in the proximity of the piers, where the shear forces are high. The post-tensioning was designed to limit the principal tensile stresses in the webs.

The continuous box girder will have expansion joints at the abutments only. The advantages of this design approach are to reduce maintenance, improve serviceability, and simplify construction, as intermediate hinges are not needed. The superstructure is fixed at the main piers and is supported on unidirectional bearings at the approach piers and abutments. The bearings restrain the transverse displacements while allowing longitudinal displacements. Two bearings are provided at each pier with vertical service capacities up to 6900 kips. The bearings will be blocked during construction and the superstructure will be temporarily fixed to the approach piers. A large modular expansion joint with a displacement capacity of 30 in. accommodates displacements caused by temperature, creep, and shrinkage at the west abutment. The east abutment requires a joint with a 16-in.-displacement capacity.

Substructure

The main span piers—Piers 5 and 6—consist of twin concrete walls, which frame into the superstructure. The twin pier walls provide the necessary strength and stiffness during cantilever construction and, at the same time, are longitudinally flexible to accommodate deformations caused by creep, shrinkage, and temperature changes. The approach piers—Piers 1, 2, 3, 4, and 7—have a rectangular section with 45-degree chamfers.

The foundations consist of reinforced concrete footings and concrete drilled shafts socketed in the underlying hard sandstone. The average length of drilled shafts is about 45 ft. Two pre-construction drilled shaft load tests, using the Osterberg method, were performed prior to final design. These tests verified the ultimate end bearing and side shear capacity to be used.

Construction

This project was advertised in February 2007 using competitive bidding between the segmental concrete box girder alternative designed by T. Y. Lin International and a steel box girder superstructure with the same span arrangement that was developed by another consultant.

The contract was awarded to Brayman Construction Corp. with a low bid for the concrete alternative of $82,864,247. The low bid for the steel box alternative was $112,910,000. The construction contract includes a small amount of roadway work, MSE walls, and minor changes to the existing bridge. These items were the same for the steel and concrete alternatives. The segmental box girder superstructure was designed to be built by the balanced cantilever method using cast-in-place segments supported by two pairs of form travelers. The project has a total of 160, 16-ft-long, cast-in-place segments in seven pairs of cantilevers. Falsework is required to cast the pier tables and the end segments near the abutments.

Bridge construction—scheduled to be completed by the end of 2010—has sparked local attention, which is expected to peak in the summer of 2009 with the closure of the main span cantilevers. When completed, area commuters will enjoy significant improvements in safety and traffic capacity in this segment of I-64.

Aesthetics

The proposed segmental box girder bridge is a harmonious design with simple and consistent forms with the same basic cross section between abutments. The selected cross section, with long overhangs and inclined webs, will result in a light appearance. The shadow created by the overhang will reduce the perceived superstructure depth. The inclination of the webs will lessen the volume of the superstructure. The curved approach spans will give a sense of openness and continuity with the graceful main span. The edges of the main span piers embrace the webs of the superstructure, thus subdividing the box girder depth. The piers have a modified rectangular section, with 45-degree chamfers, which reduce the perceived width of the columns in skewed views. A textured architectural treatment is used in the transverse faces of all piers and abutments. An applied concrete finish will be used on the surfaces of the substructure and superstructure elements

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Santiago Rodriguez is an associate vice president of T.Y. Lin International, Alexandria, Va., and served as project manager and lead bridge designer for the Kanawha River Bridge Project.

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

American Coal Ash Association

The American Coal Ash Association (ACAA) is devoted to educating engineers, concrete professionals, standards organizations, and others about coal combustion products or "CCPs"—materials produced by coal-fueled power plants. These include fly ash, bottom ash, boiler slag, and flue gas desulfurization materials. Fly ash concrete has been specified because of its high strength and durability for numerous bridge projects worldwide, including the longest cable-stayed bridge in North America, the John James Audubon Bridge near Baton Rouge, La. The I-35W bridge near Minneapolis, Minn. has been reconstructed using a unique mix design that included fly ash concrete to ensure a long-lasting, high performance structure. Caltrans required high volume fly ash mixes for the largest bridge project in its history—the San Francisco-Oakland Bay Bridge. Using innovative specifications and blending techniques, Caltrans was able to improve its workability, hardening, and permeability properties of the bridge's concrete. A number of engineering standards and specifications define CCP applications, thus ensuring high quality performance and products.

Though these materials' properties vary according to coal composition and power plant operating conditions, experts can advise on quality and determine the best mix design for most any condition and project. Mix designs exceeding 40 percent fly ash have proven successful in many projects. Experts with first-hand experience may be located by contacting ACAA. The technical, environmental and commercial advantages of CCPs contribute to global sustainability.

In addition to a myriad of core performance attributes in sustainable construction, CCP use can conserve natural resources, reduce greenhouse gas emissions and eliminate need for additional landfill space. For more information, contact ACAA at info@acaa-usa.org or call 720-870-7897.

A NEW WELCOME AT THE PORT COLUMBUS INTERNATIONAL AIRPORT

by Kevin M. Gorak and Troy D. Jessop, RW Armstrong

Main Photo: The trio of structures provides a handsome solution for access around the expanded airport. Photos: RW Armstrong.

Crossover Taxiway Bridge Creates New Look

The Port Columbus International Airport located in Columbus, Ohio, recently undertook a major expansion project. The expansion consisted, in part, of a new connector taxiway between the airport's two runways to ease aircraft congestion on the east side of the airfield and provide the needed runway access for a proposed new Midfield Terminal. The new taxiway crosses the airport's new relocated primary entrance road named International Gateway. International Gateway is a depressed roadway that accommodates seven vehicular traffic lanes and two light rail transit tracks. Three single-span, post-tensioned bridges cross International Gateway for various uses at the airport. One of the structures is 74 ft 0 in. wide, carries vehicular traffic along the new airfield perimeter road, and connects to a new parking lot access ramp. Another structure is 29 ft 6 in. wide and provides for traffic circulation around the airport. The most notable structure is the Crossover Taxiway Bridge, which is 191 ft 3 in. long and 217 ft 6 in. wide. This bridge enables aircraft from the existing terminal building to access the outer runways of the airport.

profile

PORT COLUMBUS INTERNATIONAL AIRPORT CROSSOVER TAXIWAY BRIDGE / COLUMBUS, OHIO

ENGINEER: RW Armstrong, Indianapolis, Ind.

ARCHITECT: Rosales, Gottemoeller & Associates, Boston, Mass.

CONTRACTOR: C. J. Mahan Construction Company, Grove City, Ohio

CONCRETE SUPPLIER FOR DRILLED SHAFTS: Arrow Concrete, Columbus, Ohio

CONCRETE SUPPLIER FOR SUPERSTRUCTURE AND ABUTMENTS: Anderson Concrete, Columbus, Ohio

AWARDS: *2008 Portland Cement Association Bridge Award*

Impressive in its scale, the Crossover Taxiway Bridge accommodates the largest Group V aircraft loading while welcoming travelers entering the airport.

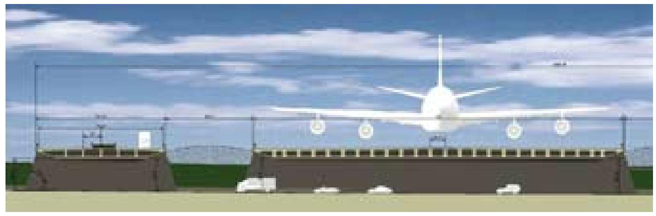


Illustration Inset (left)
The centerpiece of airport expansion structures is the Crossover Taxiway Bridge at the Port Columbus International Airport.

The scale of the abutment can be seen in this photo of a partially completed wall and the reinforcement in another segment ready for form installation.

Defining Goals and Selecting Alternatives

The Crossover Taxiway Bridge spans International Gateway and serves as a significant landmark. It creates a major visual impact for the public as they enter the airport. Consequently, aesthetics played a major role along with the basic design criteria set for the project. The goal was a slender structure with a large clear opening. However, the structure was also required to carry Group V aircraft loading, which includes the Boeing 747-400 series plane that weighs 894,000 lb. The structural depth of the bridge was an issue due to the impact on the design of the International Gateway road below the bridge. Since the road is a depressed section, a shallow superstructure would allow the road alignment to be higher and ensure an elevation above the water table. This would also help reduce the impacts associated with a storm-water pump station that was also under construction for the airport expansion.

A Structure Study Matrix was performed and 40 plausible conceptual alternatives were evaluated to satisfy the design parameters. Seven of these alternatives were then selected to be analyzed in more detail. They were selected based on cost, size, appearance, and constructability. A rating criterion to be used in selecting the proposed structure type was determined with input from the client. Some of the more important criteria to the Columbus Regional Airport Authority were capital cost, life-cycle cost, aesthetics, durability, and schedule. The winning alternate that received the highest score in the matrix was a single-span, post-tensioned box girder bridge that featured an arch-shaped profile.

Due to the geometry and required capacity of the structure, the design needed to utilize high-performance materials and a structural system that would allow for a sleek and durable structure. The result was a superstructure made integral with the substructure providing for frame action and a shallow depth using high-strength, post-tensioned concrete.

Structural Analysis and Design

The design of this integral structure required a three-dimensional finite element analysis that would account for construction staging and long-term material effects. The bridge consists of a cast-in-place, post-tensioned concrete box superstructure cast integral with the abutment walls that are supported by drilled shafts. The concrete box superstructure was wider than its length and was loaded by nontraditional live loads of various Group V aircraft. Due to these factors, two separate finite element models were used for analysis of the bridge design.

The first analysis modeled the cross-section of the concrete box with two-dimensional plate elements. This allowed for unique wheel configurations of various aircraft to be placed anywhere on the bridge deck. The resulting forces in the plates yielded results to design the transverse components of the superstructure. This included the transverse reinforcement and post-tensioning in the top slab of the concrete box. This model was also used to determine the distribution of the aircraft loading to the webs of the multi-celled superstructure. Since this structure is very wide compared to its length, it cannot be assumed that the aircraft loading will be distributed equally to the

CAST-IN-PLACE, POST-TENSIONED BOX GIRDER / COLUMBUS REGIONAL AIRPORT AUTHORITY, OWNER

BRIDGE DESCRIPTION: Single span, post-tensioned, cast-in-place concrete, box girder bridge with integral abutments, supported by drilled shafts

POST-TENSIONING SUPPLIER-CONTRACTOR: Freyssinet LLC, Sterling, Va.

REINFORCEMENT: JB Steel, Columbus, Ohio

COST: $10.5 million

webs and throughout the cross section of the structure.

The second finite analysis modeled the bridge with one-dimensional beam elements. It incorporated the distribution results from the previous analysis to design the flexural components in the superstructure, the connections at the integral abutments, abutment walls, and the drilled shafts. The drilled shafts were modeled with soil springs acting as the soil resistance. The stiffnesses of the springs were based on the modulus of horizontal reaction provided in the geotechnical report. This analysis also accounted for construction staging, material properties, and long-term prestress losses. The stresses in the structure were checked and verified that they did not exceed the maximum allowable compression and tension stresses during any construction phase. The long-term stresses after all losses have occurred combined with the various Group V aircraft loadings were also checked.

High-strength concrete with a specified compressive strength of 7200 psi in the superstructure used in conjunction with longitudinal post-tensioning resulted in optimized geometry of the multi-cell box. The 217-ft 6-in.-wide cross section consisted of 24 cells. The depth varied from 7 ft 6 in. at the abutment to 5 ft 0 in. at midspan. This provided the arch look that the airport authority desired. The utilization of post-tensioning was a key component for the slender design of this bridge. The superstructure required 5562 yd^3 of 7200 psi concrete, ninety-two 27-strand tendons for the longitudinal post-tensioning, and eighty-two 7-strand tendons for the transverse post tensioning. To ensure the integral connection between the superstructure and abutment, one hundred and ninety-four 1¾-diameter post-tensioning bars were used at each abutment. These abutments alone were massive structures, 230 ft long and 30 ft tall. The wall thickness varied from 6 ft 0 in. at the top to 7 ft 6 in. at the bottom. The abutments consumed 3055 yd^3 of 6000 psi concrete and were supported by 54-in.-diameter drilled concrete shafts.

Even beyond the structural and aesthetic features of design, another unique feature had to be accommodated within the bridge. Tubing was installed in the deck to prevent the structure from icing. This system consists of circulating glycol to radiate heat during winter conditions. The system is automated and is activated by sensors.

Construction Innovation

The contractor constructed the bridge without the use of falsework and in a very timely manner. The existing ground line at the site was approximately at the same elevation as the bottom of the proposed superstructure. Therefore, the contractor elected to build the superstructure on grade and then excavate underneath, rather than the other way, which would require falsework for the superstructure.

The goal was a slender structure with a large clear opening.

The shallow, tapered superstructure creates the desired lightness in this photo showing the Taxiway Bridge upon completion.

Careful attention to details such as sloped overhangs, barriers and rails, abutments, and lighting provides a pleasant experience for travelers.

The integral connection of the superstructure to the substructure, combined with the enormous width of the structure, required special construction design calculations and sequencing methods to prevent cracking from creep and shrinkage. Transversely, the structure was constructed in three separate units, allowed to cure for a specific period of time, and then connected by closure placements. Longitudinally, the superstructure also had to cure for a specified amount of time prior to connecting to the substructure to reduce unwanted forces due to shrinkage. The construction process required experienced personnel from the contractor and inspection team for the post-tensioning, grouting, and drilled shaft installation. To ensure the integrity of the drilled shafts, cross hole sonic logging was performed. This verified that there were no voids in the drilled shafts and that there was adequate concrete consolidation at the bottom of the shaft.

The construction of the Crossover Taxiway Bridge was completed in the spring of 2008 and the first aircraft traveled over the structure in November of that year. The design and construction of the bridge was a success for the owner, contractor, architect, and design engineers. The use of high-strength concrete, post-tensioning, and the structural system provided a slender, open structure for massive design loadings. The bridge truly greets people with an elegant entrance to the Port Columbus International Airport.

Aesthetics Revisited

The aesthetics of this structure were of utmost importance to the owner. One main feature desired by the architect and airport was the open, single-span with a slender, variable depth profile. It was feared that a typical, multi-span structure would present a constrictive, tunnel-like experience. Other concepts desired by the architect included a slope on the outside fascias of the superstructure, a reverse taper on the abutments, a modified concrete parapet with galvanized handrail, the geometry of the wing-walls, the use of deep recesses in the faces of the concrete abutments and wing-walls, and the unique lighting scheme under the structure. The lighting beneath the bridge consisted of that required by the Ohio DOT plus additional blue strip lights were placed for aesthetic purposes at carefully selected locations including the abutment recesses.

The authors are Kevin M. Gorak, senior project manager, who was a design engineer on the project and Troy D. Jessop, associate, who was project manager, RW Armstrong, Indianapolis, Ind.

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

PCI Advisory on I-Girder Stability during Handling and Construction

by Chris D. Hill, John S. Dick and Maher K. Tadros

This advisory has been prepared to inform owners, designers, fabricators, and girder erectors about issues affecting long-term sweep of pretensioned concrete girders during manufacturing, shipping, and erection. Jobsite incidents have been reported involving excessive deformations and, in extreme cases, failure. The use of increasingly long, slender girders made possible by stronger concrete and larger prestressing strands may render the issues discussed below more significant in modern design and construction of I-girder bridges.

This alert is not intended to alarm or discourage bridge designers from using long, slender I-girders. They have proven to be significantly less expensive than alternative steel plate girders, which are even more slender. When concrete I-girders are constructed with due care and in accordance with published guidelines, there should be no concern about stability problems. Numerous examples exist of good practices. A bridge in Calgary, Alberta, Canada, utilized 65-m (213-ft)-long, 2.8-m (9-ft 3-in.)-deep girders. In many states including Nebraska, Oregon, and Washington, long-slender girders are increasingly being used.

For the purposes of this discussion, two fundamental terms must be understood.

Initial Sweep (IS)—lateral midspan deviation from a straight line measured at or close to the time of strand release and removal from the form.

Long-Term Sweep (LTS)—lateral midspan deviation from a straight line occurring after IS and until the time the deck is cast on the girders.

Effects of Sweep

Sweep should be considered for all precast concrete products, keeping in mind that the effects are magnified as girder length and slenderness increase.

The core issue is the performance of the system consisting of girders seated on bearings in any given span, before the deck is placed and cured. The interaction between girders and bearings must be considered for all projects.

Recent Events

I-girders are much weaker and more flexible about their vertical axis than about their horizontal axis. In some instances, the ramifications of IS and LTS have been experienced with a general lack of understanding of this behavior. There are examples where girders have been rejected on arrival at the jobsite because sweep was measured while the girder was on a truck sitting on unlevel ground. In other cases, girders have been rejected and removed from the bridge. In other instances, remedial action at the jobsite has been permitted to straighten girders. In rare situations, girders have become unstable and fallen from their supports after being erected. This is obviously a potential danger to people and property.

Bearing Design Concerns

Some bearing types such as cotton duck pads and relatively stiff steel-reinforced elastomeric pads (SREPs) have demonstrated superior performance. They have a minimal first cost impact on the overall project and require practically no maintenance. However, current design specifications for SREPs can produce a wide range of solutions, some of which can lead designers to select relatively soft and thick bearings that could be also be considerably narrower than the width of the girder's bottom flange. Any IS or LTS that is present in a girder will likely be amplified when seated on such bearings.

When a girder is placed on a narrow bearing and not exactly centered, slight eccentricity would create significant lateral stress about the girder's weak axis, and significant additional LTS. This situation would be magnified if the girder web were not plumb.

A 9-ft 3-in.-deep, 213-ft-long girder being shipped in Calgary, Alberta, Canada, using a reinforcing steel truss attached to the top flange for additional stiffness. Photo: Con-Force Structures.

An NU2000 (6-ft 7-in.-deep), 183-ft-long girder used for the construction of the Riverview Road Bridge over I-80 in Omaha, Neb. The bearing pads are 36 in. wide, 8 in. long and $1^5/_8$ in. thick. The wide, thin, pads provide stable support for these long girders. This bridge has steel mid-span diaphragms but no diaphragms on the piers. Photo: Coreslab Structures (OMAHA) Inc.

Initial Sweep versus Long-Term Sweep

IS is a function of production means and methods. IS of precast, prestressed concrete girders is generally limited to a tolerance on straightness of $^1/_8$ in. per 10 ft of length. Measurements of IS must be made just after form stripping and strand release in a "plant controlled" environment with the girder sitting plumb, on rigid dunnage, and lateral rotation at support locations is restrained. It is a quality-control measurement that can be indicative of the prestressing force eccentric to the vertical axis. Reliable measurements can only be made before the beam is exposed to direct sunlight. A "straight" girder subjected to uneven sunlight exposure will deform laterally in the direction of the warm side. Prior to shipment, LTS measurements should be made to quantify elastic and time-dependent effects of storage conditions on sweep in relation to tolerances.

Gravitational load effects and relevant details such as "roll-axis," "shear-center," and girder symmetry result in changes in the behavior of the girder as it is handled. Simply stated, from the time of loading the girder on the truck until the girders are integrally joined by bracing and/or by a rigid concrete slab, the girders are flexible elements that will deform in various ways in response to the combination of forces and restraints to which they are subjected. Such forces are principally the heat of the sun, gravity, and wind. The restraints are principally the girder supports at the different phases of construction, including dunnage rigidity, eccentricity of lifting inserts, and bearing pad rigidity. Additional LTS may develop as a result of these effects.

It is not possible to measure IS at a jobsite. It may only be measured at the time of strand release and stripping from the forms in the plant. A measurement of LTS under jobsite conditions may include a combination of the original IS due to production, and the additional cumulative effects of storage, shipping, and erection. LTS is beyond the control of the precast concrete manufacturer.

An important condition exists when the girder is being handled by a crane using the girder's lifting devices. If the lifting devices are slightly eccentric relative to the vertical centerline of the girder, an otherwise straight girder will deform laterally. As the laterally deformed girder is set on "soft/narrow" bearings, the IS/LTS will remain or be amplified by unequal deformations in the bearing. Conditions may be made considerably worse if the girder is inadvertently seated off-center of the bearing. A girder seated on a wide, rotationally rigid support, such as cotton duck pads or hardwood blocking, will tend to self straighten. In the absence of a rotationally rigid support there must be some other means available to "force" the girder to a plumb, straight configuration.

Consequences of Initial Sweep and Long-Term Sweep

Excessive IS can become a source of subsequent LTS. The ramifications of LTS are of broader concern since the forces producing the LTS are seldom self-correcting once the girders are set in the bridge. Methods must be provided to balance external forces and prevent lateral movement and transverse rotation of the girder ends. Without such methods, LTS can lead to girders rolling off their supports. Should LTS be present, the cause and significance must be immediately investigated and remedied if needed. Otherwise, the risk exists that it will be further magnified by creep effects, creating the potential for failure.

An informative article on lateral stability by Robert F. Mast was published in the *PCI JOURNAL*, Vol. 34, No. 1, January-February 1989, pp. 34-53.

The simplest treatment of girder erection to avoid excessive LTS, irrespective of bearing type, is to:

1. Confirm that the girder is plumb at the bearings, and
2. Lock the girder ends in a fixed condition preventing lateral and rotational movements through the use of rigid, unyielding bracing before releasing the girder from taunt crane lines.

After the deck is constructed, or the girders are otherwise integrated in a manner that prevents the girders from rolling off their supports, temporary bracing may be removed.

This photo shows long-term sweep. The LTS was subsequently removed by straightening, plumbing beam ends, and reattaching cross bracing to the straightened girders.

Example of a narrow, tall bearing pad that must be given attention by all project stakeholders and avoided by designers.

Precautions Suggested by PCI

Personnel involved in various design stages should not hesitate to refer questions regarding the suitability of specified details affecting LTS, such as handling and bearing details, to their local girder producer. All concerned should be involved in this process, including owners, designers, design checkers, and personnel involved in the drafting of contract plans or shop drawings. Ultimately, contractors must be aware of bearing details. They must formulate careful girder erection procedures that minimize LTS. Bearing components should be stiff in the transverse rotational direction. Girders must be centered on the bearings. The girder webs must be in a plumb position at the time they are fully seated on their supports. Full rotational restraint must be provided at girder supports. The first girder to be erected in a span should be braced to the substructure. Subsequent girders can be braced against previously erected girders.

Chris D. Hill is senior project manager/project engineer with Florence & Hutcheson Inc. Consulting Engineers, Lexington, Ky., John S. Dick is a consultant in the concrete industry and executive editor of ASPIRE™ *magazine, Monument, Colo., Maher K. Tadros is principal technical professional, Structures, PBS&J, Tampa, Fla., and the Leslie D. Martin professor of civil engineering, University of Nebraska, Lincoln, Neb.*

EDITOR'S NOTE

This article was reviewed and approved by the Committee on Bridges, the Transportation Activities Committee, and the Technical Activities Committee of the Precast/Prestressed Concrete Institute.

Advertisers Index

To perform efficient and cost-effective repairs on bridge abutments, the Ohio Department of Transportation places activated-zinc anode strips (in red) parallel to epoxy-coated reinforcement (green) after the delaminated concrete is removed. The anodes provide global protection for the abutment reinforcement and extend the abutments' service life. The project shown is the Kirkwood Bridge in Sydney, Ohio.

Minimizing REPAIR IMPACT

by Craig A. Shutt

Repairing deteriorating bridges without causing considerable impact to users creates a difficult balancing act. The Ohio Department of Transportation has found a solution for its abutment repairs by using activated-zinc anode strips distributed throughout a new reinforced concrete facing. Compared to previous repair methods, the galvanic encasement combination extends the bridge's service life and provides global protection to the abutment in a quick and economical way rather than protection only to the patched area.

The department's designs for cast-in-place concrete, continuous, slab bridges typically have a construction joint located over the abutment. This exposes the abutment to chloride penetration from deicing salts and subsequent corrosion of the abutment reinforcement. Typically, the slabs remain in good condition, with only the abutment under the joint deteriorating.

Previously, to repair the damage, temporary shoring would be placed under the slab and the abutments would be replaced. This required either complete bridge closure or phased construction. Both of these created traffic delays and disruptions. But the other options of doing nothing or replacing the bridge were not feasible either for safety or economic reasons.

Ohio began using discrete activated-zinc anodes several years ago, first as a localized repair. The puck-sized anode units, supplied by Vector Corrosion Technologies, Tampa, Fla., attach to the exposed reinforcement using integral tie wires, and consist of a zinc core surrounded by a highly alkaline cementitious matrix. The zinc has a higher corrosion potential than the reinforcing steel, allowing the anode to corrode rather than the steel.

Providing this galvanic protection allowed isolated patch repairs to be accomplished quickly, with minimal impact on traffic and at a low cost. However, the localized benefit provided by the discrete zinc anodes assured protection only around the patch to mitigate the "halo" effect. This effect involves the area around the patch that begins to corrode at an accelerated rate.

To provide extra protection for the entire abutment face, the department has completed several projects that now supply global protection through the use of activated distributed zinc "strip" anodes. In this process, the delaminated concrete is removed, and the new reinforcing steel is installed along the face of the exposed concrete. Zinc anode strips are placed parallel with the epoxy-coated reinforcement and are connected back to the reinforcing steel in the existing abutment. Then a monolithic concrete placement encases the anodes and fills in the repaired areas.

This solution has been used for several years and offers several advantages, including the short time required for this comprehensive repair and future protection. Monitored locations indicate that the anode strips will provide over 20 years of protection, but this can be adjusted by changing the amount of zinc provided or the anode spacing.

This approach also provides an inexpensive repair method. At the time of repair of the Kirkwood Bridge, located near Sidney, Ohio, rehabilitating the abutment with anode strips cost approximately $319,000. To replace the abutment and provide temporary shoring cost about $427,000, while replacing the entire structure cost about $4.5 million.

The program has worked so well that it has been extended to other concrete structures. The anode strips have been used in eight bridge deck overlays in a Lake County, Ohio, project, as well as to protect columns with reinforced concrete jackets, pier-cap repairs, and pile protection in marine structures. The Ohio DOT projects continue to be monitored to ensure the repairs are performing as expected.

This article is based on a presentation produced by Brad Lightle, director of Planning for District 7 of the Ohio Department of Transportation, and Chris Ball, vice president of Vector Corrosion Technologies, Tampa, Fla.

Fabric Repairs
HISTORIC ARCHES
by Stacie L. Dovalovsky, Clark Dietz Inc.

As the City of Kankakee, Ill., has grown, so too has its need for improved infrastructure to handle the increased traffic. Updating the Station Street Bridge, built in 1924, required careful consideration and planning to ensure its historic appearance was not altered. To achieve this goal, E-glass reinforcing fabric was used to confine the concrete in the bridge's arches and to provide protection from the weather.

The 379-ft-long bridge, listed on the Illinois Historic Bridge List and eligible for the National Register of Historic Places, crosses the Kankakee River with five cast-in-place concrete, open-spandrel arches. Built to carry 1920s-era vehicles and streetcar tracks, it now carries nearly 7000 vehicles every day. The bridge's historic status limited the options for repairing the substructure and superstructure to meet today's needs.

The deck and spandrel columns had been replaced in 1978, but the arches had received little attention and were in dire need of repair. City officials had three key goals: bringing the project in on time, on budget, and with little disruption to the bridge's appearance. The use of fiber-reinforced polymer composite wrappings for the arches helped to achieve all these goals.

The 379-ft-long Station Street Bridge in Kankakee, Ill., had its five cast-in-place concrete, open-spandrel arches repaired with fiber-reinforced polymer composite wrappings. The repair was accomplished for less than original cost estimates.

After careful consideration of options and selection of the best type of wrappings, a detailed analysis of the arches was performed to determine the potential construction sequence. Before the arches could be wrapped, deteriorated concrete had to be removed and replaced. But if too much of the cross-section of the arch was removed, it could fail under the weight of the superstructure's dead load.

Conventionally formed concrete and shotcrete were used for repairs, after which the arches were wrapped with the fiber-reinforced polymer composite. They were then painted to protect the composites and to give the repaired concrete a like-new appearance. To provide a consistent look to the entire bridge, the existing concrete not wrapped was painted to match the repaired substructure. All work on the bridge was performed under the direction of the prime contractor, Kankakee Valley Construction, Kankakee, Ill.

The fabric had been used in Illinois to strengthen existing columns in high-seismic areas, but it had not been used before to strengthen a spandrel arch bridge. Initially, engineering estimates had limited the project to wrapping only the two exterior arches, which were significantly more deteriorated. However, the low bid also allowed the center arch to be wrapped and the project to be completed for $1.9 million or $600,000 below the original estimate.

The reinforcing fabric improves the structural integrity of the arches by confining the concrete, providing protection from the weather, and preventing future spalling. Most importantly, this approach preserved the bridge's historic appearance. It gives the city a virtually maintenance-free structure for the next 20 to 25 years. Much of the material used on the project was supplied by Sika Corp., Lyndhurst, N.J.

To further enhance the project's history, the existing IDOT-standard light poles placed on the sidewalks during the 1978 repairs were replaced with historical period lighting. The new light poles were located on the back of the parapets and out of the sidewalks. Special cantilever pedestals were designed for the new lighting; thereby, improving driver and pedestrian safety. The lighting ties into the city's master lighting plan and allows for future expansion of the period lighting throughout the neighborhood.

Planning for the future is a key goal throughout Kankakee, especially for its infrastructure needs. This project provides a new way to meet those needs while retaining the city's historic charm and improving safety at the same time.

More detail can be found in the article, "Station Street Repair" published in ICRI Concrete Repair Bulletin*, July/August 2008.*

Stacie L. Dovalovsky, is a project manager with Clark Dietz Inc. in Chicago, Ill.

The arches on the bridge, which is listed on the Illinois Historic Bridge List and eligible for the National Register of Historic Places, needed to be repaired so that its historic nature was not disturbed.

The contractor's low bid on the project allowed city officials to extend the wrapping work to include the center arch and still have the total cost come in below the original engineering estimate.

The historic Rainbow Bridge near Smiths Ferry, Idaho, had its deteriorating rails replaced with precast concrete units that were match-cast in color and texture to provide a consistent look for the entire structure.

A PERFECT MATCH

by John Hinman, CH2M Hill

The Rainbow Bridge near Smiths Ferry, Idaho, was built in 1933 as a cast-in-place arched structure. Its design has made it a statewide landmark and led to its listing on the National Register of Historic Places. But its condition had become less noteworthy, leading to the need for delicate repairs that would not tarnish its historic nature. To accomplish this, new precast concrete rails were installed, with all pieces cast using color and texture to match the existing pieces.

The bridge required significant work, because its rails and decorative features were disintegrating, and corrosion was occurring in the reinforcement of the stringer ends, bents, and spandrel columns. Under ideal conditions, the bridge could have been closed and cast-in-place concrete could have been used to replicate the original design, giving the contractor full access. Unfortunately, this wasn't feasible, as the bridge had to remain open at all times.

Initially, work focused on the substructure, stabilizing corrosion in the arches and columns with electrochemical chloride extraction (ECE), repairing stringers, and performing other patching incorporating galvanic anodes and replacement work. Analysis showed that the concrete had retained its strength, but needed to be upgraded to control the corrosion deterioration caused by significant chloride contamination from deicing chemicals.

The main focus at the deck level was replacing 841 ft of rail using precast concrete sections. This approach was taken to ensure the bridge could remain open avoiding traffic next to an unprotected edge. The key to success was finding the proper concrete mixture to ensure the new components would exactly match the shape, color, and texture of the original rails.

On the assumption that the original concrete mix comprised local aggregates, considerable scouting was done to find suitable sources. Concrete cores were taken from the existing bridge, and these were compared to cores taken from new samples cast with different aggregates. Tinting wasn't an option, as it would begin to weather and create a disparity. It was determined that some local aggregates were totally unsuitable, but ultimately a close match was created. The new concrete is expected to weather over the next few years to closely match the existing components.

Casting and erecting the precast concrete rails created additional challenges, as each piece was unique due to the grades, superelevations, and curves. The complexity was immense, with a lot of individual customization needed for most of the components. Expanded polystyrene pieces were carved using computer-controlled cutters to create the forms for each piece.

The bridge's arches and main piers around the joints underwent an electrochemical chloride-extraction process, while galvanic anodes were embedded in the concrete-patch repairs in other areas.

The precast concrete rails were cast in forms created with expanded polystyrene pieces that were carved using computer-controlled cutters. Each railing piece is unique, owing to the grades, superelevations, and curves.

The resulting forms were coated with plastic to achieve a smooth and durable surface. The surface quality of each cast component still required close attention. The work was overseen by general contractor Mowat Construction Co. in Woodinville, Wash., with the precast concrete components produced by Central Pre-Mix Prestress Co. in Eagle, Idaho.

Officials at the Idaho Department of Transportation also implemented a corrosion-mitigation program to prevent further deterioration. After considering various options, they decided on the ECE method in the arches and main piers around the joints and the embedment of galvanic anodes in the concrete-patch repairs in the non-ECE-treated areas.

The ECE treatment reduces the amount of chloride ions in the concrete and generates higher alkalinity around the reinforcing steel, reinstating the passivity of steel reinforcement. It directly addresses the cause of the corrosion from the concrete, with no permanent system left in place to be operated, maintained, and monitored. Approximately 8000 ft^2 of concrete surface was treated in less than two months. The ECE treatment was designed by Corrosion Control Technologies in Sandy, Utah. Vector Corrosion Technologies in Wesley Chapel, Fla., supplied the galvanic anodes and executed the ECE work as a subcontractor to Mowat.

The result of this careful attention to detail is a design that perfectly blends new and old. The proof is in the enthusiastic response from drivers, who had to crawl past the construction and wait for traffic when only one lane was open. While many times such situations create ill will against the construction crews; in this case, drivers were rolling down their windows to compliment the contractor on how good the bridge was looking. And, with a comprehensive corrosion-mitigation strategy in place, the bridge is expected to perform for years to come.

This bridge was named the 2007 Project of the Year by the International Concrete Repair Institute; for more details on the project, see ICRI's November/December 2007 issue of *Concrete Repair Bulletin*, or visit http://www.icri.org/AWARDS/2007/rainbowbridge.asp.

John Hinman is principal bridge engineer with CH2M Hill in Boise, Idaho.

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.wvdot.com/projects/I64_Bridge
This West Virginia Department of Transportation website contains information about the I-64 Dunbar to South Charleston Bridge over Kanawha River. Photographs and three web cameras are provided to show construction progress.

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.

www.pcine.org
The Precast/Prestressed Concrete Institute Northeast (PCINE) is the northeast regional arm of the national Precast/Prestressed Concrete Institute. Click on "Resources" and "Bridge Guidelines" for the "Guidelines for Accelerated Bridge Construction using Precast/Prestressed Concrete Components" mentioned on page 50.

www1.co.snohomish.wa.us
The Snohomish County website provides the opportunity to search for information about bridges in the county including the award-winning South Slough Bridge 91.

http://cms.transportation.org/?siteid=34&pageid=1484
This website lists the preliminary versions of the balloted items from the AASHTO 2008 Subcommittee on Bridges and Structures meeting. Balloted items in pdf format may be downloaded by scrolling to the bottom of the page.

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.

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 52 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.

Bridge Research

www.trb.org/news/blurb_detail.asp?id=8815
The U.S. FHWA's Turner-Fairbank Highway Research Center (TFHRC) has released a report that provides a brief overview of individual TFHRC laboratories, their current activities, and laboratory managers.

http://ntlsearch.bts.gov/tris/index.do
The Transportation Research Information Services (TRIS) online database contains over half a million records of published transportation research including technical reports, books, conference proceedings, and journal articles.

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. Some completed projects are described below:

http://trb.org/news/blurb_detail.asp?id=3257
NCHRP Report 517, Extending Span Ranges of Precast Prestressed Concrete Girders, contains the findings of research performed to develop recommended load and resistance factor design procedures for achieving longer spans using precast, prestressed concrete bridge girders. Spliced girders were identified as the design option with the greatest potential for extending span lengths.

www.trb.org/news/blurb_detail.asp?id=8693
NCHRP Report 584 Full-Depth Precast Concrete Bridge Deck Panel Systems examines recommended guidelines and the AASHTO LRFD specifications language for design, fabrication, and construction of full-depth precast concrete bridge deck panel systems. Recommended guidelines and proposed revisions to the LRFD specifications language are available as online appendices.

ENHANCING THE ENVIRONMENT—Part 2

by M. Myint Lwin, Federal Highway Administration

The Federal Highway Administration (FHWA) is committed to preserving and enhancing the environment through research and stewardship. In the previous issue of *ASPIRE*,™ I reviewed the accomplishments following the passage of the National Environmental Policy Act. In this issue, I explore the opportunities for research, development, deployment, and education for enhancing the natural and built environment.

Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy For Users (SAFETEA-LU)

SAFETEA-LU contains several provisions on environmental planning, research, and education. FHWA is working with its partners at all levels to share research results and promote environmentally sound practices. The states have learned from experience that incorporating environmentally responsive technologies and practices early in the project development process saves project costs and time. The following research programs can help address issues dealing with meeting the environmental goals of "Green Highways and Bridges."

State Planning and Research Program

The State Planning and Research (SP&R) Program is intended to solve problems identified by the states. State Departments of Transportation (DOTs) are encouraged to establish research, development, and training programs that anticipate and address transportation concerns before they become critical problems. High priority is given to applied research on state or regional problems, transfer of technology, and research for setting standards and specifications. The state DOTs have used SP&R funds for substantial research into regional environmental issues. For example, an ongoing research project at the state level is the "Investigation of Stormwater Quality Improvements Utilizing Permeable Pavement and/or Porous Friction Courses." The research is sponsored by the Texas DOT using SP&R funds. Research that contributes to "Green Highways and Bridges" will meet the purpose of the SP&R Program.

Section 505 of Title 23, USC establishes a set-aside of 2% of the sums apportioned to a state each fiscal year for state planning and research activities. Furthermore, the states must allocate 25% of the set-aside for research, development, and technology transfer activities. In FY 2006, the set-aside amounted to about $600 million, providing about $150 million for the SP&R Program.

Surface Transportation-Environmental Cooperative Research Program

SAFETEA-LU SEC 5207 establishes the Surface Transportation-Environmental Cooperative Research Program (STEP). STEP is intended to improve understanding of the complex relationship between surface transportation, planning, and the environment. The program is authorized at $16.875 million per year for FY 2006 through FY 2009 and is administered by the Federal Highway Administration (FHWA).

All photos: Shutterstock.

Research is being proposed and conducted in the areas of planning, air quality, noise abatement, wetlands, vegetation management, wildlife connectivity, brownfields, and stormwater. Other proposed research would examine tools such as the geographic information systems (GIS) and global positioning systems (GPS) to better map important ecosystem features, including wildlife corridors and invasive plants; and to improve the ability to recognize and address environmental concerns very early in the process of project planning and development. Research ideas in the areas of "green bridges" for enhancing the environment are welcome from the bridge engineering community.

Center for Environmental Excellence

SAFETEA-LU SEC 5309 establishes a Center for Environmental Excellence for promoting and supporting strategic national surface transportation programs and activities relating to the work of the state DOTs in environmental areas. The center is funded at $1.25 million per year for FY 2006 through FY 2009.

The American Association of State Highway and Transportation Officials (AASHTO) has been selected on a competitive basis as the Center for Environmental Excellence with the responsibility for program administration The center has been provided $3.1 million in funding over the next three years to provide technical assistance, information sharing of best practices, and training in the use of tools and decision-making processes that can assist states in planning and delivering environmentally sound surface transportation projects. With the SAFETEA-LU funding, AASHTO actively promotes environmental excellence in transportation by providing a wide variety of services aimed at defining the state-of-the-art in environmental protection, restoration, and enhancement while

promoting innovative techniques that maximize the efficiency, reliability, and consistency of delivering environmentally sound transportation projects and programs. AASHTO serves as an important resource for AASHTO member states and their partners seeking technical assistance, training, information exchange, partnership-building opportunities, and quick and easy access to environmental management tools. For detailed information about the center, visit http://environment.transportation.org/center/about.

The AASHTO Center for Environmental Excellence maintains and updates the Transportation Environmental Research Ideas (TERI) database. TERI is the central storehouse of the AASHTO Standing Committee on Environment for tracking and sharing new transportation and environmental research ideas. Suggestions for new ideas are welcome from practitioners across the transportation and environmental community. Anyone can view the TERI database or suggest new research ideas. Members of subcommittees within AASHTO's Standing Committee on Environment (SCOE) have responsibility for regularly rating the ideas in TERI to provide a gauge of each research idea's merit for practitioners. TERI may be accessed at www.environment.transportation.org/teri_database.

TERI provides a timely, organized, and comprehensive list of research ideas to policy makers and researchers as they make choices in forums such as NCHRP's 25-25 and 8-36 research programs about research priorities. As the best research ideas in TERI are implemented, the Transportation Research Board's Research in Progress (RiP) database is updated to provide the latest information about the status of research ideas. After research is completed, one can search the U.S. Department of Transportation and Transportation Research Board's TRIS online catalogue to find information about final reports and other research products.

Call for Environmental Research Ideas

The AASHTO Center for Environmental Excellence issues annual "Call for Environmental Research Ideas" on transportation and environmental research through the TERI. The 2008 Call for Environmental Research Ideas was closed on April 23, 2008. The center will be working with the AASHTO's SCOE to select and refine a group of the best ideas listed in TERI. The call for research ideas was posted on the website: http://www.transportation.org/?siteid=89 with information on the lists of focus areas and how to submit research ideas. This information will be useful in responding to future calls for research ideas. Priority research ideas will be developed into NCHRP-style problem statements and promoted by SCOE for inclusion in national research initiatives. Over the last 2 years, an estimated $1.5 million in research originating from TERI ideas has been funded through NCHRP alone.

The bridge engineering community is encouraged to submit environmental research ideas that contribute to "green bridges" through TERI or other research organizations.

Additional Information

For additional information on the AASHTO center or to request advice, contact Shannon H. Eggleston, AASHTO's Director of Environmental Programs at (202) 624-5800, or environment@aashto.org. Additional information on the environment program may also be obtained by contacting Fred Skaer, Office Director, FHWA Office of Project Development and Environmental Review at fred.skaer@dot.gov.

Summary

Congress finds that research, development, deployment, and education are critical to developing and maintaining a transportation system that meets the goals of safety, mobility, economic vitality, efficiency, equity, and environmental protection.

The AASHTO Center for Environmental Excellence is established to promote and support research and programs in the area of environment to assist states in planning and delivering environmentally sound projects.

FHWA works together with AASHTO and its customers and partners in promoting and supporting research, development, deployment, and education for advancing the state-of-the-art in environmental protection, restoration, and enhancement, and promoting innovative ideas and practices.

The bridge engineering community is encouraged to submit and promote environmental research ideas in the following topics in support of sustainability of the ecosystems and "green bridges" for protecting and enhancing the environment:

- Sustainable site selection and planning
- Wild life and ecosystems
- Enhance renewable resources
- Recycle depletable resources
- Water quality and wetlands
- Air quality
- Climate change and the accompanying effects
- Construction and preservation practices

Bridges and tunnels form major and important links in the surface transportation system. What we build and maintain today has consequence to the present and future generations. Our goals are to build and maintain bridges and tunnels that contribute to safety, mobility, economic vitality, efficiency, equity, and environmental protection. Our aim is to have clean air and water, and sustainable ecosystems for ourselves and our co-inhabitants for generations to come. Coordinated and integrated environmental research will lead us to an environmentally responsive surface transportation system, a greener earth, and a healthier global environment.

In the next issue of *ASPIRE*, we will explore the global efforts in contributing to "Green Highways and Bridges." The author invites readers to share ideas and suggestions, facts and figures, case studies, photographs, etc., on these topics by writing to him at myint.lwin@dot.gov.

U.S. Department of Transportation
Federal Highway Administration

Concrete Bridges in

New Hampshire

by Mark W. Richardson, David L. Scott, and Jason A. Tremblay, New Hampshire Department of Transportation

Designing and constructing economical and durable highway bridges has always been a challenge for state transportation agencies. Conflicting needs such as system expansion for safety and capacity versus system preservation and maintenance compete for dollars. Shrinking state transportation budgets compound the problems at the same time that increasing numbers of highway users overburden our aging infrastructure. State and federal agencies nationwide have worked individually and collectively to develop design concepts and materials to address these needs. The New Hampshire Department of Transportation (NHDOT) continues to be involved in developing solutions to some of the problems facing the public transportation community in the twenty-first century.

Over the past 15 years or so, many NHDOT bridge projects have built on the success of previous projects and details. Initial efforts concentrated on the development of standards for high performance concrete (HPC) for bridge decks. In turn, this technology was applied to other structural elements. Through support from PCI Northeast (PCINE), the New England bulb-tee (NEBT) girder utilizing HPC was developed as an economical standard precast, prestressed concrete bridge member. Details were developed for partial- and full-depth precast, prestressed concrete deck panels that also utilized HPC, again learning from previous successes and challenges. This article presents several of the many NHDOT bridge projects that make use of proven HPC and precast, prestressed concrete technologies. Although comparatively small in scope, these projects demonstrate the effectiveness, efficiency, and economy of precast concrete systems and details for bridge rehabilitation and construction.

Completed Bristol Bridge carrying NH 3A over the Newfound River used partial-depth deck panels.

Bristol – NH Route 104 over Newfound River

Built in 1995, this 65-ft-long single-span bridge was NHDOT's first use of HPC. The five AASHTO Type III girders were spaced at 12 ft 6 in. and used a specified compressive strength of 8000 psi at 28 days. This was the highest ever specified in a NHDOT design. The wide girder spacing necessitated an HPC deck with a specified 28-day strength of 6000 psi, which is significantly higher than NHDOT's typical 4000 psi deck concrete. The selected deck mix design was based on research performed by the University of New Hampshire. This research involved casting deck slabs from three unique concrete mixes and then subjecting those slabs to truck loading at the entrance to a landfill.

Bristol – NH Route 3A over Newfound River

Based on the success of the first Bristol project, NHDOT constructed a second HPC project in 1999. This project utilized four NEBT girders spaced at 11 ft 6 in. to achieve the 60-ft-long span. To avoid the expensive deck falsework prices of the first project, partial-depth precast deck panels were used. These were then topped with an HPC concrete overlay.

Rollinsford – Rollins Road over Main Street and B&M Railroad

The existing four-span bridge, constructed in 1938, was built with steel beams and concrete deck and had a total length of 168 ft. The new bridge, built in 2000, was constructed using NEBTs with a single 110 ft span over the railroad and roadway. Five girders, spaced at 7 ft 5 in. on-center, were used to construct the bridge. This project is especially noteworthy because the deck reinforcement for the cast-in-place deck was a non-corrosive carbon fiber reinforced polymer (CFRP) grid, 9 ft wide by 7 ft long. Individual grid elements were sized to replicate the ultimate strength of Grade 70, No. 6 reinforcement, and used a similar spacing as conventional deck reinforcement. Since each grid is light enough to be carried by an individual worker, placement was easier and faster than that of conventional steel reinforcement. The deck contains numerous fiber optic strain gauges for performance evaluation and continues to be monitored by the University of New Hampshire.

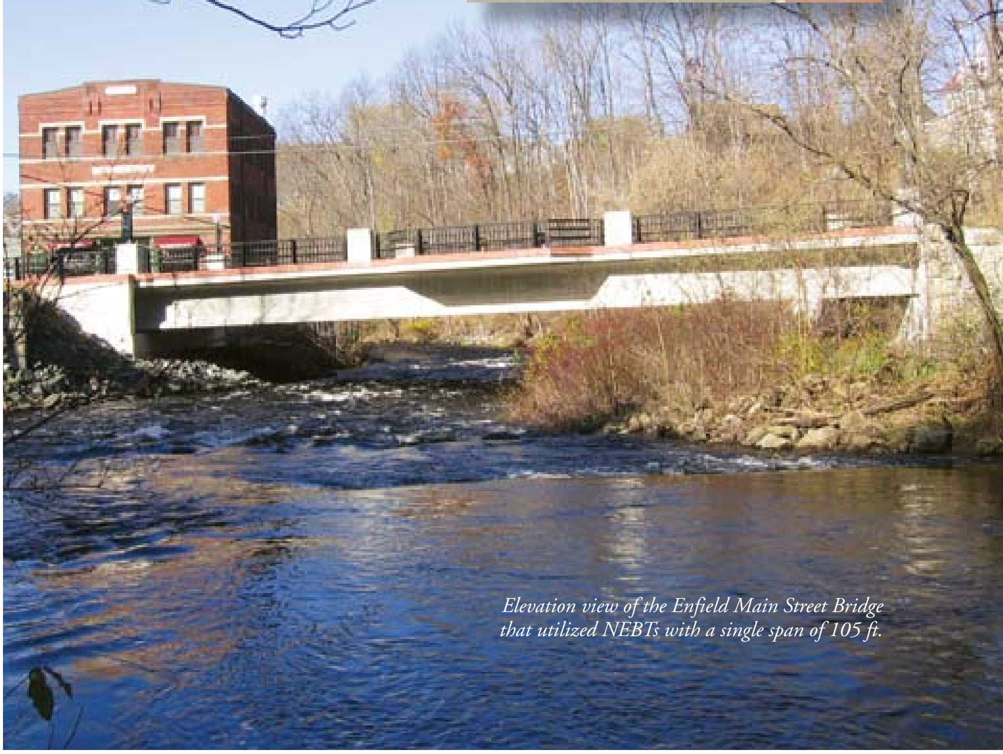
Workers begin installation of CFRP grids in Rollinsford.

Enfield – Women In Service to Enfield (WISE) Main Street Bridge over Mascoma River

The Main Street Bridge over the Mascoma River replaced an existing three-span concrete encased jack-arch girder bridge built in 1916. The original bridge had three equal spans of 34 ft with both piers located in the Mascoma River. The new bridge, constructed in 2002, utilized NEBTs with a simple span of 105 ft. Five girders support the cast-in-place concrete deck with 11 ft 4 in. typical lane widths plus 5-ft 6-in.-wide sidewalks. The upstream sidewalk included a "bump out" at midspan for use by fishermen and those viewing this scenic portion of the river and adjacent mill area. Both sidewalks specified red-colored concrete with an embossed brick pattern to replicate the brick sidewalks constructed on the bridge approaches.

The NEBTs were 72 in. deep using both straight and harped prestressing strands. NHDOT typically designs for zero tensile stress in the precompressed tensile zone of prestressed concrete girders. With an 8-ft 10-in.-girder spacing, the required concrete strengths for the girders were 5800 psi at release and 8000 psi at 28 days. The result was a very economical structure that eliminated the pier obstructions from the river and provided an attractive crossing for both vehicles and pedestrians.

Completed Main Street Bridge with historic mill in the background.



Elevation view of the Enfield Main Street Bridge that utilized NEBTs with a single span of 105 ft.

Placement of the first precast footing segment in NHDOT's first entirely precast bridge in Epping.

Eight days after the first precast footing piece was placed, the Mill Street Bridge in Epping was paved and opened to traffic.

Epping – Mill Street Bridge over Lamprey River

NHDOT constructed this bridge using totally precast substructure and superstructure components. The existing crossing was comprised of two simple spans each 30-ft-long and separated by a 60-ft-long pier/island. It was replaced with a 115-ft-long simple span consisting of 3-ft 0-in.-deep box beams, transversely post-tensioned.

The NHDOT used this bridge as a pilot project to see how fast a totally precast bridge could be constructed, once site preparation had been completed. With the town allowing the road to be closed during site preparation and construction (a short detour was available), the Mill Street site was well suited for this experiment. Months of design and planning went into the project before any construction began. Site preparation work, including lowering of the pier/island, took approximately 2 months. Once the first precast footing piece was placed on the prepared subfooting surface, the contractor was allowed 14 days before opening the bridge to traffic. With an assembly plan in place that detailed the contractor's entire proposed work, including contingency plans addressing any changes to the work (for example: equipment breaking down), the contractor completed the bridge construction in only 8 days. An incentive/disincentive clause was included to either reward or penalize the contractor so they would adhere to the specified 14-day time frame.

NHDOT's first use of precast, prestressed full-depth deck panels on the redecking of the Mosquito Bridge over Lake Winnisquam.

Due to the success of this project, precast details from this project have been incorporated into PCINE's *Guidelines for Accelerated Bridge Construction Using Precast/Prestressed Concrete Components* (available for download at http://www.pcine.org/view_file.cfm?dir=\resources\design_tools\165\&filename=Accelerated_Bridge_Guidelines.pdf).

Sanbornton & Belmont – NH Route 3 (Mosquito Bridge) over Lake Winnisquam

NHDOT's first use of full-depth deck panels for the replacement of the deck was on this bridge. NHDOT has used partial-depth deck panels since the early 1990s and with FHWA's Innovative Bridge Research and Deployment (IBRD) funds, decided to experiment with full-depth deck panels.

The four-span bridge, with exterior spans of 104 ft 0 in. and interior spans of 130 ft 0 in., has a 53 ft 3 in. out-to-out width. A total of one hundred and sixteen 8-in.-thick panels, each 8 ft long, were fabricated for this project. Post-tensioning ducts were incorporated into each panel and spliced together once the panels were set. The post-tensioning strand was placed through the duct, tensioned, and the entire duct grouted. After post-tensioning, shear stud blockouts were also grouted.

Due to traffic phasing, half the panels were 26 ft 4 in. wide and the other half were 25 ft 11 in. wide. This required a closure placement over the middle girder. Unlike a closure between girders, the panels required support from the middle girder while casting the closure and developing reinforcing steel in the negative moment region over the girder. This required a blockout in the panel to splice the reinforcement.

IBRD funds were used on this project to allow for an incentive/disincentive clause to see how fast the contractor could remove and replace the deck using full-depth panels. Learning from the successes and setbacks of this project, the NHDOT has advertised another deck replacement project using full-depth deck panels and has gained more knowledge on their application for future projects.

Summary

The projects described have been very successful and have provided significant information and experience on which future projects can be developed. As more details become standardized and as more contractors in the northeast region gain experience with these materials and techniques, the cost and required construction time should be reduced. Although not suitable for every site or for every bridge application, precast bridge elements have clearly demonstrated their effectiveness in addressing the concerns of state transportation agencies—namely, by providing efficient and durable bridge elements that can be quickly and easily installed at an economical price to provide low maintenance bridge structures. When considering the overall deteriorated condition of the nation's transportation infrastructure, these advances in bridge technology and construction will provide safe and effective project delivery for the traveling public. NHDOT is pleased to be a part of that effort and to contribute toward that goal.

Mark W. Richardson is administrator, Jason A. Tremblay is senior project engineer, and David L. Scott is design chief with the New Hampshire Department of Transportation, Bridge Design Bureau, Concord, N.H.

For more information on New Hampshire bridges, visit www.nh.gov/dot/index.htm

South Slough Bridge 91. This bridge has won several local and national awards for innovative design and construction techniques including the use of lightweight cellular concrete. It was a winner in the 2008 Portland Cement Association Bridge Awards program. For more information visit www1. co.snohomish.wa.us and search "Bridge 91."

Snohomish County Incorporates Sustainable Issues in Bridge Designs

by Darrell Ash and Kinyan Lui, Snohomish County, Washington

In 1976, Snohomish County began the development of our current bridge inventory system. At that time, nearly 90% of our bridges were made with timber. Since then, the county has focused on replacing and rehabilitating these structures using concrete. Currently, 62% of the county's bridges are made of concrete, 11% are steel, and only 27% of the bridges are timber. We construct three to four projects per year and maintain a total of approximately 200 bridges.

Both precast concrete bulb-tee girders and slabs are used, primarily because they are quickly erected, allowing faster access for vehicles. Excellent quality control is also a feature of the factory-cast process and materials are readily available in the local area. Several manufacturers of precast components are located in and around Snohomish County, which shortens the time from bid to production and delivery.

Climate Leads to Concrete

Concrete's durability is another key reason that it has become the primary construction material for our bridges. The Pacific Northwest receives a lot of rain all year, which causes timber bridges to rot and steel bridges to rust. A bridge's life-cycle cost has become a critical factor in determining what material to use. Typically, precast concrete is the most economical when all factors are considered.

Initial in-ground costs can be deceiving. Strictly speaking, timber bridges are the cheapest to build, but they won't last as long as precast concrete bridges, and they will require far more maintenance, increasing their total operating cost. As a result, we gravitate to precast concrete unless otherwise dictated, because, historically, it has had the cheapest life-cycle cost.

Global Warming Adds Challenges

The growing desire for a 100-year service life has created an additional factor when we design bridges and decide on pier locations. We anticipate that river channels will migrate over the decades as a result of global warming and we need to do the best possible job of predicting how the rivers will perform and where scour areas will occur. With this in mind, we place piers to minimize impact throughout the life-span of a bridge.

Innovative Use of Cellular Concrete

Although most of our bridges are fairly standard construction, in 2007 we completed a unique project that widened a two-span concrete Luten arch bridge built in 1918. The new deck is 62% larger in area with precast concrete slabs, which would have added a substantial amount of weight to the bridge. To counterbalance the additional dead load, the soil inside the arches with a density of about 125 pcf was replaced with lightweight cellular concrete having a density of 30 pcf.

Load-distribution analysis and a well-planned construction sequence ensured the project was completed successfully, providing new life for an historic county bridge at a fraction of the cost it would take for total replacement. In addition, no environmentally sensitive area was disturbed during construction.

Darrell Ash is the manager and county bridge engineer for the Construction Group, and Kinyan Lui is supervisor of the Bridge Design Group for Snohomish County, Wash.

North Fork Stillaguamish River Bridge 424. Nearly 95% of the county bridges cross water, and virtually all of those waterways impact endangered species.

Sustainability

Environmental concerns are another important factor to be considered. Nearly 95% of our bridges cross water and virtually all of those waterways impact endangered species. This means that we absolutely do not put piers into the water unless there is no other option. We also strive to minimize environmental impacts during construction by doing as much work outside the water as possible and coordinating with the permitting agencies at an early stage. The environmental process of a bridge project, including mitigations and permitting, can take more time than the design and construction phases.

2009 Interim Changes Part 1

by Dr. Dennis R. Mertz

The American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Bridges and Structures (SCOBS) considered and adopted five agenda items specifically related to concrete structures at their annual meeting in Omaha, Neb., in May 2008. Over the past several years, Technical Committee T-10, Concrete Design, developed Agenda Items 58 through 62 and moved them to the subcommittee ballot last year. The agenda items represent revisions and additions to the AASHTO LRFD Specifications. These agenda items along with the complete agenda for the recent SCOBS meeting can be found on the AASHTO website at http://cms.transportation.org/?siteid=34&pageid=1484. The 2008 concrete structures agenda items, which will become the 2009 interim changes, are reviewed in this and the next issue.

Agenda Item 58 revises existing articles of the AASHTO LRFD Specifications to conform to companion Agenda Item 66, developed by Technical Committees T-5, Loads and Load Distribution and T-14, Structural Steel Design. Agenda Item 66 clarifies the fatigue and fracture limit state by adding a second load combination, Fatigue I, which explicitly provides infinite fatigue life for steel and concrete members. The previous fatigue load combination becomes Fatigue II and is used for finite life design of steel members only. Infinite life design was included in the existing fatigue provisions in a more implicit manner. With the 2009 interim changes, it becomes explicit with the addition of this new fatigue load combination.

In Agenda Item 58, Article 5.5.3 is rewritten into the format of the fatigue-related provisions of other articles of the AASHTO LRFD Specifications with reference to the new fatigue load combination. All of the fatigue provisions for concrete members are based on designing for infinite life by applying the new explicit Fatigue I load combination and constant-amplitude fatigue thresholds.

Further, the compression stress check of Table 5.9.4.2.1-1, which relates to fatigue resistance, is removed from the table and placed within Article 5.5.3 to clarify that this compression stress limit is a fatigue consideration and that the Fatigue I load combination should be used with this check.

Finally, the exemption of concrete deck slabs in multi-girder applications from fatigue considerations is extended to reinforced concrete box culverts.

Agenda Item 59 revises various articles of the AASHTO LRFD Specifications clarifying the limited application of reinforcement conforming to ASTM A1035/A1035M, Standard Specification for Deformed and Plain, Low-carbon, Chromium, Steel Bars for Concrete Reinforcement. Most importantly, the agenda item clarifies that reinforcement conforming to ASTM A1035/A1035M may only be used as top and bottom flexural reinforcement in the longitudinal and transverse directions of bridge decks in Seismic Zones 1 and 2, as one of many options. Also, while the specified yield strength of reinforcing bars used in design must not exceed 75.0 ksi, the splice length of the ASTM A1035/A1035M reinforcement should be determined using its specified minimum yield strength of 100 ksi.

Agenda Item 60 limits the use of concrete with compressive strengths above 10.0 ksi to normal weight concrete only when allowed by specific articles. This agenda item clarifies a recent change, which permitted the use of concrete with compressive strengths above 10.0 ksi where appropriate but did not limit it to normal weight concrete. The application of concrete with compressive strengths above 10.0 ksi is based upon recent National Cooperative Highway Research Program (NCHRP) projects on high-strength concrete that did not include lightweight concrete.

The additions and revisions represented by Agenda Items 61 and 62 will be reviewed and discussed in the next issue.

NW Full Elevation.

Under Deck.

Maple Avenue Bridge
Deck 1.

Jack System.

Kiewit constructed a liquid nitrogen plant to lower the initial temperatures of the concrete for mass concrete placements.

Looking from the Pier 3 cantilever towards Pier 2, shows the height of the structure over the water and the reconstruction efforts required for the slope

Pier 3 in June 2008.

The cantilevers starting in August 2008.

Bar reinforcing at one of the pier tables was very dense due to seismic requirements.

The precast concrete tub girders were placed in only two nights, with two crossing the northbound side of the highway set in one night, and the span crossing the southbound side set another night.

A cast-in-place deck was used for the walkway (Deck pour span six).


STOP

The concrete box girder in the approach spans measures 64 ft wide and 16 ft deep. Photo: T.Y. Lin International.

The segmental box girder bridge is a harmonious design.

Comprising a total of seven approach spans, the bridge's total length is 2975 ft. Illustration: T.Y. Lin International.

Photos: T.Y. Lin International.

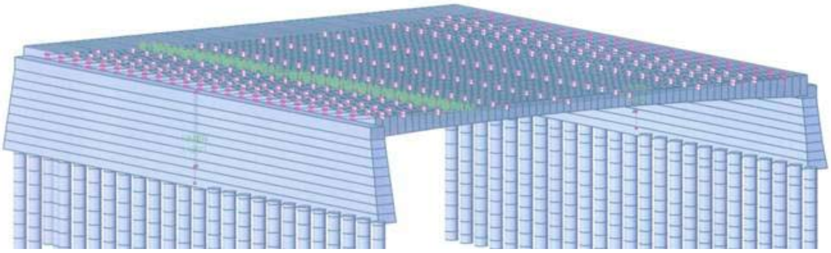
Photos: T.Y. Lin International.

Photo: Ahmed N.K. Mongi, of the WVDOT.

Work continues on the Kanawha River Bridge with completion expected by the end of 2010. Photo: Ahmed N.K. Mongi, of the WVDOT.

Photo: Ahmed N.K. Mongi, of the WVDOT.

Rendering Elevation.



Analysis modeling.

Aerial View During Construction.

PT Duct Layout

PT End Block.

Drilling Shaft Installation.

Bridge Construction.

View from along Bridge.