ASPIRE™
THE CONCRETE BRIDGE MAGAZINE
FALL 2008
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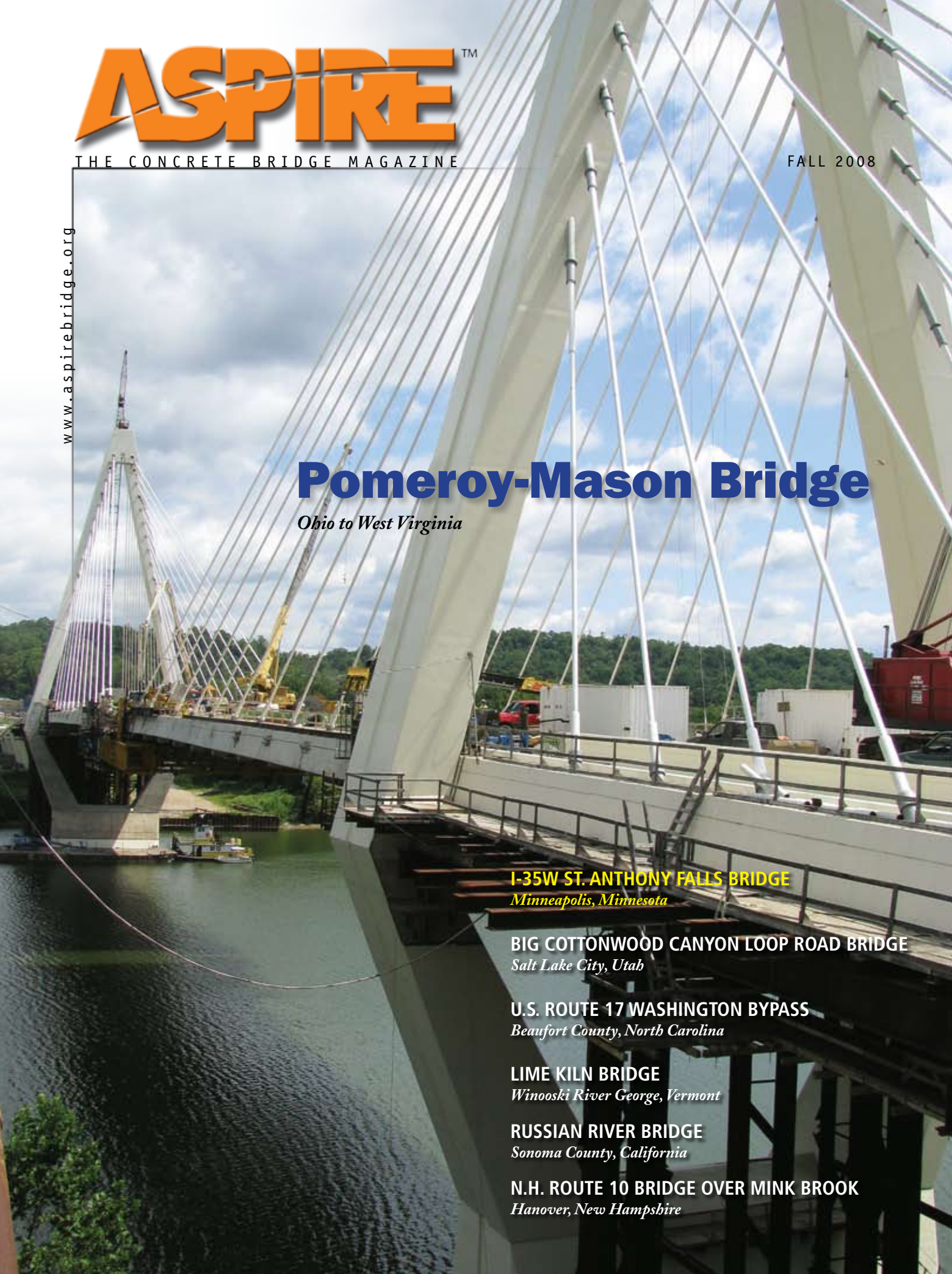

Pomeroy-Mason Bridge

Ohio to West Virginia

I-35W ST. ANTHONY FALLS BRIDGE
Minneapolis, Minnesota

BIG COTTONWOOD CANYON LOOP ROAD BRIDGE
Salt Lake City, Utah

U.S. ROUTE 17 WASHINGTON BYPASS
Beaufort County, North Carolina

LIME KILN BRIDGE
Winooski River George, Vermont

RUSSIAN RIVER BRIDGE
Sonoma County, California

N.H. ROUTE 10 BRIDGE OVER MINK BROOK
Hanover, New Hampshire

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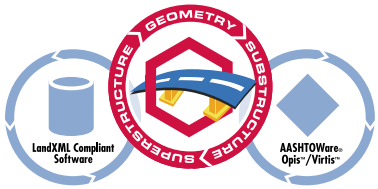

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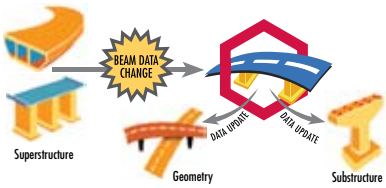

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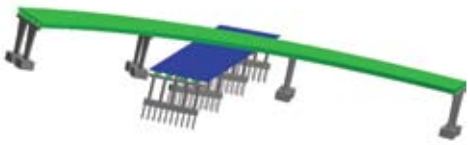

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Photo: Michael Baker Jr. Inc.

Pomeroy-Mason Bridge
Photo: URS.

EDITORIAL

Photo: Ted Lacey Photography.

Bridge Sustainability, Part Four: Environmental Considerations

John S. Dick, *Executive Editor*

This issue of *ASPIRE*™ concludes our year-long effort to define sustainable issues in bridge design and construction. On page 16, Cory Imhoff and David M. Taylor of HDR Inc. discuss the "environmental" aspects of sustainable concrete bridges. In just the small space available, they present an encouraging view of the material's accomplishments, the improvements in recent years, and a bright outlook. This compelling narrative is augmented with examples from recent projects.

Further reinforcing the recyclability of concrete, on page 20, Geoff Crook of the Oregon Department of Transportation describes his state's dramatic process of putting old concrete to new uses. The article showcases for other agencies how to effectively plan for the economical reuse of concrete structures.

This issue's featured design consultant is URS. Rooted in the past with visions to the future, URS sees opportunities in design-build, research, and new technologies. Sustainability and creativity are surfacing in client discussions from the beginning.

Colorado is our featured state. While they have been relying on concrete structures for more than 40 years, most applications were simple bridges with shorter spans. Exceptions began when the unique and exciting segmental bridges were constructed on I-70 in Glenwood Canyon and Vail Pass. Colorado has had standards for precast concrete trapezoidal box beams for some 15 years. More recently, they have produced innovations by extending spans through splicing these sections and even using precast trapezoidal boxes with horizontal curves!

One of the most dramatic stories of concrete bridges in the U.S., the I-35W replacement bridges now in their final stages of construction in Minneapolis, begins on page 24. The bridges will certainly remain a standard-setting project for many years in the accounts of sustainable design and construction. The variety of challenges, including context sensitivity, speed of construction, aesthetic attributes, and durability, are skillfully described in articles by Jay Hietpas of the Minnesota Department of Transportation and by Linda Figg and Alan R. Phipps of FIGG.

The article by M. Myint Lwin of the Federal Highway Administration traces the genesis of the environmental protection movement by the federal government. On page 60, he recounts where it began, setting the stage for the environmental provisions of SAFETEA-LU, which will be reviewed in the next issue of *ASPIRE*.

Finally, environmental sensitivity couldn't be better illustrated than through the project articles featured in this issue. The creative solution being used by Flatiron Constructors for the Washington Bypass in North Carolina (see page 40) greatly minimizes the disturbance of sensitive wetlands. Then, the innovative use of cast-in-place concrete solves a particularly difficult environmental challenge faced by Michael Baker Jr. engineers in Utah's foothills (page 36).

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Cover:
Pomeroy-Mason Bridge,
Ohio to West Virginia
Photo: URS.

READER RESPONSE

I'd like to obtain three copies of your Fall 2007 issue as it contains an article about our Segmental Guideway for the Light Rail in Seattle.

Rachel Quesinberry
PCL
Bellevue, Wash.

I would like to get more information about an article in the Fall 2007 issue "Short Span Spliced Girders Replicate Historic Design." I am looking for a copy of the contract plans.

Luong Tran
Olympia, Wash.
[Ed. Note: References were gladly provided.]

What I like about ASPIRE™ is that it features all types of bridges.

Kevin Nelson
City of Saint Paul Public Works
Saint Paul, Minn.

I do get [ASPIRE] magazine along with a number of our other engineers. It is one of the few that actually gets read and discussed within our structures group.

Jim Deschenes
Michael Baker Jr. Corp.
Salt Lake City, Utah

VHB has made a few presentations and award applications for the bridge (Lime Kiln) but having an article in ASPIRE will be a definite highlight for the project and, I think, of interest to your readers.

Chris Baker
VHB-Vanasse Hangen Brustlin Inc.
Bedford, N.H.

I just wanted to let you know that ASPIRE magazine has aspired, pardon the pun, to more than my expectations. It is really looking good.

Larbi Sennour, PhD, PE
Executive Vice President
The Consulting Engineers Group Inc.
San Antonio, Texas

Congratulations on your ASPIRE Magazine. It is absolutely excellent. The Concrete Bridge Industry has needed this for some time.

Ed Rice
CTS Cement

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

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.

Cory Imhoff is a project manager in HDR's Kansas City office and specializes in the design and construction of concrete and steel bridges.

David M. Taylor is HDR's national director of sustainable transportation solutions.

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 2008/2009

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

October 27-29
PTI Bonded Post-Tensioning Certification Workshop
J.J. Pickle Research Campus, The University of Texas, Austin, Tex.

November 2-6
ACI Fall Convention
Renaissance Grand & America's Center, St. Louis, Mo.

November 3-5
PCI Quality Control & Assurance Personnel Training & Certification Schools and Certified Field Auditor School
Embassy Suites Hotel - Nashville Airport, Nashville, Tenn.

November 10-12
Third North American Conference on the Design and Use of Self-Consolidating Concrete "SCC 2008: Challenges and Barriers to Application"
Marriott O'Hare Hotel, Chicago, Ill.

November 17-19
ASBI 20th Anniversary International Symposium on Concrete Segmental Bridges
Fairmont Hotel atop Nob Hill, San Francisco, Calif.

January 11-15, 2009
Transportation Research Board Annual Meeting
Marriott Wardman Park, Omni Shoreham, and Hilton Washington, Washington, D.C.

February 3-6, 2009
World of Concrete
Las Vegas Convention Center, Las Vegas, Nev.

March 15-19, 2009
ACI Spring Convention
Marriott Rivercenter Hotel, San Antonio, Tex.

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

April 22-26, 2009
PCI Committee Days
Westin Hotel, Chicago, Ill.

May 3-5, 2009
Post-Tensioning Institute Conference and Exhibition
Marriott Downtown Waterfront, Portland, Ore.

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

July 5-9, 2009
AASHTO Subcommittee on Bridges and Structures Annual Meeting
Hilton Riverside Hotel, New Orleans, La.

September 13-16, 2009
PCI National Bridge Conference
Marriott Rivercenter Hotel and Henry B. Gonzales Convention Center, San Antonio, Tex.

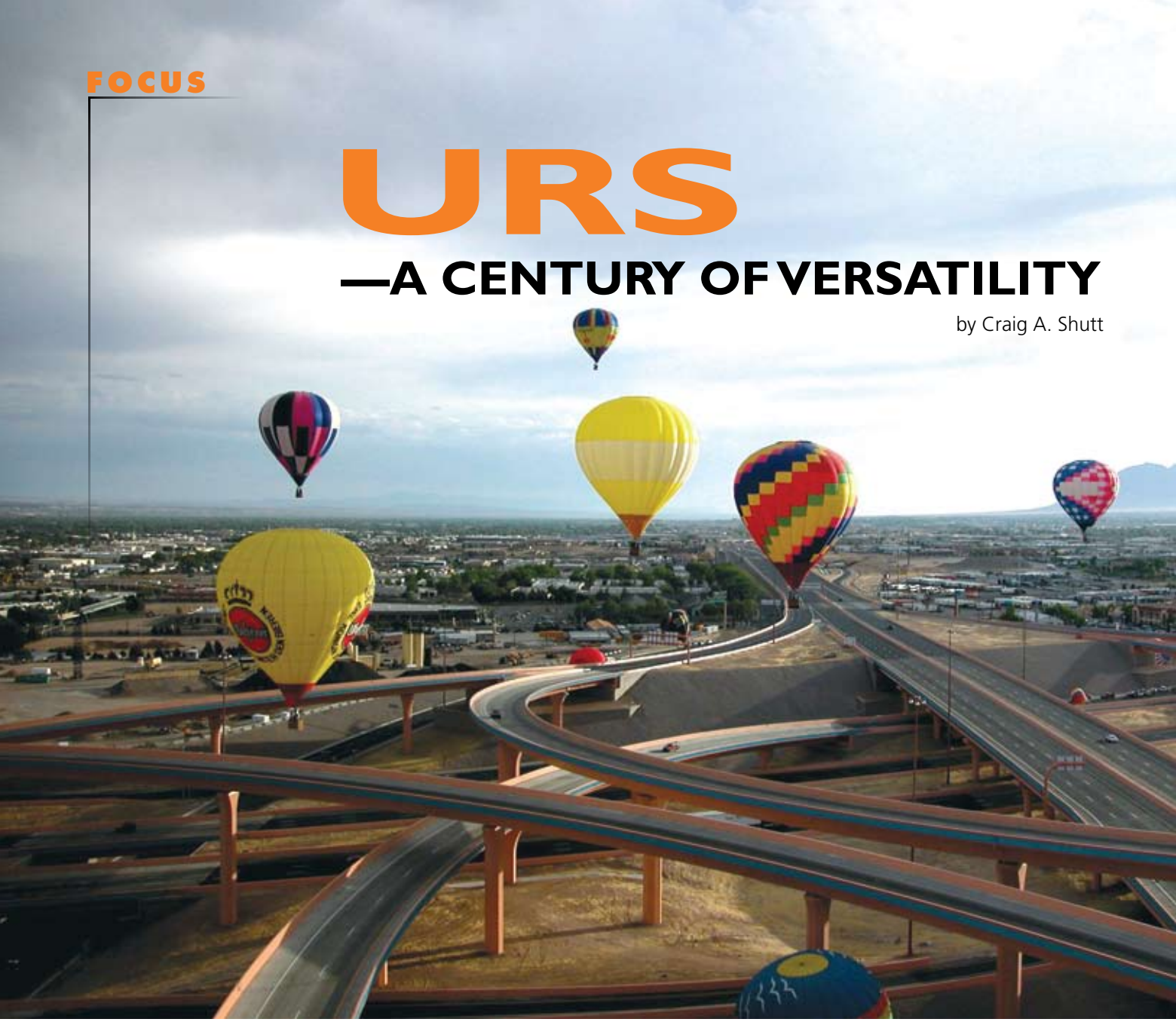
October 25-27, 2009
2009 ASBI 21st Annual Convention
Hilton Hotel, Minneapolis, Minn.

November 8-12, 2009
ACI Fall Convention
Marriott New Orleans, New Orleans, La.

FOCUS

URS —A CENTURY OF VERSATILITY

by Craig A. Shutt



The Big I project in Albuquerque, N.M., is the only full freeway-to-freeway interchange in the state. The $300-million project included 62 bridges and was completed ahead of schedule and within budget

Using expertise gained from a 100-year history with all types of bridges to meet owners' needs

Since URS established its roots more than a century ago, the bridge industry has evolved and adapted to meet new needs and challenges. The company has done likewise, expanding and building on its expertise to secure its position as the largest bridge design firm in the country. While reaching those heights, the firm has tackled projects of every size, every material, and nearly every style, watching trends develop along the way.

"We have a wide experience with every type of bridge and material, including concrete, steel, timber, and even composites," explains Steven L. Stroh, vice president and deputy director of surface transportation for major bridges. "We don't limit ourselves to one bridge type, and we've handled everything from simple-beam bridges to complex, cable-supported structures and even movable bridges; the entire gamut."

That expertise ensures the designers find the best solution to each challenge, adds David Jeakle, senior structural engineer.

'Owners are faced with very severe budgetary limitations today, so they want durable and cost-effective bridge designs.'

"We don't have a particular product we push; we can show strength in a wide variety of structure types." Even so, the designers note, some materials and styles are gaining ground today, due to evolving technologies and owners' focus on changing needs.

"Owners are faced with very severe budgetary limitations today, so they want durable and cost-effective bridge designs," says Stroh. "We have to get creative with our design ideas, including the overall approach to the project." More often today, he notes, that can mean using a design-build delivery method or working with a public/private partnership. "There can be very creative contract mechanisms to stretch the available dollars and move projects forward before the funding actually is available."

Design-Build Growing

For that reason and others, design-build is definitely gaining supporters, he adds. "The industry is going to have to adapt to this delivery method. It's a challenge, but it can offer benefits to owners." Design-build-operate formats, in which the contractor maintains ownership for some time afterward, also are gaining interest. "The industry is still in the early stages of developing these arrangements, and owners are still experimenting with the options, which will continue to play out over the next few years. The jury is still out on which approaches are more effective."

The range of such collaborations—and the unique designs that can be achieved using them—can be seen in two recent examples from the firm's portfolio. The cable-stayed Kap Shui Mun Bridge, with the connecting Ma Wan Viaduct in Hong Kong, China, were delivered via the design-build method. The $250-million structures, part of the Lantau Fixed Crossing system of toll bridges, connect Hong Kong and Kowloon to Hong Kong International Airport.

The double-deck bridge is 4040 ft long, with a cable-stayed steel main span of 1410 ft and side spans featuring post-tensioned concrete box girders that were incrementally launched into their final position. "The combination of materials resulted in a very efficient and cost-effective design that could be completed within the project's stringent time frame of 42 months from notice-to-proceed to turnover of the rail envelope for testing," says Stroh.

The bridge, which provides 164 ft of vertical navigational clearance, provides three vehicle lanes in each direction on the upper deck while the lower deck contains dual rail-transit lines and enclosed roadways for emergency vehicles during tropical storms. It is the world's largest fully enclosed, double-deck cable-stayed bridge that carries auto and heavy commuter rail traffic.

The adjoining viaduct structure is approximately 1630 ft long and consists of twin six-span, cast-in-place on falsework, multi-cell, concrete box girders, with span lengths of 240 to 285 ft. The traffic arrangement replicates the format for the main bridge. The viaduct's

The cable-stayed Kap Shui Mun Bridge in Hong Kong, China, is part of the crossing to the Hong Kong International Airport. The side spans use post-tensioned concrete box girders that were incrementally launched into their final position.

The Arapaho Road Bridge, Addison, Tex. won a PCI 2006 Design Award for Best Bridge with Spans Greater than 135 ft for extensive use of precast, prestressed U-beams and deck panels.

'Some owners have very clear standards for what they want, while others rely on our expertise.'

Precast concrete deck panels are being used to replace the deck on the Chesapeake Bay Bridge.

box-girder superstructure rests on cast-in-place concrete piers that are about 150 ft tall in most areas.

Closer to home, the Big I project, involving the I-25/I-40 interchange in the heart of Albuquerque, N.M., features a unique public/private partnership. State officials used a new risk-management approach to obtain private industry buy-in to the public agency goals for the $300-million project, the only full freeway-to-freeway interchange in the state.

"The schedule was extremely aggressive—requiring all design work to be completed in 16 months, with construction completed in 24 months," says Stroh. The designers had to create a plan that could work for that time frame, including handling traffic issues. The entire project involved 62 bridges, including eight precast concrete, segmental box-girder flyover structures that were the first such designs ever used in the state.

More than 165,000 yd^3 of concrete were used in the total project, which included five miles of freeway reconstruction and 10 miles of new frontage roads paralleling the freeway. The project remains the largest transportation project ever constructed in the state, and it was completed ahead of schedule and within budget.

Designs Depend on Owners

The design approaches considered depend on the owners' comfort level and familiarity with designs, notes Stroh. "Some owners have very clear standards for what they want, while others rely on our expertise," he says. "Some are more sophisticated in their approach, with huge research programs that help them create clear ideas of what works best for them. There are always opportunities to promote new ideas if we can make a case, but some states are more willing to listen and learn new techniques."

Many times, designs are determined by the local landscape, as well as local expertise, in an effort to play to local strengths. Similarly, states often learn new techniques from each other, picking up successful approaches. For the recent expansion of the Paseo Bridge in Kansas City, Mo., for instance, the Missouri Department of Transportation officials used a design-build delivery system in which they allowed any technology already used successfully in other states, even if they were unfamiliar with it.

Owners are trying new techniques—and demanding more creativity from their construction teams—because their needs are more diverse, the designers say. "Owners' needs are changing,"

says Jeakle. "Durability is a major issue during the design phase, and many decisions are being made on that basis alone." They also want accelerated construction schedules, to reduce user costs and improve safety, while also maintaining good aesthetics. And, needless to say, it all must be achieved more cost effectively than ever.

Concrete More Popular

For these reasons, Jeakle sees a trend toward the use of more concrete components, especially precast ones. "We're precasting everything possible today: box girders, edge girders for cable-stayed bridges, pile bent caps, deck panels, footing caps, anything. The main impetus is to minimize disruptions for the traveling public and shorten construction duration."

High-quality precast concrete components can be produced quickly off site while other prep work is underway, he explains, and they can be erected efficiently once they arrive on site. "The goal today is to get in, install the bridge, and get out," he says. "The fast erection also can minimize labor and provide a safer environment. I'd much rather have construction crews working in a well-defined casting yard with set procedures than performing work over water or live traffic."

Creating precast concrete designs puts more demands on the engineers during the design phase, he notes. "We need to know a lot more about the means and methods that contractors use. We have to thoroughly understand the construction process." That can mean discussing key points, such as tolerances, weights, and delivery issues, with contractors early in the design phase, especially for unusual structures.

"The initial design fees may be higher because there's more planning and coordination work to be done early, but that's a small percentage of the overall cost, and that initial planning pays off with reduced construction costs. So there is a net savings in the end."

Speed is a key ingredient in the westbound Chesapeake Bay Bridge project currently underway. The deck on the suspension spans and through-cantilever truss spans is being replaced with match-cast precast concrete deck panels that are post-tensioned together. All the work is being accomplished at night while the westbound traffic is diverted onto the eastbound bridge,

'The goal today is to get in, install the bridge, and get out.'

URS is the engineer of record for the cast-in-place segmental, cable-stayed bridge across the Ohio River between Pomeroy, Ohio and Mason, W.Va.

The Palm Valley Bridge over the St. John River in Florida uses spliced, post-tensioned concrete I-girders for the main span of 290 ft.

'LEED for bridges may be coming in the not-too-distant future.'

A Century of Development

URS Corporation's oldest predecessor company—Greiner Engineering—was founded in 1904. URS was established in 1951 and incorporated as Broadview Research in 1957. Its management developed a growth strategy 10 years later that focused on building the company into a multidisciplinary professional services firm. In 1968, Broadview Research acquired United Research Inc. of Cambridge, Mass. The company's name was changed to United Research Services and finally to URS.

Greiner Engineering established by J. E. Greiner—a noted structural engineer—was acquired by URS in 1996. Greiner Engineering specialized in bridge design and achieved significant success in its early years, and provided URS with a large measure of their bridge design capabilities.

URS has continued its policy of aggressive acquisitions and internal growth and, today, it is organized into three divisions: The URS Division provides all the services required to rehabilitate and expand public infrastructure, including bridges and every type of transportation network, as well as water supply, conveyance, and treatment systems and many types of facilities, such as healthcare complexes, schools, and courthouses. The EG&G Division provides system engineering and technical support services to U.S. federal government agencies, including NASA and the Departments of Defense, Homeland Security, and Treasury. The Washington Division provides engineering, construction, and technical services for environmental management, industrial processes, infrastructure, mining, and power projects.

Overall, URS operates in more than 30 countries with more than 50,000 employees. In the 2008 rankings by *Engineering News-Record*, it was listed as the largest engineering firm in the country and the largest bridge design firm.

Its long and extensive experience in bridge design has allowed URS to maintain a staff of more than 500 structural engineers supported by an equally sized staff of CADD structural draftsmen and technicians. The firm also has more than 35 off-the-shelf and proprietary software-application packages specifically created for designing bridges and structures.

with the bridge reopening at 5 a.m. each day. Included in the work is the installation of a new deck-joint system and an aerodynamic-stabilization system for the main suspension spans.

Design Options Expand

Another tool being used more often is the spliced concrete girder, says Jeakle. "For many of our projects today, owners are requiring at least one segmental alternative be considered during the preliminary phase," he says. "Previously, we'd create one only in special situations. It's becoming very popular." Stroh adds, "It's an economical way to create relatively long spans. We have designed spliced concrete I-girder spans as long as 290 ft, and that's an attractive alternative to steel bridges."

The firm has designed a plethora of segmental concrete and spliced-girder concrete structures across the country, including the segmental box girders used in the Big I interchange in Albuquerque, N.M.; two segmental concrete box-girder bridges designed for the I-35 Crosstown connector project in Minneapolis, Minn.; eight segmental concrete bridges created for the Palmetto/Dolphin Interchange project in Miami, Fla.; and the spliced, post-tensioned concrete, I-girder design, complete with a 290-ft main span, for the Palm Valley Bridge over the St. Johns River in Florida.

"Overall, I do believe we're creating more concrete bridges today than any other kind," says Jeakle. "When we provide steel and concrete alternatives for long-span bridges, the steel alternative may be more competitive

at first, but the owners have recently been selecting the concrete design due to its durability and minimal long-term maintenance. It's challenging to quantify life-cycle costs appropriately versus in-ground costs, but when steel and concrete are reasonably cost competitive, more clients are choosing the concrete alternative. They have the money to build the bridge but not to maintain it. They want something today that is less maintenance intensive."

Encouraging New Ideas

For that reason alone, URS' designers continue to stay abreast of new techniques and new ideas. These come from their suppliers, owners, and their own efforts, which are funneled into their Center of Excellence in Tampa, Fla., where both Stroh and Jeakle work.

URS' designers, for instance, currently are conducting experiments with the Florida Department of Transportation and the University of Southern Florida on double-composite box girders. The girders feature a steel box section with a concrete slab on top, as well as a concrete slab in the negative-moment region on the bottom. The girder currently is being fatigue tested at Florida DOT's structures laboratory in Tallahassee, after which it will be tested for serviceability and ultimate strength.

"We're always looking at new research and new concepts," says Stroh. "We're seeing more places where lightweight concrete, self-consolidating concrete, and high-strength or high-performance concrete can be used effectively. Whenever anyone has something new to talk about, we'll listen."

The designers pick up techniques from all of the company's offices and projects, both domestically and in their international markets. "When we find techniques that are proving successful, we bring them back and pollinate the rest of our organization with them," he says. That distribution ensures that URS remains on the leading edge and keeps it growing no matter what challenges lie ahead.

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

The Isle of Palms Bridge in South Carolina was constructed using the top-down approach to minimize impact to the pristine saltwater marshland and shell fishery.

'Green' Building Becoming Key

"A bridge's impact on the environment also is becoming a more significant factor to consider," says Steven L. Stroh. "We're going to see more of a trend toward green building and using renewable resources wherever possible." A key influence will come from the Leadership in Energy & Environmental Design (LEED) standards established by the U.S. Green Building Council for buildings of all types. Those standards focus on energy savings, water reclamation, recycled and recyclable products, and energy used in the manufacture and transportation of construction materials.

"LEED for bridges may be coming in the not-too-distant future," he says. URS has looked into ways to adapt the standards for bridges, he adds, as more owners are expressing an interest in meeting the goals, at least as they can be translated to bridges. "We have implemented some of the ideas they present." Key aspects may involve salvaging materials from existing bridges and performing rehabilitation that will extend a bridge's service life.

"I expect that some decisions on bridge design will soon be made based on the impact of the structure's overall carbon footprint. Clearly, a lot of work will need to be done for that to happen, but I believe we're headed in that direction now."

The impact on the environment has led to a variety of new erection processes, including girder launchers and other techniques that allow top-down construction to minimize disruptions to the land and waterways below. The firm's work on the Isle of Palms Connector Bridge in Charleston County, S.C., shows one way this is happening. URS led a joint venture that provided complete service, including an environmental impact study, for creation of one of the longest bridges in the state.

The structure provides the only access between the mainland and the barrier island community, and was constructed after the previous access, via an obsolete swing bridge, was destroyed during Hurricane Hugo. The 2-mile-long bridge spans a pristine saltwater marshland and shell fishery. "The prescribed environmental conditions required that we keep construction out of the waterway," Stroh explains.

To achieve that, the design used precast, prestressed concrete I-girders, which were erected using a work bridge that only touched the pilings within the tight environmental requirements. Completed in 1993, it was one of the first projects to use this approach, providing the top-down construction that left the waterway intact. "This solution is being use more today in these situations, as are gantries and other techniques," he says. "It gives us one more tool in our tool box."

Mattaponi River Spliced Girder Bridge,
West Point, Virginia

Lalon Shah Precast Segmental Bridge,
Bangladesh

Hood Canal Floating Bridge,
Seattle, Washington

Bridges for the 21st Century

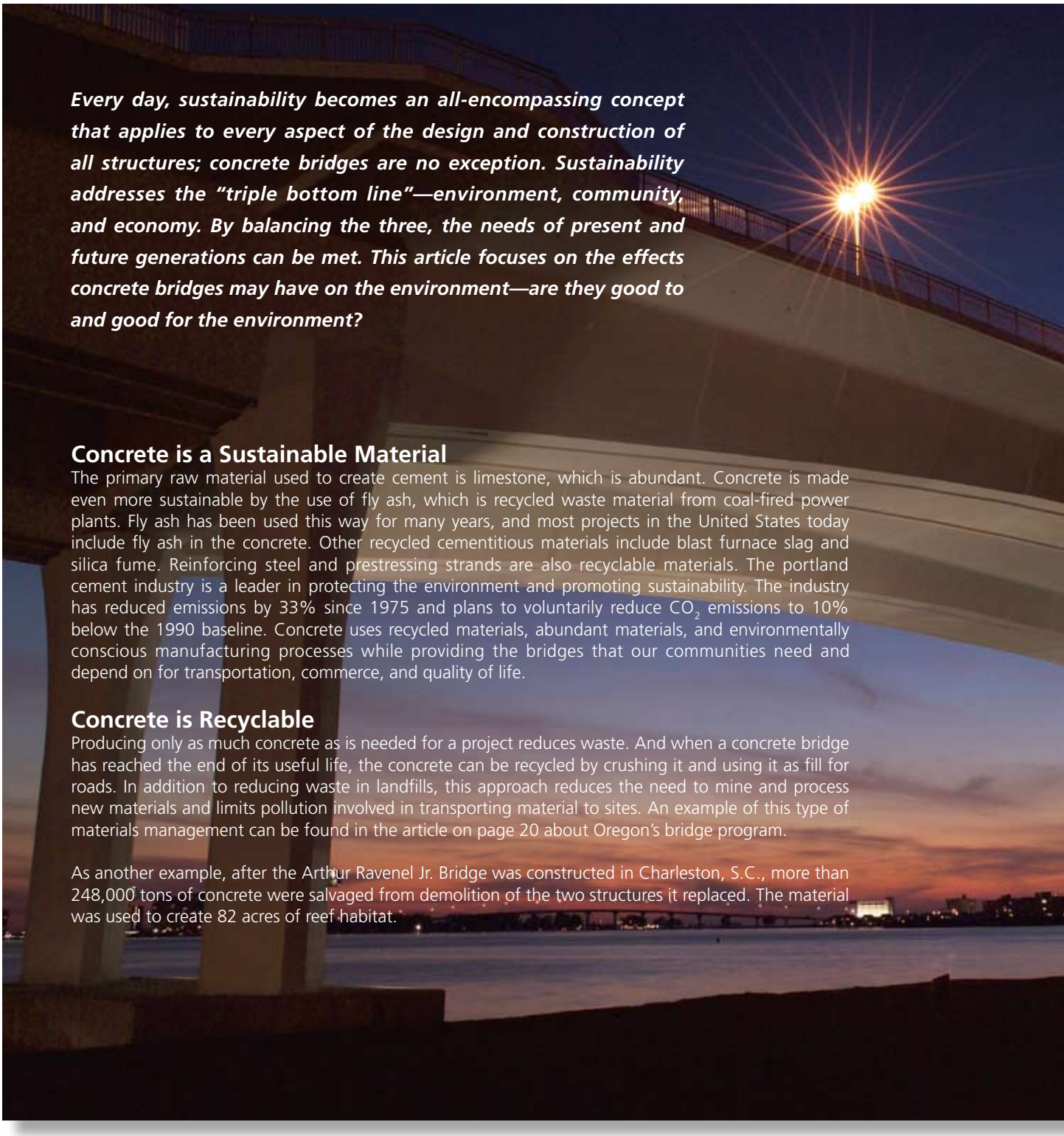
www.pbworld.com

PARSONS BRINCKERHOFF

Sound Transit Guideway Structure,
Seattle, Washington

Arthur Ravenel Jr. (Cooper River)
Cable-Stayed Bridge,
Charleston, South Carolina

ENVIRONMENTAL Benefits of Concrete Bridges



Every day, sustainability becomes an all-encompassing concept that applies to every aspect of the design and construction of all structures; concrete bridges are no exception. Sustainability addresses the "triple bottom line"—environment, community, and economy. By balancing the three, the needs of present and future generations can be met. This article focuses on the effects concrete bridges may have on the environment—are they good to and good for the environment?

Concrete is a Sustainable Material

The primary raw material used to create cement is limestone, which is abundant. Concrete is made even more sustainable by the use of fly ash, which is recycled waste material from coal-fired power plants. Fly ash has been used this way for many years, and most projects in the United States today include fly ash in the concrete. Other recycled cementitious materials include blast furnace slag and silica fume. Reinforcing steel and prestressing strands are also recyclable materials. The portland cement industry is a leader in protecting the environment and promoting sustainability. The industry has reduced emissions by 33% since 1975 and plans to voluntarily reduce CO_2 emissions to 10% below the 1990 baseline. Concrete uses recycled materials, abundant materials, and environmentally conscious manufacturing processes while providing the bridges that our communities need and depend on for transportation, commerce, and quality of life.

Concrete is Recyclable

Producing only as much concrete as is needed for a project reduces waste. And when a concrete bridge has reached the end of its useful life, the concrete can be recycled by crushing it and using it as fill for roads. In addition to reducing waste in landfills, this approach reduces the need to mine and process new materials and limits pollution involved in transporting material to sites. An example of this type of materials management can be found in the article on page 20 about Oregon's bridge program.

As another example, after the Arthur Ravenel Jr. Bridge was constructed in Charleston, S.C., more than 248,000 tons of concrete were salvaged from demolition of the two structures it replaced. The material was used to create 82 acres of reef habitat.

Photo: Scott Dobry.

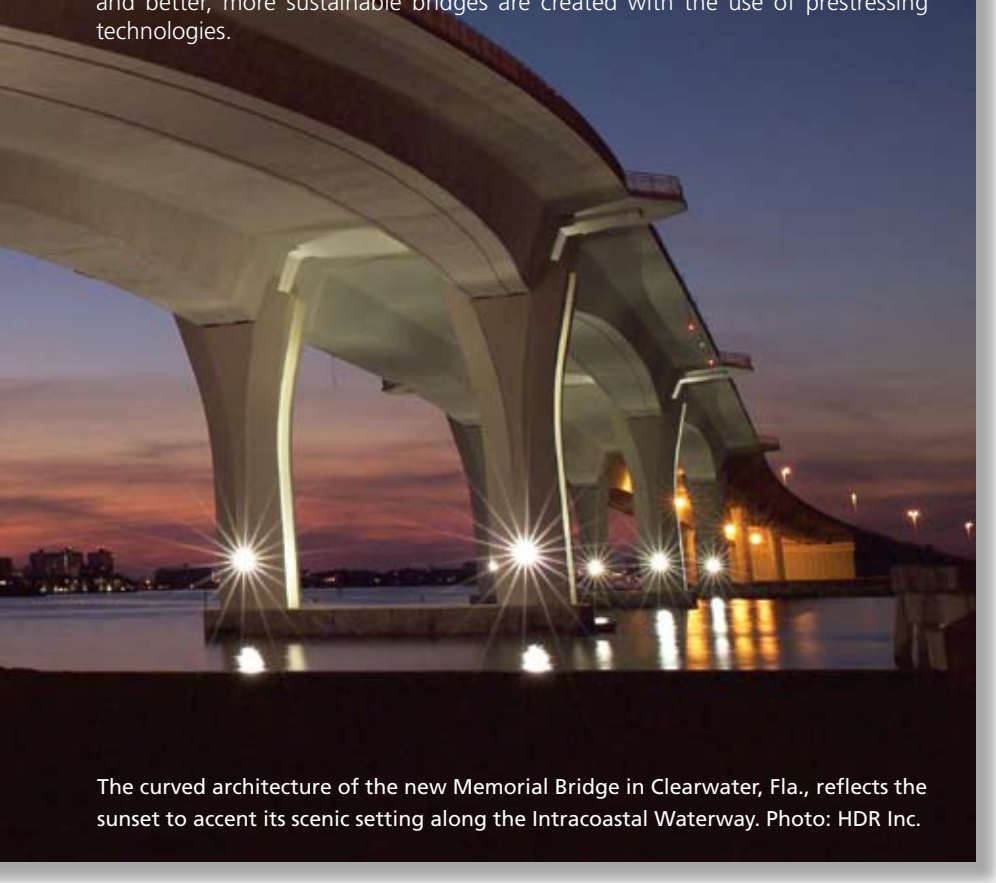
by Cory Imhoff and David M. Taylor, HDR Inc.

Concrete Creates Long-Lasting Structures

Concrete can withstand a wide range of environmental challenges, from temperature extremes to corrosive environments. Concrete is made even stronger through the use of the previously mentioned recycled cementitious materials. As a result, concrete bridges can have service lives approaching or exceeding 100 years.

The concrete industry is continually improving material quality and capabilities, and bridge designers are finding new and innovative ways to use these materials. For example, the advent of high-performance concrete (HPC) has resulted in longer spans, taller towers, better decks, and safer, more durable structures. With these improvements, even more sustainable solutions can be developed.

The use of prestressed concrete is a longstanding practice in the bridge industry. This technology improves the performance and longevity of concrete bridges by maximizing what concrete does best—resisting loads via compression. Pre-tensioned and post-tensioned concrete bridges are extremely resilient to deterioration, even when subjected to the harshest environments. Longer spans and better, more sustainable bridges are created with the use of prestressing technologies.



The curved architecture of the new Memorial Bridge in Clearwater, Fla., reflects the sunset to accent its scenic setting along the Intracoastal Waterway. Photo: HDR Inc.

Concrete from the Arthur Ravenel Jr. Bridge in Charleston, S.C., was given new life as artificial reef habitat. Photo: HDR Inc.

Fiber reinforced plastic (FRP) reinforcement is becoming more available and brings the potential to further enhance the performance of concrete bridges. Trading the traditional steel reinforcement bar for an FRP bar eliminates the expansion that comes with corrosion of an embedded steel reinforcing bar. This is the most common form of distress and deterioration observed in reinforced concrete bridges. As the use of FRP bars increases, the reputation of concrete as an already great sustainable material is sure to grow even more.

From the outset, the concrete industry, including concrete producers, designers, contractors, and precasters, has continually aspired to find new and better ways to use and improve this material. From plain concrete to the development of reinforced concrete to the use of HPC with prestressing and FRP bars, the efforts continue. More advancement is sure to come and will further improve the longevity and sustainability of concrete bridges. For example, the Massachusetts Institute of Technology has been applying nanotechnology to concrete to determine whether it's possible to both improve concrete performance and reduce carbon-dioxide emissions during its production.

The use of 183-ft-long precast, prestressed concrete beams across the Union Pacific Railroad tracks eliminated the need for intermediate bents. A similar design was used for the 162.5-ft-long Alder Creek Bridge to eliminate foundations in the water. Photo: HDR Inc.

Improvements in Technology Enhance Environmental Mitigation Efforts

Minimizing environmental impacts during construction is nothing new. What is new is that innovations in concrete are making this easier to accomplish. Issues such as minimizing stream disruption and wetland displacement, accommodating seasonal migratory patterns, and reducing side slope erosion are all possible with concrete bridge structures.

Furthermore, concrete makes it possible to facilitate accelerated construction; thereby, reducing greenhouse gas emissions caused by traffic delays and construction equipment operation. The Federal Highway Administration's Highways for LIFE program supports this initiative by contributing funds for accelerated construction projects. Prefabricated concrete components are the heart of the accelerated bridge construction trend as illustrated by the following examples.

One of the projects in the Oregon Transportation Investment Act III State Bridge Delivery Program involved U.S. 26 at Alder Creek. The contractor used 162.5-ft-long beams to create a single-span structure over the creek. This design approach eliminated the need for foundations in the water, causing less disruption to the natural setting. Using the big-beam technology also reduced the time needed for construction, speeding up the return to normal traffic operations. By reducing environmental impacts and saving time and money, this use of a concrete design addressed all components of the triple bottom line.

For the project to replace the 24th Street Bridge over I-80/I-90 in Council Bluffs, the Iowa Department of Transportation had to consider the effect lengthy closures would have on the surrounding business corridor. Retail, casino, lodging, and recreational businesses in the area depend on traffic entering and exiting via the 24th Street interchange. A precast concrete deck system accelerated the schedule and made it possible to stage construction to allow at least three lanes of traffic to remain open at all times. As a result, the community will benefit from reduced impacts to traffic and the economic well-being of the local businesses.

Concrete is a Compatible Material

While much attention goes to the natural environment, the built, historic, and cultural environments must be considered. Compatibility may be expressed in terms of aesthetic value, community acceptance, or historical significance. Some concrete bridges are viewed as landmarks in their communities and include architectural ornamentation that adds drama and interest. Advancing technologies create new opportunities for concrete bridges to add to the built and historic fabric of our communities.

The new Clearwater Memorial Bridge in Florida employs a curved architecture to reflect the sunset from the structure and accent its setting. Additionally, the chosen alignment through downtown allowed efficient traffic movement while supporting continued economic development—again providing social and economic sustainability benefits.

Summary

Bridge designers face a new set of parameters today. Beyond the question of economics and functionality, they must ask themselves whether their designs will be long-lasting; do they help protect the natural environment; can they complement the built and cultural environments; and can they help reduce the carbon footprint?

When it comes to concrete bridges, the answer to these questions is "Yes."

New Life in Old Material

by Geoff Crook, Oregon Department of Transportation

Concrete Reuse and Recycling on Oregon's Bridge Program

With a 10-year duration, involving 365 bridges, and costing $1.3 billion, the Oregon Transportation Investment Act (OTIA) III State Bridge Delivery Program is Oregon's largest infrastructure project in five decades.

The massive scope of the bridge program has given the Oregon Department of Transportation (ODOT) an opportunity to make the three "Rs" of reduce, reuse, and recycle standard practices in bridge and highway construction. In 2005, the agency and the Oregon Department of Environmental Quality worked to develop a set of materials performance standards for use on the bridge program. These standards direct contractors to handle construction waste, including concrete debris, to achieve the "highest and best end use," preventing waste generation and minimizing disposal in landfills.

According to the Construction Materials Recycling Association, more than 140 million tons of concrete are recycled every year in the United States. ODOT is eager to contribute to this process. Halfway through the bridge program, we already have many successes to report.

Recycling: Making the Old New Again

For contractors working on the bridge program, the benefits of recycling are many, such as the avoidance of hauling costs and landfill fees. For local communities, recycling on site or nearby means less noise and truck traffic and better air quality. In addition, recycled or reused concrete conserves land and aggregate resources.

Contractor Staton Cos. helped ODOT set the standard for success in reuse and recycling early in the program when it demolished the Burlington Northern Santa Fe railroad bridge in Madras and the California Avenue and Green Springs Drive Bridges in Klamath Falls, both on U.S. 97. On these projects, Staton salvaged 100% of the concrete from the demolitions.

In Madras, almost 580 tons of concrete were delivered to Cinder Butte Rock in Redmond for crushing and reuse. In Klamath Falls, the company was able to set the bar even higher by recycling the material on site. It removed 7227 tons of concrete from two bridges and crushed it into 1-in. rubble. Five hundred tons of

On the OTIA III State Bridge Delivery Program, ODOT took an opportunity to capitalize on the program's scope and emphasized environmental consciousness. Because many of Oregon's bridges are built using precast concrete, the potential for recycling and reuse is tremendous. All Photos: ODOT.

this gravel were then reused as fill and to pave an approach road.

On a separate project near Cottage Grove, Capital Concrete Construction matched Staton's achievement by recycling all the concrete from a demolished bridge into new embankments.

To give an idea of the savings involved in avoiding disposal costs, Hamilton Construction, which rebuilt two bridges south of Portland, estimates 3000 tons of bridge demolition materials, including 1000 yd^3 of concrete, were either reused (15%) or recycled (85%), resulting in an estimated savings of $120,000 in landfill fees.

When they can't use the rubble they generate themselves, contractors recycle by collaborating. Holm II Inc. and its subcontractor, Goodfellow Bros. Inc., were demolishing and rebuilding an overpass above I-5 south of Eugene that would leave them with roughly 30,000 yd^3 of rubble. A short distance away, Ross Bros. & Co. needed nearly 40,000 yd^3 of embankment materials to use beneath four bridges and to widen an I-5 interchange. Working together, the three independent contractors agreed to exchange the aggregate free of charge. Goodfellow Bros. avoided disposal costs, and Ross Bros. avoided purchasing fill.

'More than 140 million tons of concrete are recycled every year in the United States.'

The collaboration was made possible by ODOT's commitment to the design-build method of construction, which gives contractors the flexibility to propose creative solutions that address current needs, future needs, or both. On a tightly packed construction schedule, this sort of collaboration keeps everyone on time and within budget. In addition to keeping the rubble out of a landfill, Goodfellow Bros. and Ross Bros. saved money on transportation costs. Because the work sites were less than two miles apart, fuel costs and pollution were decreased significantly.

ODOT saved money through this initiative as well. Every construction contract has a clause that allows for rising fuel prices. Reusing the waste material and transporting it over a shorter distance reduced the amount of money spent on diesel fuel, making the contract price more stable and helping to stay under budget.

Upping the Ante: Reuse of Bridge Beams

While we strive to keep concrete out of landfills whenever possible, the reuse of intact bridge beams saves even more time and money than recycling by avoiding the need to crush the aggregate, as well as cast new beams. Reuse requires creativity and

ODOT has been proactively addressing Oregon's aging bridges for more than six years. Oregonians have not seen an investment of this magnitude in highway and bridge construction in 50 years, since the state's interstate freeway system was built in the 1950s and 1960s.

Of the 365 bridges in the program, 119 are currently under construction, and another 76 have been completed and opened to traffic.

ODOT's 1.3 billion OTIA III State Bridge Delivery Program is replacing or repairing hundreds of bridges like this one to ensure that motorists and freight reach their destinations quickly and safely.

Hundreds of tons of epoxy-coated reinforcement were used for the Green Springs Drive Overpass on U.S. 97 in Klamath Falls, Ore. When the original structures were demolished, the contractor recycled 100% of the concrete.

forethought that demonstrate ODOT's and contractors' joint commitment to sustainability as more than just an economic decision.

Near Creswell, a manager from Goshen Forest Products noticed construction taking place near his lumber mill, so he approached the superintendent for the contractor, Holm II, about needing some bridge beams for his lumberyard. After construction was complete, rather than demolishing the beams and grinding the concrete to rubble, Holm II decided to take the beams out in pieces and deliver them to the mill.

The six 105-ft-long beams and bridge deck equate to approximately 214 yd^3 of concrete that will be diverted from local disposal or recycling facilities. The mill will reuse the beams in their entirety as foundations for supporting harvested logs.

In other cases, strategic planning leads to thoughtful reuse of bridge beams. A standard plan for keeping traffic moving when replacing an interstate highway bridge is to install a temporary detour structure. Because CH2M Hill was both the designer and the builder of 10 replacement bridges on I-5 between Eugene and Roseburg, it was able to design an early detour structure so that most of its 88 prestressed concrete box beams could be reused on three subsequent detour bridges. Because each beam is worth approximately $6300, reusing 80 of them reduced the cost of the contractor's bid by about $500,000.

As the cost of quarrying and casting concrete beams continues to rise, it makes increasing sense to preserve them for future use even when no immediate need exists. Recently, ODOT and Hamilton Construction collaborated to salvage 56 precast, prestressed box beams, each 115 ft long, from a detour bridge near Eugene and deliver them to a storage lot on the other side of the city. With five years of bridge program construction ahead, we are confident there will be a future need for these salvaged beams. And when we supply them to contractors, the state will save an estimated $1 million off the contracts in which they're reused.

On the I-5, Clarks Branch to Tunnel Mill Race project, contractors demolished the River Drive overpass and salvaged 30,000 yd^3 of rubble, which was reused as aggregate on another OTIA III State Bridge Delivery Program project.

Good planning on the bridge program has allowed contractors to reuse precast concrete beams from detour structures. On a project near Eugene, 56 precast, prestressed box beams were salvaged from a detour structure and will be used on later projects.

On the California Avenue overcrossing project, Staton Companies, an ODOT contractor, recycled 100% of the concrete from the demolitions.

Next Steps

In 2008, ODOT will include special provisions in construction contracts to guide and better track waste management activities. Construction companies will be asked to forecast the percentage of materials they anticipate reusing or recycling on their bridge projects and submit quarterly reports about their actual progress.

Targets have been established for various material types, upward of 80% for concrete, depending on the area of the state. To assist contractors, ODOT has developed template reuse and recycling plans, reporting forms, and a statewide recycling directory and guidebook.

With these new tools, ODOT will be able to collect complete and accurate information about what is feasible. These data will provide information about our business practices and help us set realistic goals for the future. We also want to highlight the good work that contractors are doing on behalf of the environment in the course of bridge repairs and replacements.

The economics of recycling concrete are more than convincing. Crushed recycled aggregate saves money and landfill space. Reused beams recover the value of the raw materials, as well as the labor that goes into their long-lasting construction. And perhaps most compelling of all are the benefits for ourselves and future generations as we lessen our demand for non-renewable natural resources.

Geoff Crook is the environmental program manager for the Oregon Department of Transportation's OTIA III State Bridge Delivery Program.

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

I-35W St. Anthony Falls Bridge

Planning the Replacement

by Jay Hietpas, Minnesota Department of Transportation

In a little over 1 year since the tragic collapse of the I-35W Bridge on August 1, 2007, two new river crossing bridges and their approaches will be completed this year. Although the contract requires that the construction be completed by December 24, 2008, the project was opened to traffic on September 18. The rapid replacement of the I-35W over the Mississippi River once again re-established the vital transportation link to destinations such as downtown Minneapolis and the University of Minnesota.

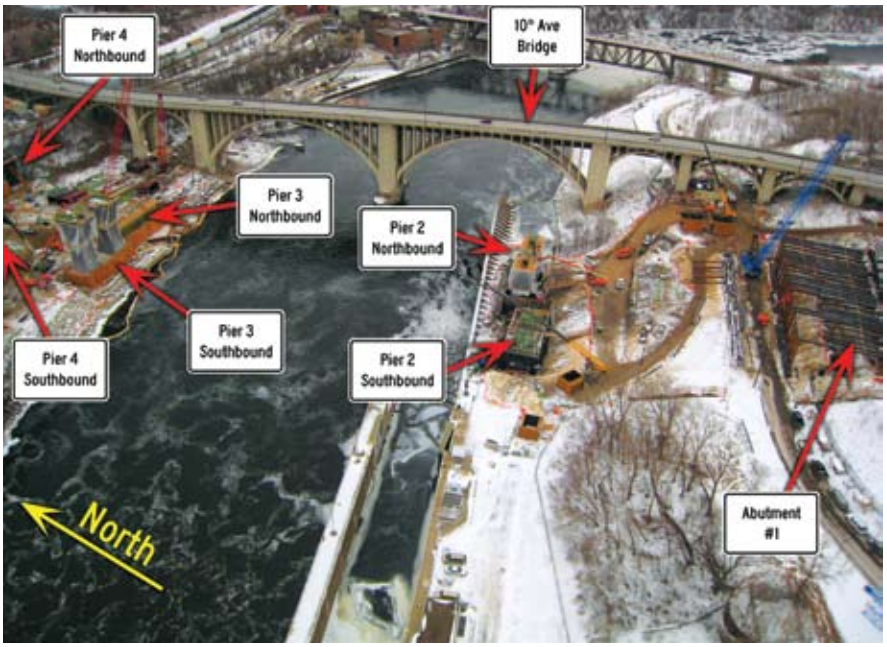
The 140,000 vehicles that used the previous eight-lane structure had to find alternative routes. The impact resulted in additional congestion on the local and regional road system, with a daily road user cost of $400,000. This impact value does not include the economic impact resulting from the closure of I-35W.

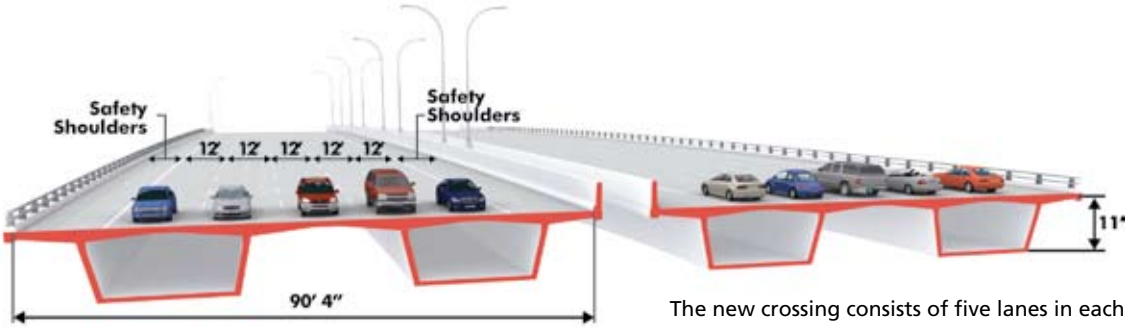
Moving forward with the rebuilding effort was much more complex than simply replacing the structure. The roadway approaches did not meet current capacity or design standards. A large portion of the project site contained contaminated materials from past industrial uses. Stakeholders and citizen groups expressed differing views on the visual quality approach to the project. Site conditions included an Army Corps of Engineers lock and dam system, limited right-of-way to expand capacity, six railroad tracks under the structure, major underground utilities, and dealing with the removal of the collapsed structure.

By working closely with stakeholders within days of the collapse, the Minnesota Department of Transportation (Mn/DOT) rapidly defined the scope of the project. The new I-35W bridge was to be reconstructed as two new river bridges, each built to accommodate five lanes of traffic in each direction for a total of 10 lanes plus standard-width shoulders. Project elements also included improving the geometric deficiencies in the corridor, reconstructing the ramps at the interchanges on each side of the bridge, and accommodating a future light-rail transit system on the new structure.

Schedule Prior to Contract Award	
August 1	Bridge 9340 collapses
August 4	Mn/DOT issues RFQ
August 8	Five teams respond to RFQ
August 8	Mn/DOT short-lists five teams
August 23	Mn/DOT issues RFP
September 14	Technical proposals due
September 18	Price proposals due
September 18	Mn/DOT interviews design-build teams
September 19	Project letting
October 8	Contract executed

The process was expedited in order to begin construction prior to the winter season. Photo: Mn/DOT.





The new crossing consists of five lanes in each direction with standard width shoulders, and can accommodate a future light-rail transit system. Rendering: © FIGG.

Design-Build Process

Within days of the collapse, Mn/DOT began the process of rebuilding this vital transportation link. To expedite the project delivery, Mn/DOT chose to use design-build over a traditional design-bid-build approach. Design-build allowed for speed of project delivery, design flexibility, and construction innovation. Mn/DOT allowed design-build teams to choose from seven allowable bridge types, propose geometric solutions that address current substandard elements, and develop the visual quality components to the project.

The statutes require a two-step procurement process for design-build projects.

Minnesota state statutes require a two-step procurement process for design-build projects. The first step involves short-listing the most highly qualified teams in response to a Request for Qualifications (RFQ). In step two, the short-listed teams submit technical and price proposals in response to a Request for Proposals (RFP). The price proposals remain sealed until the scoring of the technical proposals is complete.

The design-build process was expedited in order to begin construction prior to the winter season. On a typical Mn/DOT design-build project, the procurement timeline is typically 6 to 12 months. On the I-35W project, letting of the contract occurred on September 19, only 50 days after the collapse.

Due to the expedited nature of this procurement process, Mn/DOT had extensive communication with the design-build teams during the development of the design-build RFP. Daily one-on-one meetings were conducted with the design-build teams. These meetings allowed design-build teams to receive real-time updates on scope changes and ask questions about the project. Mn/DOT also allowed each team a weekly one-hour site visit. In addition, each design-build team established a single point of contact that had 24-hour access to Mn/DOT's design-build communication manager.

In addition to extensive communication with the design-build teams, Mn/DOT had extensive contacts with regulatory agencies, utilities, and impacted stakeholders during the procurement process. Mn/DOT secured eight out of ten regulatory permits prior to letting. The other two permits were the responsibility of the contractor. By actively involving all the interested design-build teams in the utility coordination process before letting, a major gas relocation line could be relocated concurrently with the design-build procurement process. Mn/DOT established a Visual Quality Advisory Team (VQAT) to define the aesthetic framework for the project. Design-build teams met with the VQAT on several occasions to develop their aesthetic approach for incorporation into their proposals. Coordination with the railroad allowed for the removal of five railroad tracks and shortening of the bridge.

As the RFP was being developed, Mn/DOT used the goals of the project to define how the design-build proposals were going to be evaluated. The goals of the project included constructing a project safely, producing a high-quality project, completing construction by the end of 2008 within the allowable budget, allowing public input into the design and visual quality aspects of the project, and addressing stakeholder concerns throughout the project.

On a traditional process, the public input and visual quality aspects would have been addressed prior to letting. On this project, these processes occurred simultaneously with the project. Many stakeholders were concerned that the public would not have adequate input into the design features of the bridge. To address these concerns, Mn/DOT emphasized design flexibility to the design-build teams. The proposed approach was to not only obtain public input, but also provide a mechanism to incorporate public feedback into the design and construction process.

During the proposal preparation process, Mn/DOT allowed each team to submit up to eight Alternative Technical Concepts (ATC). An ATC allows a team to submit an equal or greater value change to the RFP. To expedite the Mn/DOT review times, ATCs were limited to the structural and foundation sections of the RFP. Each ATC was kept confidential and not shared between the competing teams.

Design-build teams were allowed to submit a 20-page response to the RFP. In addition, 10 pages were allowed for design plans and 10 pages were allowed for resumes. Four teams submitted proposals for the project.

Mn/DOT had extensive communication with the design-build teams and stakeholders.

The winning bid included a proven approach to visual quality that allowed the community to select several visual components of the bridge and approaches. Rendering: © FIGG.

Scoring Method

Technical proposals were scored by a six-person evaluation panel. The average score of the six scoring members for each team became the official technical score. In addition to the six scoring members, 21 other individuals assisted with the evaluation process. The evaluation group included Mn/DOT, City of Minneapolis, the National Park Service, the Federal Highway Administration, the Association of General Contractors, and the Minnesota Department of Administration.

Evaluation Criteria	Points
Experience of key individuals on similar projects	20
Design and construction relationships	10
Safety approach	10
Construction quality approach	10
Visual quality enhancements	10
Visual quality approach with stakeholders	10
Roadway design elements	10
Life-cycle structural design approach	5
Public involvement	15

In addition to the technical score, the price and time components were also evaluated. In accordance with state statutes, the selection formula consisted of cost plus time, divided by technical score. Design-build teams were allowed to bid between 337 and 437 calendar days to complete the project. The number of days was multiplied by $200,000 (half of the daily road user cost) and added to the price proposal. This value was then divided by the technical score. The lowest adjusted score was determined as the best value.

The technical scoring was completed before the price and time components for the project were known. The technical scores ranged from 55.98 to 91.47, the cost ranged from $177 to $234 million, and the time components ranged from 367 to 437 days. The contract was awarded to Flatiron-Manson, who had the technical score of 91.47, a price of $234 million, and a time component of 437 days.

Although the Flatiron-Manson team had the highest cost and longest time, their technical approach and score was substantially higher than the other proposing teams. The Flatiron-Manson team eliminated the six geometric deficiencies, accommodated future infrastructure needs in the area, and provided structural benefits that reduced future maintenance and reconstruction costs. The Flatiron-Manson approach also included a proven approach to visual quality that allowed the community to select several visual components of the bridge and approaches.

This project was a major engineering challenge for all design-build teams. With limited access to the project site due to the collapsed structure, the design-build teams had to rely on limited subsurface investigation data. The project also presented major cost and schedule risks due to utility relocations, unknown site conditions, and contaminated materials. Due to these risks, construction could have easily extended into the summer of 2009.

Incentives

To ensure that the project would likely be completed in 2008, Mn/DOT offered incentives to complete the project on time. If the job was completed on time and the contractor waived all outstanding claims, a $7 million incentive would be paid to the contractor. The contract also allows early completion incentives up to an additional $20 million if the project is completed 100 days early. This incentive value is calculated based on half of the roadway user cost impacts to the project.

Jay Hietpas is design-build program manager and I-35W design-build project office manager with the Minnesota Department of Transportation Office of Construction & Innovative Contracting.

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

Build the Best. **Be the Best.**

FLATIRON

Less than one year after the tragic collapse of the I-35W Bridge, employees cheer as a barge-mounted crane lifts the final concrete segment into place on the main span of the new I-35W Bridge. The Flatiron-Manson joint venture expects to open the new bridge to traffic three months ahead of schedule. The bridge took just eleven months to build, but the experience will undoubtedly last a lifetime. Best moments happen all the time in people's lives. Here at Flatiron, we're proud to make some of them possible.

www.**flatironcorp**.com

A HOCHTIEF Company

I-35W ST. ANTHONY FALLS BRIDGE

SOARING ACROSS THE

A new crossing with sustainability, redundancy, and fast construction.

The side spans over land were cast-in-place on falsework using the same box girder shape as the main span. Photo: Mn/DOT.

Carefully planned design and construction strategies by the Flatiron-Manson Joint Venture, with FIGG as designer, focused on a new I-35W Mississippi River crossing with sustainability, redundancy, and fast construction. This modern concrete bridge for the future maximized the use of local labor, local materials, and multiple concurrent construction operations to optimize construction through the Minneapolis winter.

The Minnesota Department of Transportation (Mn/DOT) set requirements and expectations centered on a bridge life beyond 100 years. Mn/DOT's vision allowed innovation and enhancements to traditional quality standards. The mission was to design and build a 10-lane wide, transit-ready, interstate bridge over the Mississippi River, with a 504-ft-long main span, in 15 months. The opening on September 18 meant a design-build delivery in 11 months while achieving the quality standards set for a long bridge life.

Eight long-line casting beds were set up for the main span segments. Photo: Mn/DOT.

The bridge consists of twin 1223-ft-long concrete structures, each 90 ft 4 in. wide using two box girders per structure. In addition to crossing the river, there is an overpass at 2nd Street, a crossing of an historic stone bridge abutment wall, a railroad track, hazardous materials site, multiple underground and overhead utilities, local street crossings, and National Park Service land. Shortly after the October 8, 2007, Notice-to-Proceed,

profile

I-35W ST. ANTHONY FALLS BRIDGE / MINNEAPOLIS, MINN.

CONTRACTOR: Flatiron-Manson (a joint venture of Flatiron Construction Corporation, Longmont, Colo., and Manson Construction Company, Seattle, Wash.)

BRIDGE DESIGNER: FIGG, Tallahassee, Fla.

CONCRETE SUPPLIER: Cemstone Products Co., Mendota Heights, Minn.

POST-TENSIONING SUPPLIER: DSI, Bolingbrook, Ill.

FORMWORK SUPPLIER: EFCO, Avondale, Ariz. (Segments and Piers 2 and 3); Symons, Bloomington, Minn. (Pier 4)

Main span segments were precast while side spans were cast-in-place.

After precasting, the 120 main span segments were moved to a riverside staging area prior to transporting by barge to the bridge site.
Photo: © FIGG.

MISSISSIPPI RIVER

by Linda Figg and Alan R. Phipps, FIGG

a special design meeting, known as a FIGG Bridge Design Charette™, was held with 88 people from local communities, so they could choose various design features. They chose a curved pier shape, open railing style for vistas of the river, white bridge color, aesthetic lighting of the bridge using LEDs, and local stone abutment walls. This community involvement took place concurrently with some of the design in order to begin construction as soon as possible. Construction could only begin after detailed design plans had received the official "Released for Construction" approval, and long lead-time items had to be addressed early so that all scheduling could be optimized.

Building a Strong Foundation

Construction of the bridge began on November 1, 2007, (Day 17 from start of construction) with the drilling of a test/demonstration shaft for the foundations. The team selected 7-ft- and 8-ft-diameter drilled shafts for the main bridge pier foundations. The larger shaft diameters reduced the number of construction operations necessary at each foundation and worked within the site constraints. After successful completion of the test shaft on Thanksgiving Day, four drill rigs went to work at multiple locations. A total of 40 shafts up to 95-ft deep and socketed into rock support the main bridge piers. An additional sixty-nine 4-ft-diameter shafts up to 27-ft long support the north abutment and the 2nd Street overpass, north of the main bridge. To speed placement and achieve a monolithic, high-quality concrete, self-consolidating concrete (SCC) was used in the shafts. The SCC mix, supplied by Cemstone Products, obtained better than expected strengths. The design called for 5000 psi compressive strength concrete. Actual strengths averaged 8360 psi at 28 days. At 56 days, strengths of 9890

Rolling structures moved along the long-line casting beds to provide a heated work and curing environment during the winter months.
Photo: © FIGG.

SEGMENTAL / MINNESOTA DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: Twin 1223-ft-long box girder bridges

REINFORCEMENT: Gerdau Ameristeel, West Allis, Wisc.

DISK BEARINGS: R.J. Watson, Amherst, N.Y.

EXPANSION JOINTS: D.S. Brown, Andover, Minn.

STRUCTURAL COMPONENTS: 139 drilled shafts, four main pier footings, eight columns, and four-parallel box girders for the superstructures with precast segments for the main spans and cast-in-place construction for the side spans

psi were achieved. The last drilled shaft was completed on January 12, 2008, (Day 89).

Mass Concrete Footings and Piers

The first mass concrete footing placement for the main piers occurred on January 15, 2008, (Day 92) and the final footing was completed on February 25, 2008, (Day 133). Each rectangular footing supports two 70-ft-tall concrete piers and two concrete box girders. The four main pier footings vary in length from 34 ft to 43 ft, in width from 81 ft to 112 ft, and in depth from 13 ft to 16 ft. The footings were designed to span sections of the remaining unused foundation of the old bridge, large drainage tunnels, and other existing utilities. These mass concrete footing placements were made with careful control of curing temperatures and thermal gradients using embedded cooling pipes and a custom concrete mix design.

The curved 70-ft-tall piers were cast beginning on January 23, 2008, (Day 100) with all piers of the bridge cast by March 14, 2008, (Day 151). Pier formwork was made for each pier so that casting could take place concurrently. The sculpted pier shape had been selected at the design charette and is discussed in more detail in the Winter 2008 Issue of *ASPIRE*.™ The sweeping curves of the piers were developed to complement the parabolic curves of the variable depth concrete superstructure. In the longitudinal direction, each pier has a 26-ft-wide base, curves in to an 8-ft width at mid height and then outward to 31 ft 8 in. at the top. The concrete placement of the pier columns followed a similar process as the footings. The superstructure rests on large disc bearings at the top of the piers. Each main pier has three bearings; each bearing has a service load capacity of 5800 kips. The shape of the pier includes concrete extensions to protect and conceal the bearings.

Precast Segments for the Main Span

The main span superstructure segments were prefabricated using the long-line casting method. Eight casting beds, each approximately 250-ft long, were set up on the existing I-35W roadway on the south side of the project. The 120 segments were precast and then trucked and stored at the adjacent river staging area. Once the formwork was removed from the casting site, the new I-35W roadway was built with alignment geometry enhancements. The close proximity of the precasting operation provided good access to the river and centralized, direct coordination between construction crews and the management and engineering teams. Precast segments vary in length from 13.5 ft to 16.5 ft, vary in depth from 25 ft at the pier to 11 ft at midspan, and weigh from 380 kips to 216 kips. As with the piers, the use of multiple segment beds allowed segment production to proceed quickly; all eight beds were in production simultaneously. Concrete for the first precast segment was placed on January 30, 2008, (Day 107). Rolling heated structures moved with the segment casting to provide a reliable work and curing environment during the cold winter months. Concrete was placed even on the coldest day, February 10, 2008, when the high temperature was -4° F and the low was -14° F, with a wind chill of -36° F. The final concrete segment was cast on June 6, 2008—128 days after precasting began.

The segments were lifted into place using a 600-ton, barge-mounted crane. Photo: Mn/DOT.

Concurrent Casting of Side Spans

While the main span superstructure segments were being precast, the adjacent side spans over land were being cast-in-place on falsework. Using the same box girder shape, the formwork was installed. Then all reinforcing and longitudinal and transverse post-tensioning was placed. These spans were scheduled for an early spring concrete casting, which began on April 2, 2008, (Day 170) and was completed by the end of May. The entire bridge deck is transversely post-tensioned for added riding surface durability.

The power of creativity and innovation.

Main Span Erection—120 Concrete Segments in 47 Days

After completion of the concrete side spans, the starter precast segments in each of the eight cantilevers were erected. Precast segments were delivered to the erection site by barge from the riverfront just downstream from the nearby 10th Avenue Bridge and lifted into place using a 600-ton, barge-mounted ringer crane. The first segment placed at the pier to begin the one-directional cantilever construction began by using a 1-ft 6-in.-wide concrete closure pour to optimize precise geometric set-up. This was fine-tuned using a series of jacks on a support frame attached to the pier cap. The match-cast faces of subsequent precast segments were coated with epoxy and then connected to those previously erected using longitudinal post-tensioning. The first precast concrete segments were placed on May 25, 2008, (Day 223), while a crowd estimated at 800-1000 watched closely from the walkway of the adjacent 10th Avenue Bridge. Each pair of adjacent precast concrete segments was connected with a longitudinal cast-in-place concrete deck closure slab. After achieving a minimum compressive strength of 4000 psi, the segment pair and the connecting longitudinal closure were post-tensioned with a series of transverse, top-slab deck tendons and longitudinal, top-slab cantilever tendons. Segment erection operations continued at all eight cantilever headings, with four segments typically placed each day. The bridge's last concrete segment was erected on July 10, 2008, (Day 269) taking only 47 days to erect the main span segments. A 7-ft-long long closure pour was made at midspan in each of the four cantilevers with final stressing of longitudinal post-tensioning tendons to complete major bridge construction operations. From Notice-to-Proceed of the design-build contract to erection of the final main span segment was 9 months.

A Smart Bridge with High-Tech Bridge Monitoring

The new bridge contains approximately 323 sensors that will serve as a data resource to verify the long-term service of the bridge and provide an important tool for future bridge designs. Mn/DOT has formed a partnership with the University of Minnesota Department of Civil Engineering and the Federal Highway Administration for use of the information from the sensors.

Precast segments weighing up to 200 tons were erected quickly. Photo: © FIGG.

The 120 precast concrete segments to create the 504-ft-long main span were erected in 47 days. Photo: © FIGG.

A Modern Concrete Bridge for the Future

I-35W is a modern concrete bridge designed for the future—a sustainable, redundant, high-strength, high-performance concrete bridge. This major concrete bridge will serve as an important resource in the delivery of other major bridges in the re-building of America's infrastructure. Ultimately, the success of this bridge is a reflection of remarkable teamwork of some 400 to 600 local skilled workers, the construction team, the design team, the subcontractors and suppliers, Mn/DOT, FHWA, and the community. Mn/DOT's vision proved to be achievable, demonstrating the power of creativity and innovation.

Linda Figg is president/chief executive officer of FIGG and served as I-35W visual quality manager. Alan R. Phipps is senior vice president/director of operations of FIGG and served as I-35W design manager.

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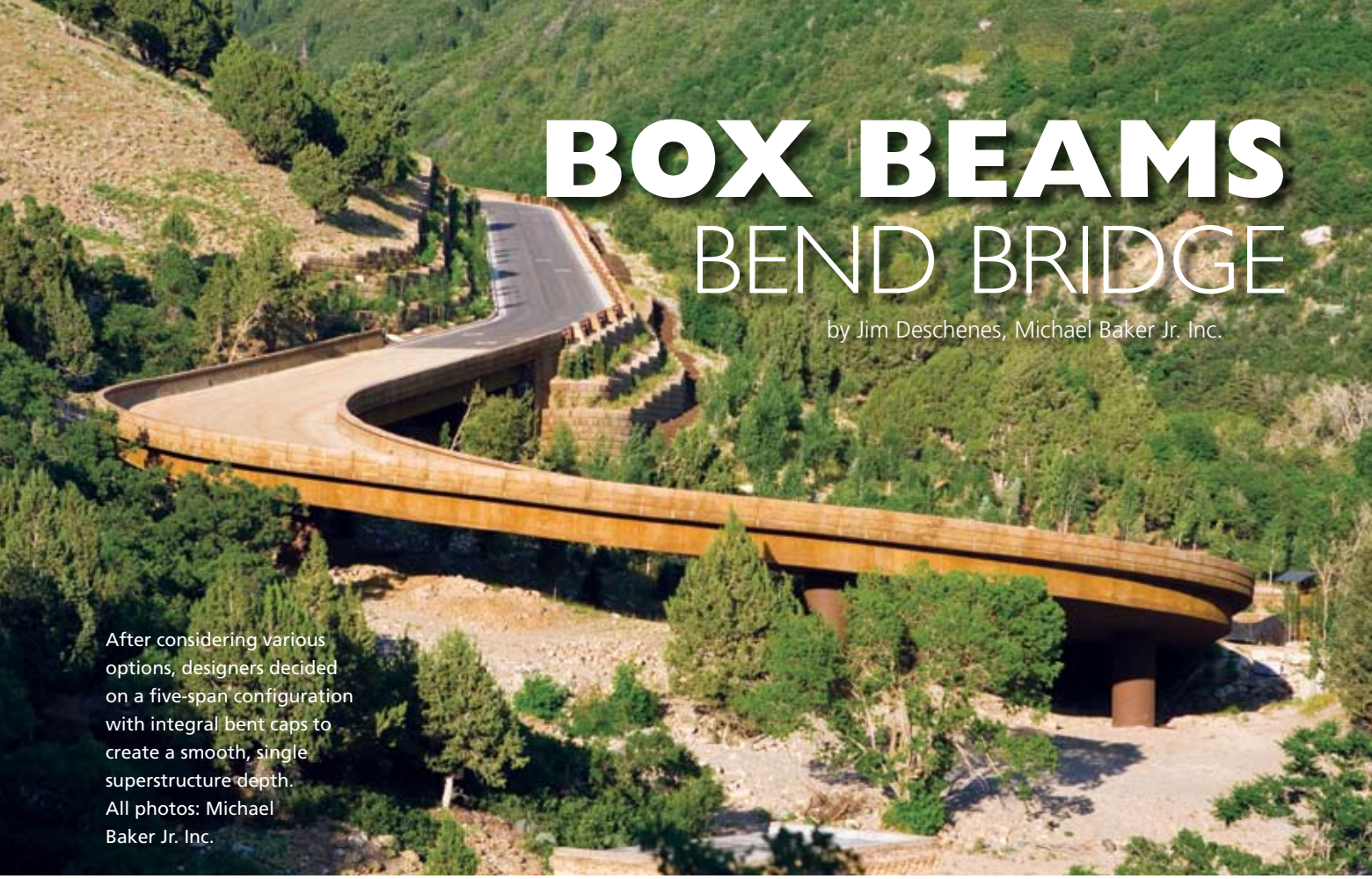


BOX BEAMS BEND BRIDGE

by Jim Deschenes, Michael Baker Jr. Inc.

After considering various options, designers decided on a five-span configuration with integral bent caps to create a smooth, single superstructure depth. All photos: Michael Baker Jr. Inc.

Concrete girders offer only alternative for five-span bridge with severe horseshoe bend

Access to a new upscale development in the foothills of Utah's Wasatch Mountains just outside Salt Lake City required a grand welcoming entrance, along a path with difficult terrain. To meet the variety of needs produced by the site, especially environmental concerns and functional demands, two reinforced concrete bridges located on "switchback" curves were built. The lower bridge, discussed in this article, was an exceptionally challenging five-span, 450-ft-long bridge with a complete switchback curve along a centerline radius of only 80 ft and a 12% grade.

Access to the site was limited by steep grades, limits of a conservation easement, and a requirement to provide for wildlife crossing. The project also was located less than 1000 ft from the Wasatch Fault. Typically, the most economical solution would involve building large walls and excavating steep slopes into the existing hillside. But foothill preservation and concerns from county officials, coupled with the desire to create an aesthetically pleasing entrance, led the owner to investigate nonconventional alternatives.

Once the concept for the switchback curves was devised, a series of design challenges developed. The curve was too severe for tangent girders without reducing span lengths to less than 30 ft, while curved steel girders were not economical at such a small radius. Designers determined that the most feasible bridge type was a conventionally reinforced, cast-in-place concrete, box girder bridge. The girders could not be post-tensioned due to the severe curvature, which would have made it difficult to resist the bursting forces in the walls of the boxes.

profile

BIG COTTONWOOD CANYON LOOP ROAD BRIDGE / SALT LAKE CITY, UTAH

ENGINEER: Michael Baker Jr. Inc., Midvale, Utah

PRIME CONTRACTOR: Ralph L. Wadsworth Construction Co., Draper, Utah

CONCRETE SUPPLIER: Harper Ready Mix, Salt Lake City, Utah

AWARDS: *2008 Portland Cement Association Bridge Award*

The most feasible bridge type was a conventionally reinforced, cast-in-place concrete, box girder.

Extensive evaluations led to a five-span configuration with integral bent caps that provided a smooth, single superstructure depth. The superstructure itself consists of a three-cell box girder with an overall depth of 5 ft 6 in.

Due to the bridge's severe curvature, the length along the outside perimeter of the deck was considerably longer than the inside perimeter. This resulted in more dead load on the curve's exterior side than on the inside. To minimize the dead-load eccentricity, the columns supporting the bridge's curved portion were offset from the centerline of the structure. Fortunately, the offset was minor relative to the superstructure's width and was not visible, so it did not affect the design's aesthetics.

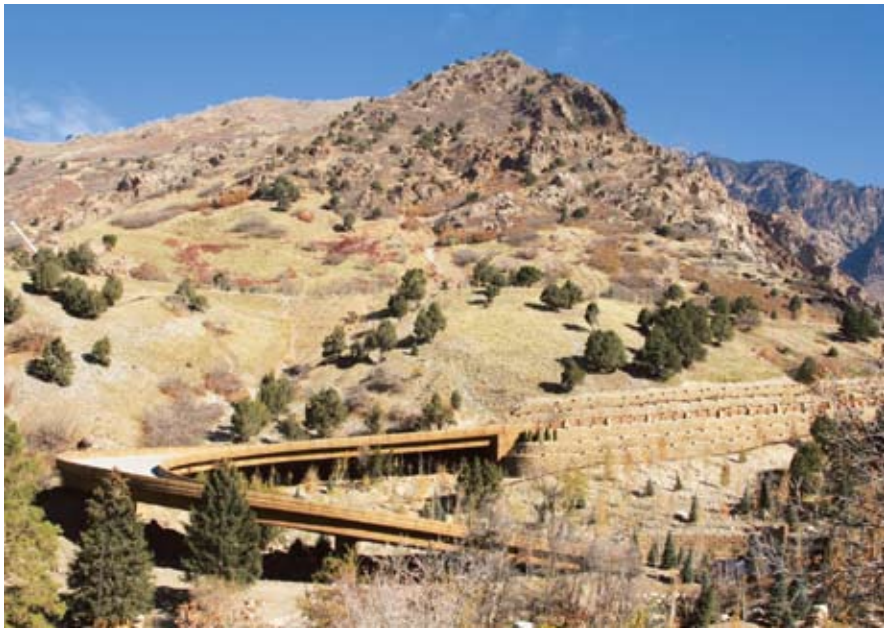
Reinforcement Added Challenges

Reinforcement layout proved complicated. The curvature was enough to require the No. 8 main longitudinal reinforcement to be bent at the bridge radius. Smaller No. 5 bars were flexible enough to be field bent and tied into place. Spacing of the transverse No. 5 bars in the deck was determined by the deck's outside edge. Around the deck's curved portion, this required a radial placement of the bars. The result was a much closer spacing around the curve's inside edge. Epoxy-coated reinforcement was used for the top slab and parapets, while the remainder of the reinforcement was uncoated.

Several analytical models were created to determine the best seismic design for the bridge, which is located along the largest and most active fault line in Utah. A site-specific analysis showed a peak ground acceleration of 176% of gravity. The final solution used Seismic Design & Analysis Procedure D from the Multidisciplinary Center for Earthquake Engineering Research guideline. A response spectra analysis was performed to determine the seismic design forces, and specific elements were designed for the maximum overstrength properties of the columns.

Two concentric reinforcement cages were used in the columns to achieve three goals: maintain an aesthetically pleasing 7-ft-diameter column size, provide the seismic design strength required in the column, and limit the column strength for which the footings had to be designed. Only the inner cage extended into the bent cap and footing. The outer cage was essentially temperature reinforcement although its effects on column strength were taken into consideration for seismic analysis of the structure and for determining the design strength for the capacity protected foundation and bent cap elements.

Post-tensioning the girders was not an option due to the severe curvature, which would have risked damage to the box girder walls.



The dramatic switchback curve achieved for the entrance to a new housing development in the foothills of Utah's Wasatch Mountains near Salt Lake City minimized the impact on the environment, but created tremendous challenges to design and construct.

450-FT-LONG REINFORCED CONCRETE BOX GIRDER BRIDGE / WASATCH PACIFIC LLC, OWNER

BRIDGE DESCRIPTION: Conventionally reinforced, five-span, three-cell, concrete box girder bridge designed for steep grade and centerline radius of 80 ft, as well as high seismic forces

BRIDGE CONSTRUCTION COST: $170/ft^2 (bridge only)

As the bridge climbed the steep hillside, adjustments were made to make the footings deeper and create a more balanced distribution of seismic forces between the columns.

Reinforced concrete offered the only option for reaching all the desired goals.

The cast-in-place concrete option provided flexibility for the tight radius and steep grades, but it also fits well with the rocky surroundings.

As the bridge climbed the steep hillside, adjustments were made to make the footings deeper and create a more balanced distribution of seismic forces between the columns. Substantial cheekwalls and finwalls at the abutments engaged soil passive pressure in the transverse direction. The columns and bent footings were required to resist longitudinal seismic forces, as the abutments were parallel to each other and could only resist seismic forces in one direction.

Ultimately, because each span was relatively short, at about 90 ft, the seismic forces that the columns were designed to meet were not unusual. The structure acts much like a table, with the superstructure so stiff that there is a significant load transfer through the box section to all of the foundations.

Aesthetic Goals Expand

Initial budget restraints limited architectural concepts to staining the concrete and adding some fractured-fin relief in the parapet. As the design developed, the owner realized the opportunity to create a showcase entrance to the development, and the budget was expanded to include architectural enhancements. The additions were made too late to include some early suggestions proposed on the owner's renderings, such as tree planters, variable-depth barriers that extended below the deck, or asymmetrical trapezoidal piers.

The design was modified to provide a more modern-looking parapet that included an LED lighting strip placed under an overhang in the parapet's

A Sustainable Solution

Preserving the natural habitat around this bridge, especially for deer and small-animal crossings, and minimizing impact to vegetation on the hillsides, were key goals in designing the structure. The county also required a public trail that could be maintained through the property. All agreed that creating a bridge was an aesthetic improvement over the other option—a large hillside cut.

Choosing the cast-in-place concrete option was driven by its flexibility in creating the structure's tight radius and steep grades, but it also fits well with the rocky surroundings. The finished structure was stained to complement the colors of the canyon.

Concrete also used Utah's abundant natural-aggregate sources. Steel would have had to be shipped from mills and then fabricated and transported to the site, whereas aggregate was readily available within a few miles of the site. The narrow space constraints also played to concrete's strengths, as steel girders would have required a large crane pad and pull-through areas for trucks. Concrete allowed the contractor to minimize site impacts by having one small crane to handle formwork, and the same pad was large enough to accommodate the concrete pump and trucks.

A critical constraint was a conservation easement located just outside the roadway's proposed edge. Spread footings were found to work well with the available soil pressure, while shoring kept the spread-footing excavations from encroaching into the easement. Caissons would have minimized the hillside cut and remained clear of the easement but would have cost more than spread footings.

LED lighting was placed under a lip at the parapet's interior, delineating the parapet's edge to drivers without casting light upward or outward to detract from the canyon's darkness. This approach alleviated light pollution and enhanced the natural environment.

The concrete design allowed the bridge to not only meet all of the owner's functional and aesthetic needs but provided a minimal impact on the natural environment, blending it with its surroundings successfully.

The owner realized the opportunity to create a showcase entrance.

face. Two 3-in.-diameter conduits were provided in the barrier to carry power and fiber optics to the LED lights, with custom light boxes embedded in the parapet.

Formwork and Concrete

Design and analysis did not stop when the design plans were released, as designers also had input into the shoring design and concrete placement sequence. Numerous site visits were made and a number of geometry checks were performed at the request of the builder, with minor detail changes made to facilitate forming.

The bridge's location allowed the superstructure's concrete slabs and walls to be cast on continuously supported formwork. Hundreds of conventional scaffold shoring towers supported a plywood deck and wall forms. The scaffolding was left in place until the top deck was cast. Parapets were placed after shoring was removed.

Bottom slab and wall forming required an enormous amount of surveying to create the correct curvature and slope. The goal was to generate smooth lines and not rely on short tangent sections to produce the curve. The web walls were short enough to allow 1/2-in.-thick plywood to be used, and it was warped around the curve. The deck was particularly difficult to form and place, as no two interior box cells had the same dimensions. The deck was formed by painstakingly custom-cutting 2x6 timbers and plywood.

The bridge's initial budget was expanded when the developer realized he could make a strong statement for the entry to the residential development.

Placement of the deck concrete proved to be one of the more challenging aspects. The horizontal curve, super-elevation, and difference in length between the deck's interior and exterior walls produced a warped surface. A simple roller screed was used, and the deck was placed in four separate sections.

Despite the 12% centerline grade, the deck was placed with the screed traveling downhill. The contractor's experience building the Olympic bobsled track and ski-jump landing hill alleviated fears that are typically associated with placing concrete downhill. The relatively light roller screed had to be pulled downhill to screed the concrete. The contractor maintained a head of concrete in front of the screed, and no evidence of poor consolidation or downhill slumping occurred.

As a final measure of protection, a 3/8-in. thick modified polymer overlay was placed on the deck approximately 1 year after the final deck placement.

Designing and constructing this project were challenging, yet the designers remain convinced that reinforced concrete offered the only option for reaching all the desired goals. The use of many computer models and hand calculations was essential, as the unique geometry pushed the engineering well beyond the scope and codes of conventional bridge design. Close interaction between the designer and builder was critical in constructing the bridge within the owner's schedule and achieving a design that provides an impressive gateway into the development.

Jim Deschenes, is an engineer, office principal, and assistant vice president with Michael Baker Jr. Inc. in Midvale, Utah.

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

AESTHETICS COMMENTARY

by Frederick Gottemoeller

Context-sensitive design has become the goal for much bridge design. The Big Cottonwood Canyon Loop Road Bridge is as fine an example of context-sensitive design as one is likely to see. Tucked into a fold in the landscape, with its single, almost centrally located columns hidden in the shadows, the bridge seems to float over the ground, looking like it has always been there. The cast-in-place concrete box girder, with all of the connections and points of force transfer hidden inside the box, shows only a smooth continuous surface following the geometry of the roadway. The torsional stiffness of the concrete box girder form allows for all of the difficult forces resulting from the extreme geometry, loads, and seismic effects to be handled gracefully. All of the details support the overall form. The parallel shadow lines of the parapet emphasize the geometry, while the color well suits the location.

The renowned twentieth century architect Mies van der Rohe famously said, "Less is More," meaning that adding more detail often detracts from, rather than adds to, a design. It is fortunate that time did not allow the addition of the "asymmetric trapezoidal piers" and "variable depth barriers" to this structure. They would not and could not have improved its appearance. The unusual geometry of the bridge has brought out the best in the designers. Best of all, it means that users can enjoy the appearance of the bridge even while crossing it.

New construction system protects environmentally sensitive areas

TECHNOLOGY DRIVEN

by Craig A. Shutt

Constructing the new Washington Bypass, an upgraded alternative route for U.S. Route 17 in Beaufort County, N.C., created unique challenges beyond traditional bypass construction. The $192-million project, encompassing 6.8 miles of roads, includes two major interchanges and bridges that span environmentally sensitive lands. To meet the variety of needs, especially the goal of minimizing impact to wetlands, the construction team created an innovative gantry system that drives piles, sets precast bents, and erects beams. After the deck is cast, the gantry progresses to the next span.

The bridge construction represents the second part of a three-part project, explains Maria Rogerson, assistant resident engineer with the North Carolina Department of Transportation (NCDOT). The first part, begun in February 2008, focused on widening

profile

U.S. ROUTE 17 WASHINGTON BYPASS / BEAUFORT COUNTY, N.C

DESIGN-BUILDER: Flatiron/United, a joint-venture company comprising Flatiron Construction Corp., Longmont, Colo., and United Contractors Inc., Chester, S.C.

ENGINEER OF RECORD: Earth Tech Inc., Long Beach, Calif.

PRECASTER: Coastal Precast Systems, Chesapeake, Va., a PCI-certified producer

GANTRY: Deal, Italy

The innovative gantry system used on the U.S. Route 17 Washington Bypass Bridge in Beaufort County, N.C., drives piles, sets precast concrete bents, and erects beams. After the deck is cast, it progresses to the next span. All photos: Flatiron.

the southern 4 miles of two-lane roadway to four lanes. Construction of the new 2.8-mile-long bridge, spanning wetlands along the 6.8-mile-long section of roadway, is now underway. It will be followed by widening 4 miles of highway north of the bridge under a contract to be let toward the end of 2009. The goal is to create an accessible 70-mph corridor from Virginia down to Wilmington, N.C., she explains.

Design-Build Opens Opportunity

"What gave us the ability to be a little bit creative on this project was the design-build process," says Rogerson. The state has created several smaller design-build projects prior to this one, she notes, but the delivery method has not been used extensively. Bidders were scored both on their creativity in meeting the variety of needs, as well as the cost to deliver the bridge. Three companies were short-listed based on their bids and technical proposals. Initially, all three bids came in too high, so adaptations were made to make the design more cost efficient. It is the largest design-build project in the state.

"The design-build process cuts the timeframe on construction before the NCDOT acquires the bridge, because the contractor is responsible for final design, right-of-way access, and construction in their contract," Rogerson explains.

The Flatiron competitively priced proposal was accepted because, among other features, it did not require the use of a temporary work bridge to erect the structure, which would have had more impact on the wetlands, she notes. "Their design required less clearance in the wetland areas, only 30 ft from the edge of the bridge, with minimal impact below." Executing this concept then became the design-build team's responsibility.

Innovative Gantry System

The bridge is being constructed using two 592-ft-long, patent-pending gantry systems starting from each end of the bridge. Each gantry consists of two parallel and connected trusses that are long enough to reach over four spans of the bridge. The gantry system begins at one end of the bridge and drives the piles for each bent. Approximately 1227 30-in.-square. precast, prestressed concrete hollow piles will be driven to support 140 spans including both portions of the Y-shaped split at the end. Each span is about 121 ft long. Earlier, test piles had been driven near the bridge's alignment to confirm the length of the piles and tip elevations.

The precast concrete piles and girders were fabricated off site while the pile caps were cast on site at a precasting yard set up at the south end of the bridge. The components are inspected and approved at both sites prior to delivery to the gantry.

Gantry Operation

The precast piles and beams are delivered to staging areas at the north and south abutments and then loaded onto a special carrier that comprises two trucks, one driving forwards and one driving backwards, explains Elie H. Homsi, vice president of engineering services at Flatiron Constructors Inc. and developer of this top-down concept.

The pile is loaded into the lead with an attachment for the hammer clamped to its top. The lead then rotates the pile into a vertical position for driving.

PRECAST, PRESTRESSED CONCRETE BRIDGE / NORTH CAROLINA DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: Precast concrete bridge consisting of 140 spans (116 spans plus two parallel structures of 12 spans) each about 121 ft long, with 1227 precast, prestressed concrete hollow piles, 922 precast beams, 140 precast post-tensioned pile cap bents and cast-in-place concrete deck

PILE DRIVING EQUIPMENT: Birminghammer, Hamilton, Ont., Canada

BRIDGE CONSTRUCTION COST: $192 million

The gantry system is used to attach pile caps in three pieces to the precast concrete piles.

On typical spans, the gantry drives nine piles, then sets the precast concrete caps in three pieces on the piles. The caps are then post-tensioned and infill concrete placed.

The trucks position the pile under the tail of the gantry, where two separate trolleys lift each end. The pile is threaded into the lead and an attachment for the hammer is clamped to the top of the pile. The trolleys move to the end of the gantry, and the lead rotates the pile into a vertical position for driving.

The entire gantry is mounted on front and rear supports. Each support can move independently forwards, backwards, and sideways. The front support can be moved to the right while the back can be moved to the left, to skew the positioning, or they can be moved in the same direction to keep components parallel, Homsi explains. The sideways movement allows the gantry to be positioned to reach the locations of the piles and the beams.

On typical spans, the gantry drives nine piles and then sets the precast concrete caps in three pieces on the piles. The caps are post-tensioned and infill concrete is placed. The concrete infill is loaded into buckets and transported to the leading end of the truss using the gantry trolley. The trolley maneuvers the bucket into the position required for concrete placement.

Next, seven beams are placed by the gantry and the concrete deck is cast. Once the 3500-psi concrete compressive strength is achieved, the gantry moves forward, and the cycle is repeated for the next span.

"This new method allowed the Flatiron/United team to break the record for top-down construction for this type of precast beam bridge by constructing 120-ft-long spans without relying on ground-based support equipment," says Homsi. The truss eliminated the need to erect a temporary bridge and significantly reduced the environmental impact. Fewer trees has to be cut down using this method.

Mark Mallett, project manager for the Flatiron/United joint venture, explains, "The gantries are essentially a bridge-building assembly line. There are three spans of bridge under construction in the launching cycle at all times. It is one challenge to get the gantry to perform each of its tasks and another to synchronize these tasks so that all three spans can be built simultaneously."

The gantry progresses in a "caterpillar" mode of movement, Homsi says, stretching out the front support to its new location and retracting the rear support as construction progresses. The gantry is driving piles for the leading or first span as the deck is cast on the second span and the deck concrete is curing in the third span.

Achieving the needed concrete strength at the rear of each segment was the key to being able to progress, Rogerson notes. About four spans could be set each month. "It moved along pretty well."

All of the construction is moving smoothly, she adds. There are penalties of $10,000 per day for late completion, but no one is worried at this point. "So far, we're remaining on schedule," she says. Meeting that schedule with such an innovative approach to the construction will no doubt gain the attention of other departments of transportation, as more states look for ways to complete projects quickly while minimizing the impact to their sensitive environmental areas.

Environmental Challenge

The challenges were significant for the design team. The key element was building the 2.8-mile-long bridge over sensitive wetlands that could not be disturbed and opening it to traffic by November 2010, bringing it in line with the widening projects planned to the north and south. Complicating this process was a moratorium by the state Wildlife Resource Commission for no "in water" pile-driving work from February 15 to June 15 to allow for fishery hatching of three species.

The innovative top-down construction method results in minimal disturbance to the wetlands during the construction operation. The only permanent impact is the actual pile footprint.

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With energy, sustainability, safety, fire resistance, and price escalation all dominating today's headlines, it is clear that the world of bridge design is changing dramatically. Designers now have to consider many more factors in their bridge solutions than in the past. Post-tensioning (PT) can be a valuable tool in addressing these concerns and has some unique advantages.

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Repeating History

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

One of America's earliest open-spandrel arch bridges is replaced while maintaining the bridge's original appearance

The original bridge built in 1913 was substantially rehabilitated in 1940 shown here and 1991.

The original Lime Kiln Bridge was the only open-spandrel, concrete arch bridge in Vermont and one of the first built in the United States. Since 1913, it stood as an architectural and scenic gem, spanning the majestic Winooski River Gorge. Ordinarily, replacing a 300-ft-long bridge would not require an elaborate design—but the Lime Kiln Bridge clearly was not ordinary. Constructing the new structure involved a challenging design, a challenging site, and a challenging process.

Officials at the Vermont Agency of Transportation (VTrans) sought to update the irreparably deteriorated structure with an efficient crossing while preserving the original's architectural and historic integrity. And, of course, the work had to be done in as short of a time frame as possible using the most cost-effective techniques.

The bridge connects South Burlington and Colchester by spanning a 100-ft-deep gorge cut by the Winooski River. The original design featured reinforced concrete arches and tee beams, which were substantially rehabilitated in 1940 and 1991. To recreate that look while meeting the variety of contemporary needs, VTrans and VHB held numerous meetings over a 3-year period to consider construction options and receive input from all stakeholders, including the Vermont Division for Historic Preservation.

Aerial Photography: Fli-Rite Aviation, Burlington, Vt.

profile

LIME KILN BRIDGE / WINOOSKI RIVER GORGE, VT.

ENGINEER: VHB-Vanasse Hangen Brustlin Inc., Bedford, N.H.

GEOTECHNICAL ENGINEER: Golder Associates, Manchester, N.H.

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

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

Ultimately, the decision was made to create a structure combining precast, prestressed concrete box beams and slabs with cast-in-place concrete arches. This combination replicated the original bridge's decorative geometrical features and ornamental railings while allowing sidewalks and travel ways to be widened. Street lighting and architecturally treated abutments and retaining walls also were added.

Many Options Considered

A number of alternatives were considered before the final selection was made. The considerations included rehabilitation possibilities, but it was ultimately decided that they would provide no more than 20 years of service life, and more was desired. A conventional steel-girder replacement bridge also was deemed incompatible with the goal of maintaining the sense of aesthetics, history, and pride of place that the original bridge created.

As a result, VHB and VTrans developed several concrete arch bridge concepts. Finding the best option required meeting specific geometric criteria, and the review process for each submission phase was much more intense than for a typical project. Fortunately, completely filling one of the two quarries that squeezed the site's perimeter allowed improved alignment options during the conceptual stages. These changes provided the opportunity to improve the project and avoid significant impacts to the local environment.

The bridge's ultimate geometry balanced a number of factors, including reducing costs, simplifying geotechnical solutions, minimizing the number of joint locations, and maximizing the service life.

The placement of the south abutment was dictated by a utility bridge, located upstream from the existing arch bridge, and by the depth of the fill overlying the bedrock, which sloped steeply down to the gorge. Soils in this area were unsuitable for spread-footing foundations, so a stub abutment on steel H-piles was selected. This configuration minimized the footprint of the abutment and eliminated the need for deep excavation adjacent to the water.

The north abutment's placement was determined by several restrictions,

The new Lime Kiln Bridge replicates the look of the original bridge, which was one of the first open-spandrel, concrete arch bridges in the United States and the first in Vermont.

CONCRETE ARCH / COLCHESTER AND SOUTH BURLINGTON, VT., OWNERS

BRIDGE DESCRIPTION: Open-spandrel arch crossing a 100-ft-deep gorge using 80 precast, prestressed concrete beams and cast-in-place arches, piers, floor beams, and deck

CONCRETE SUPPLIER: S.T. Griswold, South Burlington, Vt.

BRIDGE CONSTRUCTION COST: $6 million

The 300-ft-long bridge features precast, prestressed concrete box beams and slabs with cast-in-place concrete arches, piers, floor beams, and deck. The arch supports six intermediate 22-ft-long spans that used 1-ft-deep precast concrete solid slabs.

comprising a railroad track to the north and limited horizontal clearances from the centerline of the track to the abutment's face. The abutment was placed to allow excavation for the abutment footing without requiring temporary support of the railroad track. Other restrictions included a minimum 23 ft vertical clearance, span-length limitations, and the varying fill over the bedrock. The abutment was founded on a mechanically stabilized earth backfill because of its suitability to the height, soil conditions, and cost.

Arches Resemble Polygons

The two arches were designed with reinforced, cast-in-place concrete to closely match the shape of an equilibrium polygon under full dead load. The arch spring line was placed at equal elevations for each arch foundation. The clear distance between the arch footings was about 121 ft with the bottom of the arch rising to about 28 ft above the spring line. In section, each arch is 4.5 ft wide and varies in depth from 4 ft at the spring line to 3.25 ft at the arch's midspan.

Footings for the arches were designed to be about 12 ft wide and 22 ft long to accommodate the proposed arch and pier geometry, as well as the design loads. Information from soil borings and geological survey helped set the bottom elevations for both foundations, ensuring they were seated in bedrock for at least half of the footing's height at the back. This placement ensured

Remote-controlled, steerable dollies were used to maneuver the 104-ft-long precast concrete box beams. Photo: J.P. Carrara & Sons

sufficient resistance against the arch thrust and overturning moments.

Precast Extends Design Life

The arches support six 22-ft-long intermediate spans consisting of 1-ft-deep precast, prestressed concrete solid slabs that were transversely post-tensioned after placement. Precast concrete units were used rather than cast-in-place options to minimize formwork over the gorge and increase the deck service life. The slabs are supported by elastomeric bearings on cast-in-place floorbeams at the spandrel arch columns and pier columns.

The end spans of 59 ft and 103 ft use precast, prestressed concrete adjacent box beams that were transversely post-tensioned after placement. The box beams provided a number of benefits, including reducing costs through the use of repetitive construction for the bearings, beams, concrete overlay, and joints for live-load continuity. The relatively shallow depth of the beams provided the required vertical clearance over the railroad, while their appearance from underneath the structure is more uniform, contributing to its aesthetic appeal.

The precast concrete beams also will simplify construction phasing for future deck rehabilitation, since traffic phasing could be easily accommodated due to the continuous support provided by the underlying transversely post-tensioned beams. The box beams are supported on elastomeric bearings. Bearing connections were detailed so that the superstructure was fixed at each pier bent column with expansion accommodated at each abutment.

Aesthetics

Designers paid particular attention to aesthetics in shaping the bridge's profile. The arch was symmetrical, with concrete columns for the intermediate spans transmitting superstructure loads vertically to the arch. Aesthetic considerations included the visual depth of the approach spans, the depth of the intermediate spans, and the post spacing for the concrete bridge railings.

To aid the bridge's appearance, approach-span depths on each end were maintained at 3.5 ft, although the depths for the south approach could have been reduced to 2.25 ft. Designers decided that a uniform look provided better aesthetics and cut costs by allowing repetitive fabrication and erection procedures for both spans. The minor premium for the deeper beams was more than offset by the savings in

The end spans feature precast, prestressed concrete butted box beams that were transversely post-tensioned after placement.

Street lighting and architecturally treated abutments and retaining walls also were added, as well as historical background on the original bridge.

efficiencies and the fewer prestressing strands required in the shorter span.

For the intermediate spans over the arches, the floor beams were tapered to match the approach-span box-beam depths at the fascia. Visually, this helped tie together the intermediate and approach-span superstructure.

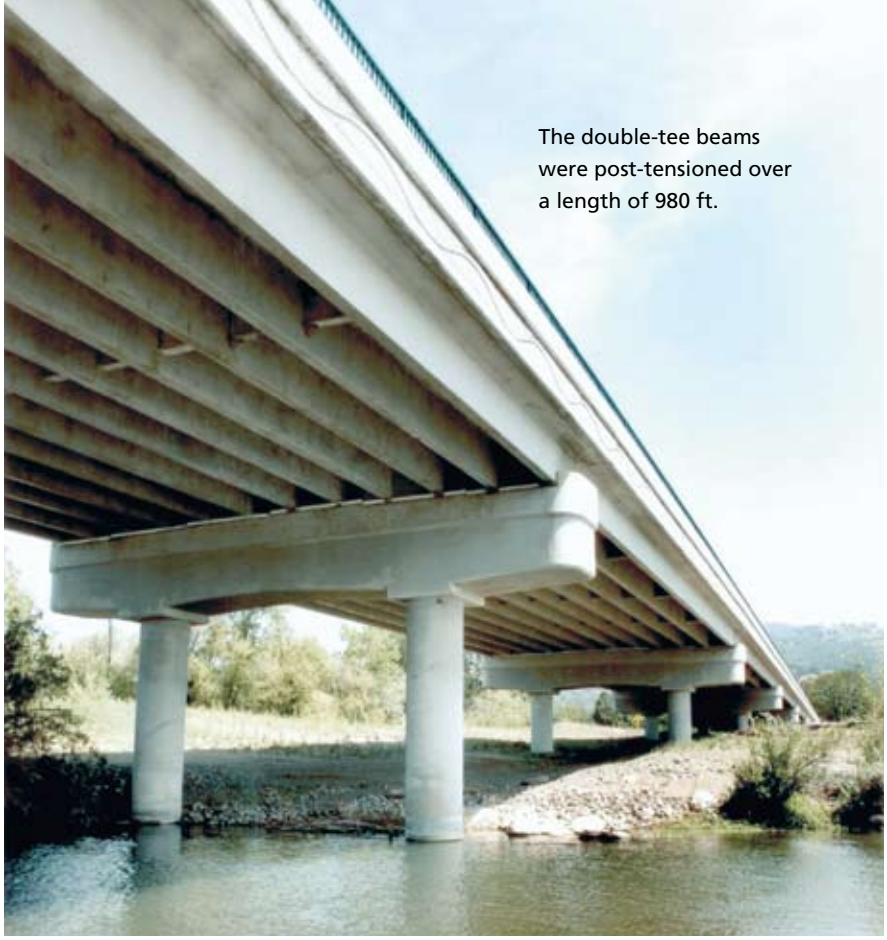
The cast-in-place concrete deck had a minimum thickness of 5 in., with a heat-applied waterproofing membrane and 3 in. of bituminous concrete. Texas classic traffic railing type T411 with decorative lighting attached was installed for security and to add to the bridge's aesthetics. The railing posts over the floorbeams and columns provided visual continuity between the superstructure and the supporting-arch structure and substructures.

The completed bridge spans the majestic Winooski River Gorge just as elegantly as did its venerable predecessor. Most important, all parties to this long, complex, process-heavy project were pleased with the result. Innovation, collaboration, patience, persistence, and constant advancement in the state-of-the-art use of concrete materials, combined with pure will on the part of the entire construction team, made this bridge possible. Contemporary materials blended with a respect for the past helped preserve the bridge's architectural and historic integrity.

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

Advertisers Index

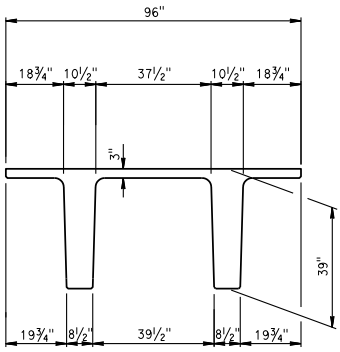
The Russian River Bridge uses non-standard double-tee beams. Photos: Steve Hellon and John Huseby, Caltrans.



The double-tee beams were post-tensioned over a length of 980 ft.

EMERGENCY REPLACEMENT OF THE RUSSIAN RIVER BRIDGE

By Ahmed M. M. Ibrahim, Linan Wang, Tariq Masroor, Minh Ha, and Ofelia Alcantara, California Department of Transportation



Dimensions of the non-standard double-tee beam. Drawing: Ahmed M. M. Ibrahim.

The existing steel truss bridge, built in 1932, over the Russian River in Geyserville, Sonoma County, Calif., was severely damaged during a series of storms in the last two weeks of December 2005. A maintenance crew from the California Department of Transportation (Caltrans) observed lateral rotation of a mid-channel pier and approximately 8 in. of differential settlement between the upstream and downstream sides. The bridge was closed to traffic on January 1, 2006, causing hardship to the local community. It is the shortest route to the high school on the other side of town and closure of the bridge resulted in a 40-minute detour every school day.

Caltrans studied the options of repairing or replacing the bridge. After site geology and scour mitigation studies were completed, Caltrans decided to replace and re-open the bridge to traffic before the next school year. The replacement bridge layout was to have the same overall length, profile, and vertical clearance over the channel as the existing bridge. Matching the existing layout was made mainly to minimize the time in acquiring right of way and to keep the number of permits to a minimum. Raising the bridge profile and consequently extending the bridge length would have led to legal issues.

profile

RUSSIAN RIVER BRIDGE / GEYSERVILLE, SONOMA COUNTY, CALIF.

ENGINEER: California Department of Transportation, Sacramento, Calif.

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

CONTRACTOR'S CONSULTANT: R.N. Valentine Inc., Gualala, Calif.

PRECASTER: Con-Fab California Corporation, Lathrop, Calif., a PCI-certified producer

AWARDS: *ASCE, Bridge Project of the Year, Region 9 (California), 2007; Associated General Contractors, Excellence in Partnership Award, San Francisco Chapter, 2007*

Sensitive environment and tight construction window led to a precast alternative.

Contract Plans

Caltrans' engineers started the design during the first week of February 2006. The replacement bridge was designed to carry two 12-ft-wide traffic lanes; 8-ft-wide shoulders at each side; and a 5.3-ft-wide sidewalk for an overall width of 49.15 ft. Overall length of the replacement bridge was 980 ft. Hydraulic considerations required the use of fewer spans for the replacement bridge. Eight 102.5-ft-long spans and two 80-ft-long spans at the ends were used. To provide free board clearance for the 100-year design flood, the superstructure depth was limited to 45 in. with a span-to-depth ratio of 27 for the longer spans.

Due to sensitive environmental issues and regulations, the limited construction window was from May to the end of August, and falsework was not allowed in the main channel. These restrictions led to the use of a precast, prestressed concrete bridge as the most suitable alternative. Four standard sections were examined during type selection: I-beams; bulb-tee beams; spread box beams; and adjacent box beams. All four alternatives used simple span beams made continuous with a cast-in-place composite deck. Every

Lifting the double-tee beams at the precasting yard.

A two-column drop bent cap with aesthetic features was used to support the superstructure.

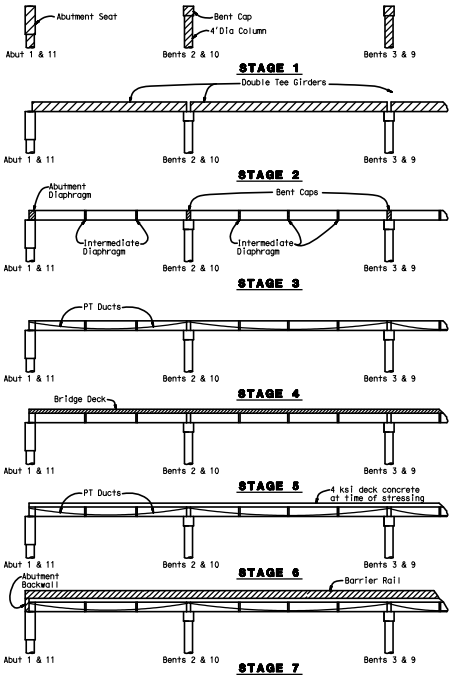
effort was made to produce a design that used state standard sections and was a fair competition for all precast manufacturers.

Standard I- and bulb-tee sections did not work due to limited superstructure depth and required the use of non-standard sections. Spread box beams required using less than 2 ft distance between the girders and the use of formwork for deck placement in such a short distance. This section was deemed impractical and was ruled out. Adjacent box beams were the only standard section that met the high span-to-depth ratio. Standard precast, prestressed AASHTO box beams 48 in. wide and 39 in. deep, with a 6-in.-thick, cast-in-place reinforced concrete deck were selected. The adjacent beams were to be transversely post-tensioned at the quarter points. A total of 120 beams would be required.

The precast box beams were to be supported on cast-in-place drop bent caps using two elastomeric bearing pads at each end of each beam. The drop bent caps would have a constant width of 6 ft and a variable depth with minimum dimension of 6 ft. Each drop bent cap was to be supported by two cast-in-steel shell (CISS) pile shafts. Cast-in-steel shell pile shafts were chosen based on their high load-bearing capacity, site conditions, and hydraulic suitability and were preferred over cast-in-drilled hole (CIDH) pile shafts because of the potential for a cave in during drilling.

A few aesthetic measures were considered for the bridge bent caps, beams, and barriers. The bent caps were designed with simulated capitals, rounded noses and arched soffits to visually reduce their otherwise massive appearance. This effort aided in bringing the bent caps and column shafts into a closer proportional relationship to each other. The smooth vertical face of the precast box beams contributed to the tidy effect of the superstructure exterior, thus complementing the nautical theme of the barriers' surface treatment and context-sensitive handrails.

By mid March, the design package of plans, specifications, and cost estimates was ready for bidding. Bids were based not only on the cost for the work to be done, but also on the product of the number of



Sequence of construction stages. Drawing: Ahmed M. M. Ibrahim.

CONTINUOUS POST-TENSIONED, DOUBLE-TEE BEAM / CALIFORNIA DEPARTMENT OF TRANSPORTATION, SACRAMENTO, CALIF., OWNER

POST-TENSIONING SUPPLIER: AVAR Construction Systems Inc., Campbell, Calif.

BRIDGE DESCRIPTION: Precast, prestressed concrete non-standard double-tee beams made continuous using a 6-in.-thick cast-in-place composite deck and two-stage post-tensioning. Eight spans 102.5-ft long and two end spans 80-ft long for a total length of 980 ft

STRUCTURAL COMPONENTS: 60 precast girders, 24 cast-in-steel shells 4-ft-diameter pile shafts, and a deck area 48,216 ft^2

BRIDGE CONSTRUCTION COST: $14.5 million

working days to complete the work and the cost per day shown on the engineer's estimate. This is a simple incentive for the contractor to submit a bid with the least amount of working days.

Contractor's Cost Reduction Incentive Proposal

CC Meyers Inc., general contractor, was awarded the contract on April 11, 2006, to build the bridge in 80 days. The very next day, the general contractor, along with the consultant designer and precast manufacturer, submitted a Cost Reduction Incentive Proposal (CRIP) to use a non-standard, double-tee precast, prestressed concrete beam with multiple stages of post-tensioning in the field. The proposed non-standard double-tee beam was twice as wide as the original design (8 ft compared to 4 ft), which resulted in half as many girders per span than in the original design (total of 60 girders compared to 120 girders). A standard double-tee section is typically suitable for 40 to 65 ft span lengths and was not an option in Caltrans approved beam sections for such long spans used for the replacement bridge.

The proposed beam design used two-stage post-tensioning to maintain continuity of the superstructure under applied loads. Cast-in-place diaphragms between beams and first stage post-tensioning were used to create continuity under the weight of the 6-in.-thick deck slab. A second stage post-tensioning was applied to carry the bridge superimposed dead and live loads. Original superstructure depth was maintained in the proposed design and no changes were made to the substructure design as a consequence. Not only was the double-tee section non-standard, but also the two-stage post-tensioning was not a standard practice for the precast industry in California.

Special precast, prestressed concrete, double-tee beams with two-stage post-tensioning were used.

Caltrans immediately evaluated the proposal and approved the concept primarily to reduce construction time and increase possible cost savings. Closure of the nearest precasting yard and the difficulty of transporting long girders on the local roads made this CRIP necessary.

A 6-in.-thick deck was cast-in-place before applying the second-stage post-tensioning.

The contractor's consultant submitted superstructure design plans to Caltrans by the end of April for review and approval. Caltran's engineers performed independent calculations using time-dependent concrete properties to check stresses in the double-tee beams during pretensioning, erection, first post-tensioning, deck casting, and second post-tensioning construction stages. The independent check also included a review of deflections at various construction stages, long-term camber, and superstructure seismic response. The Caltrans independent check resulted in modifications to the amount and location of the prestressing.

Moreover, post-tensioning a 980-ft-long continuous double-tee beam frame resulted in large longitudinal forces being transferred to the substructure pile shafts under service loads. These were not part of the original design. Caltrans requested the superstructure to bent cap connection be modified at the two outer bents to allow for longitudinal movement during post-tensioning without transferring any displacement to the pile shafts. Metal plates with a greasy surface were used to allow for superstructure sliding with minimal force transfer to the supporting bent caps. After initial shortening of the superstructure and grouting of the post-tensioning ducts, the connection was locked in place.

Caltrans engineers cooperated with the contractor's consultant to review and approve the design and detailing of the proposed double-tee beams in two weeks.

Accelerated Construction

The general contractor mobilized equipment and demolished the existing pony truss bridge while the proposed alternate superstructure design was prepared by his consultant and reviewed and approved by Caltrans. A temporary trestle was built on the upstream side of the bridge to provide access to the work site for demolition of existing bridge and the construction of the new bridge.

Construction started in early May with driving the CISS pile shafts and building the drop bent caps. Pile load testing was conducted at two different bent locations to determine actual in-situ soil resistance. No reduction in driving length was gained however, as better than estimated soil skin friction and end bearing were not warranted.

In the meantime, new beam formwork was built and the double-tee beams were fabricated and transported to the site in May and June. Erection of the beams was completed in July. The cast-in-place diaphragms and intermediate diaphragms were cast in early August, followed by the first-stage post-tensioning operation. The deck was cast and the second-stage post-tensioning took place three days later. Work around the clock resulted in the bridge opening to traffic on August 17, 2006, one week before the school year began, to the delight of the local community.

Testing of pile shafts for possible reduction in driving length.

Ahmed M. M. Ibrahim, Linan Wang, Tariq Masroor, and Minh Ha are senior bridge engineers, and Ofelia Alcantara is a supervising bridge engineer with the California Department of Transportation, Sacramento, Calif. *The authors appreciate the contribution of Jeffery Thorne.*

HAMILTON FORM CREATES FUNCTION

2 CASE STUDY

ESCAMBIA BAY BRIDGE

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Don Theobald
Vice President of Engineering
Gulf Coast Pre-Stress

The Challenge:

Gulf Coast Pre-Stress — which itself was reeling from Katrina's impact — was awarded four major bridge projects damaged by hurricanes, including Escambia Bay Bridge near Pensacola, Florida.

The bridge elements include a heavily reinforced pile cap with a unique "on-site," cast tension connection to the precast/prestressed pile. This *moment connection* was designed to provide a continuous beam configuration and provide resistance to uplift from potential future storm surges.

The Solution:

Hamilton Form built the custom formwork including the piling, pile cap and BT78 forms. The pile cap form design includes two-piece, tapered voids at the connection locations to allow the top to be "popped" after initial preset of the concrete to accommodate final stripping.

The Results:

The forms worked perfectly. The new bridge added an additional line of traffic in each direction and was fully opened ahead of schedule.

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Silica Fume Association

The Silica Fume Association (SFA), a not-for-profit corporation based in Delaware, with offices in Virginia and Ohio, was formed in 1998 to assist the producers of silica fume in promoting its usage in concrete. Silica fume, a by-product of silicon and ferro-silicon metal production, is a highly-reactive pozzolan and a key ingredient in high performance concrete, dramatically increasing the service-life of structures.

The SFA advances the use of silica fume in the nation's concrete infrastructure and works to increase the awareness and understanding of silica fume concrete in the private civil engineering sector, among state transportation officials and in the academic community. The SFA's goals are two-fold: to provide a legacy of durable concrete structures and to decrease silica fume volume in the national waste stream.

Some of the recent projects completed by the SFA, under a cooperative agreement with the Federal Highway Administration (FHWA), include:

- The publication of a *Silica Fume User's Manual*—the manual is a comprehensive guide for specifiers, ready mixed and precast concrete producers, and contractors that describes the best practice for the successful use of silica fume in the production of high performance concrete (HPC).
- The introduction of a Standard Reference Material (SRM)® 2696 Silica Fume for checking the accuracy of existing laboratory practices and to provide a tool for instrument calibration. This SRM is available from the National Institute of Standards and Technology (NIST).

A much anticipated research program nearing completion by the SFA is the testing of in-place silica fume concrete under service conditions. At the conclusion of this research the results will demonstrate the benefit of silica fume concrete's unparalleled long-term performance. For more information about SFA, visit www.silicafume.org.

PRECAST DESIGN

The first bridge to be constructed in the state of New Hampshire using the design-build format has proven a success. The project also features the first use in the state of adjacent, voided, precast, prestressed concrete slab beams with integral abutments combined with expanded polystyrene (EPS) geofoam blocks behind the abutments. The construction approach and design techniques offer great potential for future designs that are attractive, quickly constructed, and cost effective.

The new structure, located in Hanover, N.H., over Mink Brook, replaced an existing steel bridge with a precast, prestressed concrete span supported on integral abutments and a single row of steel H-piles driven to bedrock. Early in the design process, the team realized that a precast concrete design was the only solution capable of meeting the tight construction scheduling—but it also proved to be more cost effective than structural steel would have been.

New Hampshire design-build project features self-consolidating and high-performance concretes

Mink Brook Bridge features adjacent, voided, precast, prestressed concrete slab beams with integral abutments.

profile

NEW HAMPSHIRE ROUTE 10 BRIDGE OVER MINK BROOK / HANOVER, N.H.

ENGINEER: Parsons Brinckerhoff (PB), Manchester, N.H.

GEOTECHNICAL ENGINEERING CONSULTANT: Golder Associates, Manchester, N.H.

PRIME CONTRACTOR: R.S. Audley Inc., Bow, N.H.

PRECASTER: J.P. Carrara & Sons Inc., North Clarendon, Vt., a PCI-certified producer

PRESTRESSING STRAND: Strand-Tech Martin, Summerville, S.C.

AWARDS: *PCI Design Award, Best Bridge with Spans Less than 75 feet, 2007*

MEETS TIGHT SCHEDULE

by Keith Donington, PB

Railing anchor bolts were preset in the curb parapets prior to casting at the precasting plant.

The bridge's combination of voided slabs and integral abutments eliminated the need for expansion joints.

Only Partial Removal Needed

The bridge design required only partial removal of the existing bridge before constructing the new structure. This approach eliminated a significant amount of in-water demolition and minimized excavation depths. That in turn reduced the impact to the stream, environment, and existing slope vegetation. The portions of the existing bridge that remained intact were carefully selected to allow clearance for pile-driving in addition to serving as protection against scour for the new substructure.

Initially, the design-build team suggested dewatering near the abutments to remove parts of the existing wingwall foundations and to install vertical supporting piles. That approach proved too difficult and jeopardized the construction schedule. As a result and to completely avoid the existing footings, the new piles were battered in both the transverse and longitudinal directions at both abutments. This maintained stability of the structure during the temporary first stage of construction as well as for the final, as-built condition.

The bridge's combination of voided slabs and integral abutments, which was adapted from a detail supplied by the Northeast regional office of the Precast/Prestressed Concrete Institute, eliminated the need for expansion joints. It previously had been used by the New York State Department of Transportation with good results.

The precast beams were set on temporary bearing pads and made integral with the abutments when the backwall concrete was placed during the same placement as the deck overlay. The prestressing strands extending from the beams and reinforcement from the deck into the backwall resulted in a rigid connection. Thermal movements are accommodated by bending in the single row of steel H-piles oriented with their weak axis parallel to the abutments and located on a line behind the existing abutment footing. This resulted in a minimum span length of 48 ft.

The superstructure and integral abutments, together with the pile foundation, act as a rigid-frame system. It was analyzed under dead and live loads, as well as lateral loads using a two-dimensional GT-STRUDL-based plane frame computer model. Soil and pile stiffness together with the point of fixity of the piles were evaluated by geotechnical engineering consultants on the project. Those factors were included in the model together with stiffness properties of the beams and integral abutments to determine internal forces.

The adjacent slab beams were transversely post-tensioned at the abutments and midspan to help prevent longitudinal cracking along the shear keys.

PRECAST, PRESTRESSED CONCRETE VOIDED SLAB BEAMS / NEW HAMPSHIRE DEPARTMENT OF TRANSPORTATION, CONCORD, N.H., OWNER

BRIDGE DESCRIPTION: 48-ft-long, single-span voided slab bridge

STRUCTURAL COMPONENTS: 12 typical voided slab deck beams, two fascia voided slab deck beams, and two railing-curb parapets

BRIDGE CONSTRUCTION COST: $694,805

The use of self-consolidating concrete provided superior appearance and long-term durability.

The bridge's cross-section comprises fourteen 3-ft-wide, 21-in.-deep adjacent precast, prestressed concrete voided slab beams constructed with self-consolidating concrete, eliminating the need for concrete vibration. The resulting concrete is totally homogeneous with a uniform surface finish and is free of "bug" holes. It also provides a superior appearance and long-term durability. To further enhance that durability, a calcium-nitrite corrosion inhibitor was added to the mix.

EPS Blocks Stabilize Abutments

EPS blocks were placed behind the integral abutments to minimize lateral passive soil pressure on the abutments and wing walls. That placement, in turn, reduced fixed-end movements at the abutments and enhanced flexibility of the frame system. The lateral pressure from the EPS blocks acting on the back face of any vertical concrete wall or bridge abutment is considered nearly equal to zero.

High-performance concrete (HPC) was used in the 5-in.-thick deck on the beams, rather than the more customary bituminous paving on a waterproofing membrane. HPC also was used for the backwalls and approach slabs. The HPC overlay was reinforced to integrate the beams' backwall ends with the abutments, so the bridge could be designed without expansion joints. Galvanized welded wire reinforcement was used in the concrete deck.

The design-build approach and design techniques offer great potential for future bridges.

The HPC also was used to provide a second line of defense for the transverse post-tensioning that interconnects the beams, helping prevent longitudinal cracking of the grouted shear keys. Such a condition has typically occurred on more heavily trafficked adjacent, precast beam-type bridges. The overlay acts compositely with the beams for superimposed dead loads and live loads, providing more structural efficiency compared to a non-composite overlay.

The HPC used in the approach slabs included pozzolan admixtures to produce a low permeability concrete with improved durability. Using this mix eliminated the need for the customary waterproofing membrane over the slabs, which saved time. The approach slabs were set 1-1/2 in. below finished grade, rather than level with the deck concrete, to allow for a bituminous top course to be placed simultaneously with the roadway approach's bituminous overlay paving.

Railing anchor bolts were preset in the curb parapets prior to casting at the precasting plant. This resulted in parapets that matched the beams and produced both time savings and superior concrete quality.

To remove the existing bridge, the deck was longitudinally saw-cut into sections between the stringers. With a crane located behind each abutment, the beam and deck pieces were lifted onto a trailer for disposal. The existing abutments and wing walls were saw-cut horizontally and removed above the cut with an excavator-mounted hydraulic hammer.

Phased Construction Implemented

Two-phase construction was used to replace the existing bridge, with traffic maintained in an alternating one-way pattern using temporary traffic signals. Implementation of the one-way traffic pattern was delayed until after the school year, to avoid disrupting bus routes and was removed when school returned in the fall. This created a very aggressive construction schedule based on the amount of bridge work required in a limited window of time.

The first construction phase involved replacement of the east side of the bridge. Pedestrian traffic, which was maintained throughout construction, was relocated to a temporary sidewalk structure adjacent to the west fascia of the existing superstructure.

During the second phase, when the west side was replaced, both vehicular and pedestrian traffic used the bridge's newly constructed east side. Pedestrian traffic was separated from vehicular traffic using a temporary guardrail system installed with removable anchors. This ensured that the pedestrians remained on the west side of the traffic, which aided the flow, as sidewalks on both bridge approaches were on the west side of the highway.

The design approach provided key benefits to the environment while meeting local users' needs for minimizing disruption and producing a cost-effective structure. Costs also should be minimized throughout the life of the project due to the attention paid in the initial planning stages to durability needs and corrosion resistance. This project and its design-build approach offer key elements that can be used in the future in New Hampshire and in other states to reduce construction time and both short- and long-term costs.

Environmental Protection

The bridge was constructed within the limits of the New Hampshire Department of Transportation wetlands permit. Wildlife crossings beneath the bridge along both banks were provided. A stormwater pollution prevention plan was prepared in compliance with the permit requirements of the Environmental Protection Agency's Phase II National Pollutant Discharge Elimination System Program. The team's continuous coordination with the Hanover Conservation Commission, which manages the Mink Brook Nature Preserve, ensured that the appropriate landscaping and seeding mix for restoration would be implemented once the project was complete.

Keith Donington is senior supervising structural engineer with PB, Manchester, N.H.

National Ready Mixed Concrete Association

Founded in 1930, the National Ready Mixed Concrete Association (NRMCA) is the leading industry advocate. Our mission is to provide exceptional value for our members by responsibly representing and serving the entire ready mixed concrete industry through leadership, promotion, education, and partnering.

NRMCA works in conjunction with state associations on issues such as quality, business excellence, promotion, and regulatory concerns. We strive for constant communication on the latest information, products, services, and programs to help our members expand their markets, improve their operations, and be their voice in Washington.

NRMCA offers certifications for both ready mixed concrete production facilities and personnel. Certified producers strive to provide the highest quality ready mixed concrete in the safest and most efficient ways possible.

NRMCA is a principal sponsor of CONEXPO-CON/AGG. This show features over two million square feet of exhibits including an information technology pavilion and an emphasis on live demonstrations throughout the exhibit areas. The show brings together contractors, producers, and equipment manufacturers at the largest exposition in the Western Hemisphere for the construction industry.

NRMCA is also the principal sponsor of the Concrete Technology Forum, an annual symposium on state-of-the-art concrete technologies. The Forum brings researchers and practitioners together to discuss the latest advances, technical knowledge, continuing research, tools, and solutions for ready mixed concrete.

For more information, contact the National Ready Mixed Concrete Association, 900 Spring Street, Silver Spring, MD 20910, 888-84NRMCA (846-7622), www.nrmca.org.

CONCRETE CONNECTIONS

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

IN THIS ISSUE

http://www.oregon.gov/ODOT/HWX/OTIA
Information about the Oregon Transportation Investment Act is available at this site. Click on OTIA III Bridge Delivery Program for specific information related to bridges.

http://projects.dot.state.mn.us/35wbridge/index.html
Visit this website for the latest information about the I-35W St. Anthony Falls Bridge and to view the on-site webcams.

www.ncdot.org/projects/us17bypass/
This North Carolina Department of Transportation website contains information about the U.S.17 Washington Bypass.

http://environment.transportation.org/teri%5Fdatabase/
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.

http://www.franklincountyengineer.org/bridge_inventory.htm
Visit this site for an inventory of bridges in Franklin County, Ohio, including photographs and a description of each structure.

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 50 issues of HPC Bridge Views, a newsletter published jointly by the FHWA and the NCBC to provide relevant, reliable information on all aspects of high-performance concrete in bridges.

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.

http://trb.org/TRBNet/ProjectDisplay.asp?ProjectID=349
NCHRP Report 549, Simplified Shear Design of Structural Concrete Members, contains the findings of research performed to develop practical equations for design of shear reinforcement in reinforced and prestressed concrete bridge girders. Recommended specifications and commentary plus examples illustrating application of the specifications were also developed. The results of this research have been incorporated into the AASHTO LRFD Bridge Design Specifications.

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 1

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 recent years, FHWA and its partners have made substantial contributions to the environment and to the communities, through planning and programs that support sustainability, wetland banking, habitat restoration, historic preservation, air quality improvements, bicycle and pedestrian facilities, context-sensitive solutions, wildlife crossings, and public and tribal government involvement.

In this and the next issue of *ASPIRE*,™ we will explore opportunities for research, development, deployment, and education for enhancing the natural and built environment. This article describes the accomplishments following the passage of the National Environmental Policy Act (NEPA).

All photos: Shutterstock.

National Environmental Policy Act

In 1969, Congress passed the NEPA to establish a national policy for the environment, including the establishment of a Council on Environmental Quality.

The purposes of NEPA were to

- Declare a national policy that will encourage productive and enjoyable harmony between people and the environment;
- Promote efforts which will prevent or eliminate damage to the environment and biosphere, and stimulate the health and welfare of people;
- Enrich the understanding of the ecological systems and natural resources important to the nation; and
- Establish a Council on Environmental Quality.

More specifically, Congress tasked the Federal Government to use all practicable means, consistent with other essential considerations of national policy, to improve and coordinate federal plans, functions, programs, and resources so that the nation may

- Fulfill the responsibilities of each generation as trustee of the environment for succeeding generations;
- Assure safe, healthful, productive, and aesthetically and culturally pleasing surroundings for all Americans;
- Attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences;

- Preserve important historic, cultural, and natural aspects of our national heritage, and maintain, wherever possible, an environment that supports diversity and variety of individual choice;
- Achieve a balance between population and resource use which will permit high standards of living and a wide sharing of life's amenities; and
- Enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources.

Congress also directed the President to assemble a Council on Environmental Quality in his Cabinet and to prepare an annual Environmental Quality Report to Congress.

Signing the NEPA on New Year's Day of 1970, President Nixon remarked that he had become further convinced that the 1970s absolutely must be the years when America pays its debt to the past by reclaiming the purity of its air, its waters, and our living environment. Following the NEPA, the President introduced initiatives to improve water treatment facilities, establish national air quality standards and stringent guidelines

to lower motor vehicle emissions, and launch federally funded research to reduce automobile pollution. The President also ordered the clean-up of federal facilities that had fouled air and water, sought legislation to end the dumping of wastes into the Great Lakes, forwarded to Congress a plan to tighten safeguards on the seaborne transportation of oil, and approved a National Contingency Plan for the treatment of petroleum spills.

U.S. Environmental Protection Agency

Having successfully introduced the environmental initiatives, President Nixon decided to establish an autonomous regulatory body to oversee the enforcement of environmental policy.

The President declared to the House and Senate his intention to establish the U.S. Environmental Protection Agency (EPA) with the following missions:

- Establishment and enforcement of environmental protection standards consistent with national environmental goals.
- Conduct research on the adverse effects of pollution and on methods and equipment for controlling it; the gathering of information on pollution; and the use of this information in strengthening environmental protection programs and recommending policy changes.
- Assist others, through grants, technical assistance, and other means, in arresting pollution of the environment.
- Assist the Council on Environmental Quality in developing and recommending to the President new policies for the protection of the environment.

In July of 1970, the White House and Congress worked together to establish the EPA in response to the growing public demand for cleaner water, air, and land. Having cleared all the statute hurdles, the U.S. Environmental Protection Agency opened its doors in Washington, D.C., on December 2, 1970. EPA was established to consolidate in one agency a variety of federal research, monitoring, standard-setting, and enforcement activities to ensure environmental protection. EPA's mission is to protect human health and to safeguard the natural environment—air, water, and land—upon which life depends.

For more than 35 years, the EPA has been working for a cleaner, healthier environment. Remarkable progress has been made in protecting human health and safeguarding the natural environment. There is a long list of accomplishments including the following:

- Clean Air Act to set national air quality, auto emission, and anti-pollution standards.
- Agreement between the United States and Canada to clean up the Great Lakes, which contain 95% of America's fresh water and supply drinking water for 25 million people.
- Clean Water Act, limiting raw sewage and other pollutants flowing into rivers, lakes, and streams.
- Phase out of leaded gasoline.
- Fuel economy standards and tail-pipe emission standards for cars, resulting in the introduction of catalytic converters.
- Resource Conservation and Recovery Act, regulating hazardous waste from its production to its disposal.
- Superfund to clean up hazardous waste sites. Polluters are made responsible for cleaning up the most hazardous sites.
- Ban on ocean dumping of sewage sludge and industrial waste.
- Pollution Prevention Act, emphasizing the importance of preventing—not just correcting—environmental damage.
- The National Environmental Education Act, signifying the importance of educating the public to ensure scientifically sound, balanced, and responsible decisions about the environment.
- Clean Water Action Plan to continue making America's waterways safe for fishing and swimming.
- New emission standards for cars, sport-utility vehicles, minivans, and trucks.
- Regulations requiring more than 90% cleaner, heavy-duty, highway diesel engines, and fuel.
- Cleaner fuels and engines for off-road diesel machinery such as farm or construction equipment.

A lot has been accomplished. A lot more is yet to be accomplished. Federal, state, tribal and local governments, industry, academia, and corporations must continue to work together in research, development, deployment, and education to achieve the environmental protection and enhancement goals set out in 1970 when the EPA was formed. In the next issue of *ASPIRE*, I will discuss the impact of Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy For Users (SAFETEA-LU).

U.S. Department of Transportation
Federal Highway Administration

Assure Quality! Specify PCI Certification!

PCI certification is the industry's most proven, comprehensive, trusted, and specified certification program. PCI certification offers a complete regimen that covers personnel, plant, and field operations. This assures owners, specifiers, and designers that precast concrete products are manufactured by companies that subscribe to nationally accepted standards and that are audited to ensure compliance.

PCI certification is more than just inspections and documentation. It is based on comprehensive expertise. For over 50 years, PCI has set the standards and developed the knowledge for the design and construction of precast concrete structures. This feat is set on the foundation of millions of dollars of research, dozens of technical guides and manuals, a network of over 80 committees, PCI's professional and experienced staff, and support of over 2000 PCI members.

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To learn more about PCI certification and PCI, go to: www.pci.org/certification

Or call
Dean Frank, P.E.
Director of Quality Programs
Precast/Prestressed Concrete Institute
209 W. Jackson Blvd., Suite 500
Chicago, IL 60606
(312) 583-6770

Expanded Shale, Clay, and Slate Institute

Rotary Kiln Produced
Structural Lightweight Aggregate

The Expanded Shale, Clay & Slate Institute (ESCSI) is the international trade association for manufacturers of expanded shale, clay, and slate (ESCS) aggregates produced using a rotary kiln. The institute is proud to sponsor *ASPIRE*™ magazine.

Sustainable concrete bridges must be durable bridges. Durable concrete must have both low permeability and few or no cracks. Lightweight aggregate concrete has been shown to have enhanced properties in both of these issues. The enhanced performance of lightweight concrete has been attributed to a number of factors including:

- Internal curing provided by premoistened lightweight aggregate;
- Elastic matching of the lightweight aggregate and hardened paste;
- Excellent bond between the lightweight aggregate and paste; and
- Lower modulus of elasticity and higher strain capacity.

The enhanced durability of lightweight concrete, combined with the obvious benefits of reduced density, results in structures that will last longer. Such structures conserve valuable natural resources as well as scarce funds for bridge construction and rehabilitation.

For more information on lightweight concrete, including references discussing the factors mentioned above, please visit www.escsi.org. The members of ESCSI look forward to assisting owners, designers, and concrete producers in using lightweight concrete for bridges.

Long-Span Precast U-Girders in

Colorado

by Michael L. McMullen, Jamal I. Elkaissi, and Mark A. Leonard, Colorado Department of Transportation

I-270 Ramp over I-76: 2282 ft long, 230-ft-long maximum span, 764-ft-minimum radius.

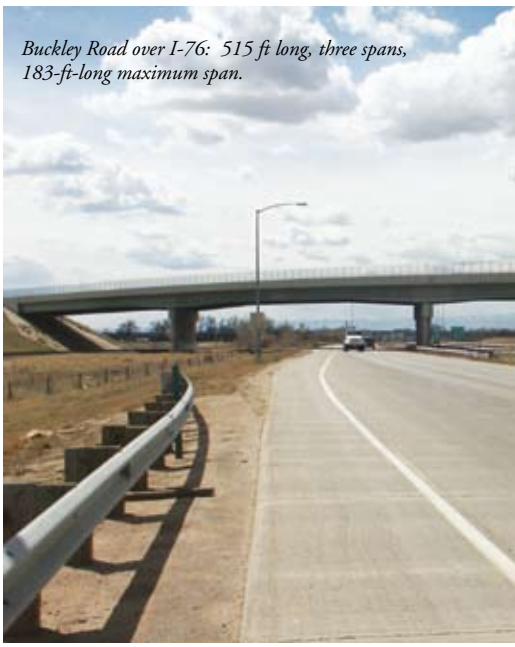
Colorado has benefited from a practice of utilizing a broad range of structure types for its bridges. The Colorado Department of Transportation (CDOT) designers and its consultants have generally been given wide latitude to use the structure type that is optimal for the conditions at a particular bridge site. Consequently, CDOT has a relative large inventory of structural steel, precast concrete, and cast-in-place concrete bridges, with a wide variety of different sections used for these three different materials.

Since the 1960s, precast, prestressed concrete beams have become the structure type used most often because of the typical economy and general construction advantages of these beams. Making the beams more efficient and easier to construct has been pursued aggressively. However, precast concrete beams tended to be used in the past for simpler bridges; the exceptions being the seven segmental box girder bridges used for I-70 over Vail Pass and the nine segmental bridges through Glenwood Canyon. These were especially large and topographically unique projects. Precast girders were generally regulated to spans less than 140 ft and to bridges with little or no curvature.

This began to change in 1992 and has increased more in recent years. This year alone, CDOT will construct four precast concrete bridges with span lengths over 140 ft using horizontally curved girders. These will be in addition to the four existing bridges built since 1995 that meet this description. The recently completed I-270 bridge over I-76 is one of these. Although not the first constructed, it was the first bridge designed using yard fabricated, long-segment trapezoidal U-girders for a bridge with significant horizontal curvature. "Long-segment" is used here to differentiate these girders from those conventionally referred to as "segmental concrete box girders" which are typically built with shorter segment lengths.

The broadened applicability of precast, prestressed concrete girders has been accomplished by adopting new beam shapes, increasing maximum shipping lengths, utilizing post-tensioning for splicing, and employing curved segments. In 1992, CDOT transitioned from precast I-beams with 5-in.-thick webs to bulb-tee beams with 7-in.-thick webs, permitting the use of post-tensioning ducts. The first precast concrete long-segment girder spliced with post-tensioning built in Colorado was the Buckley Road Bridge over I-76. This bridge was constructed in 1992 using 72-in.-deep bulb-tee beams with 96-in.-deep haunched bulb-tee pier segments.

Before the Buckley Road Bridge was built, CDOT had already begun developing plans for using precast, trapezoidal box girders for long-segment construction. The Park Avenue Ramp over I-25, built in 1995, and the I-225 Ramp over Parker Road, built in 2000, were the first long-segment box girders designed in Colorado



Buckley Road over I-76: 515 ft long, three spans, 183-ft-long maximum span.

I-225 Ramp over Parker Road: 1343-ft-long, 254-ft-long maximum span, 702-ft-minimum radius.

to be precast. Because early fabricator interest in these sections was not certain, these bridges were designed giving the contractor the option of using either precast or conventional cast-in-place concrete, but the contractor had to allow traffic below the main spans during the day. On Park Avenue, the contractor elected to use the precast girder alternative for the main spans. These segments were cast on site and moved to their final position during the night. The largest segment weighed 212 tons. On the Parker Road project, the main span segments were cast-in-place during the night.

The success of these two bridges helped stimulate local fabricators' interest in precast, trapezoidal boxes. From 1995 to 2000, CDOT developed standards for precast trapezoidal U-girder sections. The sections were developed so they could be used for either straight or horizontally curved segments and could also be pretensioned, post-tensioned, or a combination of the two. A web thickness of 5 in. can be used for fully pretensioned segments and 7.5 in. to 10 in. for segments with a combination of pretensioning and post-tensioning. Available girder depths vary from 48 in. to 96 in.

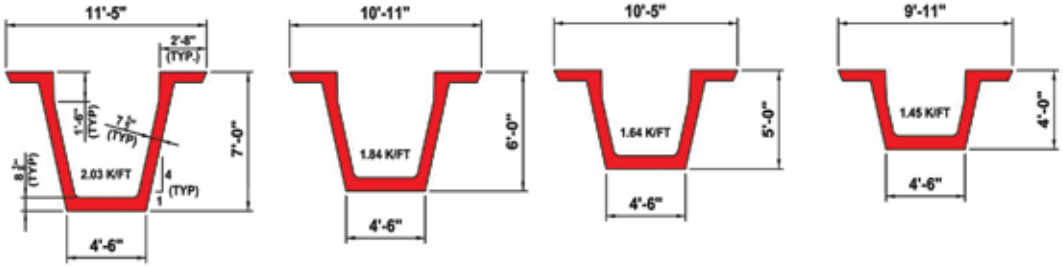
A U-shape was selected over a closed box to eliminate the expense of interior formwork that needs to be removed or sacrificed. The U-shape also facilitates having top flanges with areas that can be readily varied from project to project. It also allows easy inspection of the interior surfaces in the fabricator's yard.

With the new bulb-tee and U-girder sections and the addition of post-tensioning for splicing, shipping weights became the primary limitation on segment lengths. In 2001, CDOT worked with local fabricators and shipping and erection subcontractors to upgrade maximum shipping weights from 85 tons to 120 tons. This was especially significant for the U-girders given their greater weight per unit length.

In addition to economics, aesthetics and constructability have been central aspects of these changes to precast girders. Trapezoidal box girders became especially popular starting in the 1970s. CDOT responded by providing these sections using structural steel, cast-in-place concrete, and short-segment segmental bridges.

Cast-in-place concrete has been especially versatile for providing a variety of trapezoidal box girder sections for different conditions including long spans and complicated geometry. The new precast U-girder sections provided CDOT with a competitive alternate to structural steel girders in terms of cost, on-site construction time, and appearance. The recently completed I-270 Ramp over I-25 in Denver is an example of the elegance that can be obtained with trapezoidal boxes.

The project was bid using a contracting method where a fully detailed default design was provided in the plans and specified contractor design-build alternatives to the default were allowed. In this case, the default design was a steel box girder bridge and the successful contractor elected to use the precast U-girder design-build alternative.

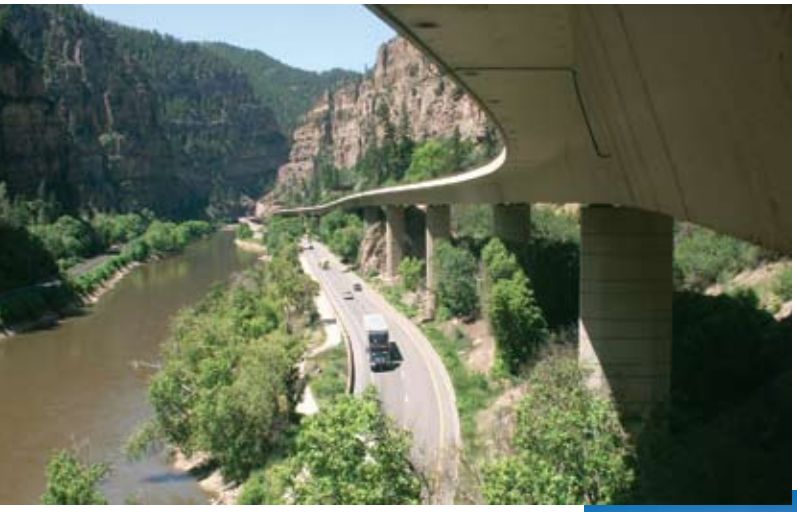


Precast U-girder — group II pretensioned or post-tensioned.

Conventional short-segment, precast concrete box girder bridges provide a trapezoidal box section and also the means for construction without the heavy influence of falsework in high traffic areas. The Hanging Lake Viaduct in Glenwood Canyon is one of the most popular bridges in Colorado for its appearance. The new precast U-girder standards, however, can provide a competitive alternate to these bridges. The U-girder sections are now commonly used in Colorado for bridges of all sizes. Three precast concrete fabricators in Colorado have the formwork necessary to readily produce these sections—making them competitive for small, as well as very large projects.

The State Highway 52 over I-25 Bridge is an example of a smaller project using the U-girders and built in 1999. This was the first vehicular bridge in Colorado constructed using shop fabricated precast U-girders. This bridge is a striking example of the clean details that can be obtained for a simple grade separation with long-span concrete U-girders, and by simply ordering the girders from a local fabricator.

I-270 Ramp over I-25: 1424 ft long, 200-ft-long maximum span, 950-ft-minimum radius.



I-70 Hanging Lake Viaduct: 6396 ft long, 208-ft-long maximum span, 1650-ft-minimum radius.

I-70 Trinidad Viaduct: NB 1985 ft long, SB 2058 ft long, 256-ft-long maximum span, 1000-ft-minimum radius.

State Highway 52 over I-25: 322 ft long, 3 spans, 190-ft-long maximum span.

The I-70 Trinidad Viaduct, currently under construction, is an example of a large project using the U-girders. Here again, CDOT employed a default design with specified contractor design-build alternatives. The default design was for a conventional short-segment concrete box girder bridge. The successful contractor elected the design-build alternative using the precast U-girders provided by a local fabricator.

Looking to the future, there are a number of enhancements CDOT would like to see. Strong-backs were used on the Buckley Road Bridge for splicing the girders without the use of shoring towers. Further developments to allow splicing the girders in the air would improve construction options. On the Trinidad Viaduct, full-width precast deck panels were used to eliminate forming the bridge deck overhangs. Other developments to reduce deck forming would reduce on-site construction time. The Park Avenue Bridge had significant vertical curvature and twisting superelevation, but was formed on-site with plywood. Form innovations that could push the limits of girder geometry would be desirable. The Parker Road Bridge used fiberglass reinforcement and carbon fiber prestressing strands for the precast deck panels. Future use of non-corrosive reinforcement and prestressing strands would enhance durability.

Having a large arsenal of different structure types readily allows for superstructure optimization for the cost, constructability, and appearance needs of a particular bridge site. The relative recent developments with precast concrete, especially the development of precast U-girders, has significantly strengthened CDOT's arsenal of potential solutions.

Michael L. McMullen is supervising bridge design engineer, retired; Jamal I. Elkaissi is supervising bridge design engineer; and Mark A. Leonard is state bridge engineer with the Colorado Department of Transportation.

For more information on Colorado bridges, visit www.dot.state.co.us.

The new King Avenue Bridge over the Olentangy River incorporates modern design while reflecting the history of the earth-filled arch that it replaced. Photos: Franklin County Staff.

Creating and Maintaining **CIVIC PRIDE** in Franklin County

by James A. Pajk, Franklin County, Ohio

The Franklin County Engineers Office is responsible for the inspection and maintenance of 363 bridges. With a population greater than one million residents, numerous communities in the county have redeveloped their historic districts, many of which have crossings that enter into these areas. Through the public involvement process, Franklin County understands the importance of creating gateways into these communities. The use and innovation of modern concrete bridge engineering has helped our office achieve goals of maintaining and creating structures with civic value.

The existing structures along the Olentangy and Scioto Rivers were designed and built as a result of the 1908 City of Columbus Master Plan and the 1913 flood. Structures on Lane Avenue, Third Avenue, and King Avenue were multi-span, earth-filled reinforced concrete barrel arches. A plan was developed to replace each structure and to design a bridge to complement its surrounding community.

Most municipalities and civic groups wished to preserve the structures that they perceive as gateways. The need to expand infrastructure facilities made preservation difficult. Ultimately, the new structures retained the aesthetic elements of historic significance while using modern construction techniques. Each new structure was designed with an expected service life of 100 years and all incorporate concrete as the predominant material. Concrete, whether it is pretensioned, post-tensioned, or simply reinforced, allowed us to expand our creative thinking in terms of appearance and design. Precasting was also used to achieve a high level of quality control, limit construction time, and minimize impacts in environmentally sensitive streams.

Lane Avenue over the Olentangy River serves as a gateway to Ohio State University. The two-span, cable-stayed bridge limited environmental impacts, and the use of concrete allowed the contractor to complete the project 5 months early.

The design for the King Avenue Bridge over the Olentangy River was selected to reflect the history of the bridge that it was replacing. The bridge serves as the south entrance to Ohio State University. Public opinion led the design team to create a five-span segmented, precast concrete arch. This structure type was the first of its kind in Ohio. Seventy individual precast arch rib sections were post-tensioned by the precaster, connected at midspan by a diaphragm, and post-tensioned together. Precast, prestressed box beams were used to span from pier seats to arch seats. The high-performance concrete deck has transverse post-tensioning to limit deck cracking.

Lane Avenue, which serves as the main entrance to Ohio State University, was to be widened from three to five lanes of traffic. A more modern bridge was selected to reflect recent expansion of university facilities and lessen environmental impacts. The result was a stunning two-span, cable-stayed bridge with post-tensioned concrete trapezoidal tub girders. The use of concrete allowed the contractor an opportunity to better control the schedule and open the bridge 5 months early.

Franklin County is fortunate to have three bridge maintenance crews very capable of fabricating and constructing concrete structures. We take pride and satisfaction in the work they perform. From late fall to early spring, barring a heavy snow season, crews precast concrete components for future contract projects.

Franklin County crews fabricated concrete slabs and stay-in-place railing panels for the Dublin Road Bridge to expedite construction.

For our Dublin Road Bridge, the crews fabricated concrete slabs and stay-in-place railing panels to expedite construction and limit the amount of formwork for the railings. Each precast concrete slab unit was unique in size and length. The railing panels were match cast for the fascia slab units.

For the Clifton Avenue superstructure replacement, the crews precast traffic barrier and wall panel sections using formliners. The use of these precast elements on contractor supplied precast, prestressed concrete box beams with a composite deck allowed the project to be completed in four months.

County crews also fabricate four-sided and two-piece, four-sided box culverts for replacement structures. The two-piece units consist of precast bottom slabs with a keyway and three-sided units, which are placed on top of the bottom slab with the joints staggered. Using two-piece units reduces the weight and allows smaller equipment to be used in the field.

Franklin County also has an aggressive concrete sealing maintenance program. All concrete barriers are cleaned and sealed with a non-epoxy silane every 5 years. In addition, all major concrete decks are sealed with a soluble reactive silicate to limit the penetration of salts and oils into any deck cracks.

In conclusion, our office will continue to use concrete as a material that will satisfy the needs of our constituents for generations to come.

James A. Pajk is Franklin County deputy engineer, bridges in Columbus, Ohio.

Load Modifier for Ductility, Redundancy, and Operational Importance

by Dr. Dennis R. Mertz

Article 1.3.2.1 of the *LRFD Bridge Design Specifications* introduces a load modifier, which is the product of factors relating to ductility, redundancy, and operational importance. The original intent of this load modifier was to encourage enhanced ductility and redundancy. Operational importance was included to provide additional reliability for more important bridges.

When the first edition of the *LRFD Specifications* was written, research into the effects of ductility and redundancy on the safety or reliability of bridges was not available. Thus, the factors were subjectively chosen as discussed in the Commentary C1.3.2.1. These subjective choices were also considered to be conservative by the specification writers. Since the writing of the first edition, research into the effects of redundancy on reliability has been completed through NCHRP Projects 12-36, *Redundancy in Highway Bridge Superstructures*, and 12-47, *Redundancy in Highway Bridge Substructures*. This research has yet to be implemented in the *LRFD Specifications*. It has been partially implemented in the forthcoming *AASHTO Manual for Bridge Evaluation* as system factors on the resistance side of the load and resistance factor rating (LRFR) equation, especially in the provisions for rating segmental concrete bridges.

A limited study of the effects of the specified load modifier on the resulting reliability of 95 girder-bridge configurations is reported in Article C1.3.2.1. The results from the study are as follows:

Reliability Index as a Function of Load Modifier

Load Modifier, η	Reliability Index, β
0.95	3.0
1.00	3.5
1.05	3.8
1.10	4.0

The placement of the load modifier, which reflects ductility and redundancy on the load side of the LRFD equation, may seem counterintuitive as ductility and redundancy are characteristics of the resistance and not the load. The modifier was placed on load side and not on the resistance side for a practical reason as they must be related to the maximum and minimum load factors of Table 3.4.1-2 used for permanent loads. This relationship is illustrated in the following equations:

For permanent loads increased by the maximum load factor:

$$\eta_i = \eta_D \eta_R \eta_I$$

For permanent loads decreased by the minimum load factor:

$$\eta_i = \frac{1}{\eta_D \eta_R \eta_I}$$

where

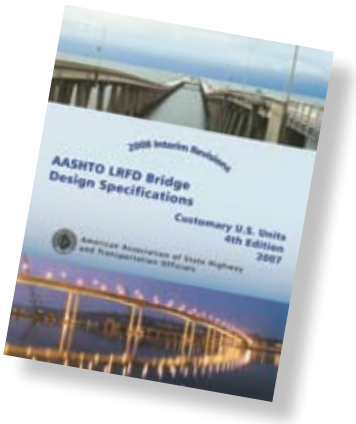
η_i = load modifier: a factor related to ductility, redundancy, and operational importance

η_D = a factor related to ductility as defined in Article 1.3.3

η_R = a factor related to redundancy as defined in Article 1.3.4

η_I = a factor related to operational importance as defined in Article 1.3.5

The notion of the load modifier, at least in terms of ductility and redundancy, may be counter to traditional bridge designer thought. Traditionally, bridge designers are taught that sufficient ductility and redundancy must be provided; differing degrees of ductility and redundancy are not typically considered. For example, bridges are categorized as redundant or non-redundant. Thus, the concept of load modifier has not been embraced by the practicing bridge engineering community. Typically, bridge owners specify that the load modifier be taken as 1.00 and that the basic requirements for ductility and redundancy in the *LRFD Specifications* be satisfied. Any enhancements to ductility are not considered to reduce the specified loads, and non-redundant structures are not allowed. Such owner-specified reactions to the load modifier of the *LRFD Specifications* can be found in many state bridge design manuals.



PCAP
Prestressed Concrete Association of Pennsylvania
www.pcap.org

CABA
Central Atlantic Bridge Associates
www.caba-bridges.org

Advantages of Prestressed Concrete Bridges:

Simple Design
A variety of components can accommodate various load-carrying capabilities and span potentials. Connections between elements are simple – carefully planned details result in economy.

Low Initial Costs
Prestressed concrete bridges are economical as well as provide for minimum downtime for construction. Carefully planned details speed the total construction process and result in overall economy.

Fast, Easy Construction
Construction is fast with prestressed concrete. As the beams are factory produced, site preparations can proceed. Prestressed concrete is ideal for limited access locations and where speed of erection is crucial.

Widely Used and Accepted
While prestressed concrete is a relatively new product – the first use of prestressed concrete in the United States was in a bridge, built in the early 1950s in Philadelphia, Pennsylvania – today, about a third of all bridges built use prestressed concrete beams.

Assured Quality
The quality of prestressed concrete bridges is controlled under factory conditions. Because of such protected conditions, weather can't affect the result of casting. Unlike cast-in-place concrete, precast concrete offers greater consistency and more options for high quality finish.

For more information, call us or any of our member companies:

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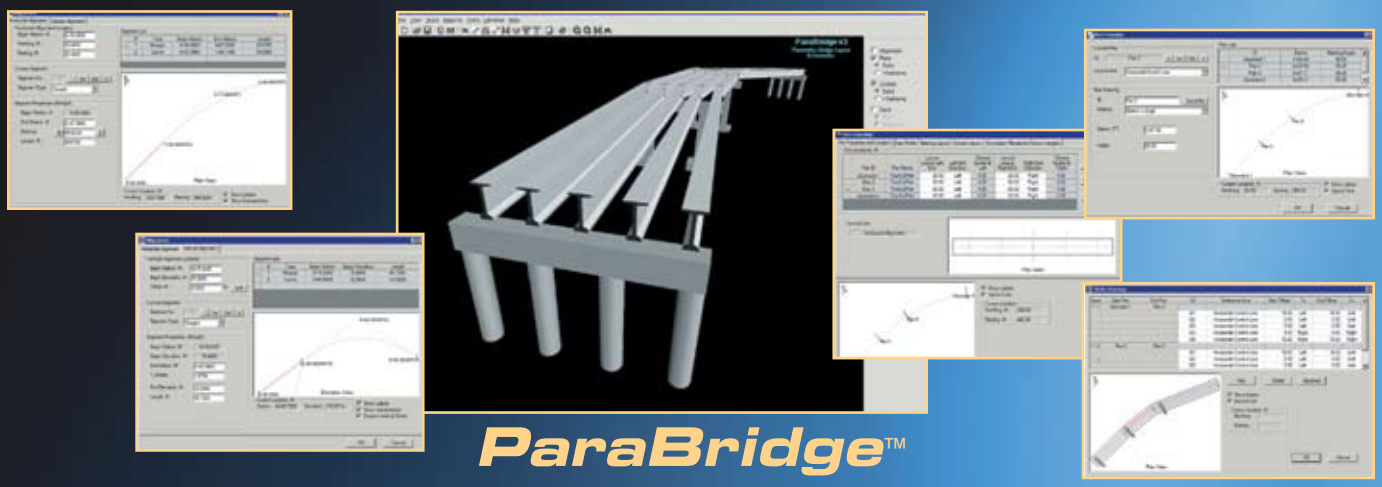
Integrated 3D Design



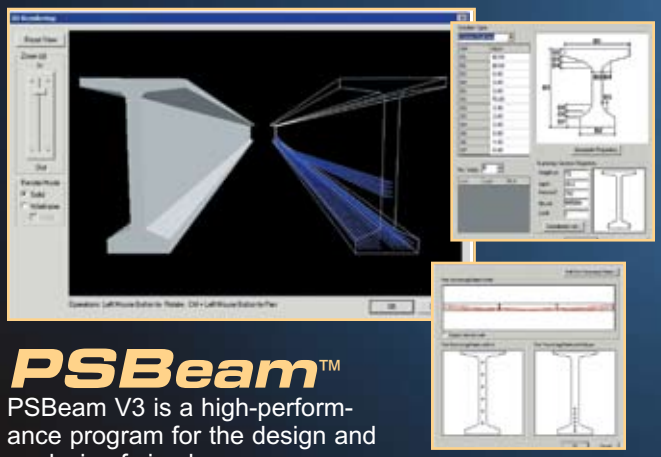
ParaBridge™

ParaBridge is a parametric 3D bridge modeling and design system that puts powerful and flexible bridge generation, geometry, and design tools at your fingertips. Designed and created within the state-of-the-art Microsoft .NET Framework, it represents the future of integrated 3D bridge engineering.

Laying out a bridge has never been easier. Powerful modeling wizards help you rapidly import or enter bridge alignment and roadway data. Girder and pier framing tools give you a highly-leverage means of describing the bridge layout. Piers and girders of multiple types can then be inserted into the project—all parametrically.

All pertinent bridge geometry is solved by ParaBridge: deck elevations, girder lengths, bearing data, quantities, etc. Element design is smooth and seamless. Both PSBeam and ETPier are tightly integrated with ParaBridge.

The main view is a true 3D object-oriented model of your bridge. Zoom, rotate, and pan the model in real time. ParaBridge utilizes technically advanced OpenGL graphics with no third party add-ins. The result: a high-performance system with no need to purchase an expensive CAD system to run it. Yet the model can be seamlessly passed to CAD software as needed.

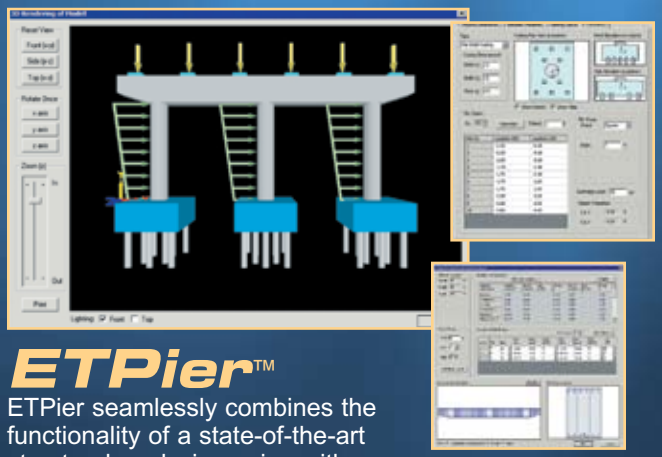


PSBeam™

PSBeam V3 is a high-performance program for the design and analysis of simple-span or continuous precast, pretensioned or post-tensioned concrete bridge girders. PSBeam is the software of choice for many bridge engineers who demand flexibility, high performance, and rock-solid reliability.

Virtually any precast beam type and pretensioning pattern can be handled by PSBeam. You can even extend spans using spliced girder technology.

PSBeam can accommodate the needs of all stakeholders in the life of a girder—from design to fabrication, through to load rating.



ETPier™

ETPier seamlessly combines the functionality of a state-of-the-art structural analysis engine with concrete column, beam, and footing design. Integration of these critical design tasks into one system means you get superior productivity and flexibility with improved quality control.

ETPier is specifically designed for bridge substructures. Powerful parametric modeling wizards are included to facilitate rapid structure layout and generation. Specify which load combinations to investigate and ETPier will automatically process them and quickly identify the governing case for each component of the structure.

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