ASPIRE™

THE CONCRETE BRIDGE MAGAZINE

SUMMER 2009

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Rigolets Pass Bridge

Near Slidell, Louisiana

BIJOU STREET BRIDGE
Colorado Springs, Colorado

I-45 GALVESTON CAUSEWAY
Galveston County, Texas

VANCOUVER LAND BRIDGE
Vancouver, Washington

LAMBERTS/BRAMBLETON VIADUCT
Norfolk, Virginia

FOX RIVER BRIDGE
North Aurora, Illinois

Social, Economic, and Ecological Benefits of Sustainable Concrete Bridges

Photo: David Evans and Associates.

Photo: Traylor Bros. Inc.

Photo: Janssen & Spaans Engineering Inc.

Features

Departments

Photo: David Evans and Associates.

Advertisers Index

EDITORIAL

Grade for the Nation's Bridges: "C"

Photo: Ted Lacey Photography.

John S. Dick, *Executive Editor*

As *ASPIRE*™ continues through its second year of exploring sustainable design, our PERSPECTIVE in this issue looks at the condition of the nation's bridges as evaluated by the American Society of Civil Engineers (ASCE). Author Andrew Herrmann of Hardesty & Hanover is chair of the Advisory Committee for the preparation of ASCE's 2009 Report Card for America's Infrastructure, which gives America's bridges a "C."

Although that grade may seem acceptable, it is the same rating bridges received in 2005, during ASCE's last evaluations. That means there has been no appreciable improvement. In fact, grades for "Roads" and "Transit" actually went down. Not surprisingly, ASCE suggests a commitment to increased funding must be made. They also propose a plan comprising five nationally-focused recommendations. Two of these are: 1) Promote sustainability and resilience and 2) Address life-cycle costs and ongoing maintenance. The details are included in the article beginning on page 14.

Sustainability, Resilience, Life-Cycle Costs, and Maintenance

State-of-the-art concrete bridges provide sustainable solutions. Recent issues of *ASPIRE* contain a PERSPECTIVE by an authority on sustainability. Plus, nearly every project report confirms our belief that modern concrete bridges help achieve this goal, with long-term durability, freedom from frequent maintenance cycles, rapid constructability, low environmental impact, and opportunity for aesthetic creativity.

This Issue of *ASPIRE*

Some unique capabilities of concrete are revealed in an article on the Bijou Street Bridge over Monument Creek in Colorado Springs, Colo. by Gregg Reese. By using post-tensioning to create four-span continuity, 60-in.-deep U-girders combine with an 8-in.-thick deck to create a main span of 148 ft with girders spaced as much as 22.8 ft apart. The article begins on page 18.

An advantageous combination of concrete components—cast-in-place, double-cell box girder segments, precast I-girders with precast deck panels, and cast-in-place concrete in the substructure and deck—will provide long-term durability for the I-45 Galveston Causeway in Texas. The article starts on page 22.

Frederick Gottemoeller, in his Aesthetics Commentary on the Vancouver Land Bridge, in Washington, says, "There are no obvious dividing lines between bridge and ramp or between ramp and site." Indeed the project, a pedestrian bridge connecting important historic and geographic attractions over a busy six-lane state highway, has been described as a landscaped interpretive work of art. The story of this unique project begins on page 26.

The state of Louisiana Department of Transportation and Development has conducted more research on high-performance concrete than most other states. Faced with considerable environmental challenges, the state puts into practice what it has learned. Read about recent examples in the article on page 46.

In a somewhat similar way, Washington County, Ore., is replacing its more susceptible bridges with state-of-the-art concrete structures. Using high-performance concrete and techniques that provide for rapid construction, the county is ever mindful of environmental issues such as bat habitats. Read their story on page 51.

This issue of *ASPIRE* includes its special semiannual section, Maintenance, Repair, and Rehabilitation of Concrete Bridges. Beginning on page 39, this segment includes reports from across the country. If you have suggestions for future reports, please contact us through the *ASPIRE* website, www.aspirebridge.org.

PCI Precast/Prestressed Concrete Institute
ASBI American Segmental Bridge Institute
PCA Portland Cement Association
EIG Epoxy Interest Group
SFA Silica Fume Association
ACAA American Coal Ash Association
ESCSI Expanded Shale Clay and Slate Institute

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Rigolets Pass Bridge, Slidell, La.
Photo: Louisiana DOTD.

READER RESPONSE

Editor,
In the Winter 2009 issue of ASPIRE™ there was an article about the bridge built across our dry canyon [see Custom Arches, page 18]. We would like to get extra copies of the magazine. A copy of the magazine was sent to us by the consultant from Portland (OBEC Consulting Engineers) that worked with the city in planning and building the bridge. Before that, our director, Chris Doty had not seen the publication. We were awarded the 2008 Portland Cement Association Bridge Design Award and want to use the magazine as part of the display of the award, to have at our city hall building, and to display at several other buildings that feature our city's accomplishments; and of course to archive in our files. It took several years, lots of paperwork, meetings, patience, and perseverance to accomplish this bridge of which we are all very proud. Thank you for your help.

Becky Leslie
Public Works Department
City of Redmond, Ore.

Maple Avenue Bridge, Redmond, Ore.

Editors,
Thanks for sending along some extra copies of ASPIRE. The article on the Cotton Lane Bridge in Arizona looks fantastic. You guys did a wonderful job—thanks once again!

Laura Craig, marketing specialist
Michael Baker Jr. Inc.
Phoenix, Ariz.

Editor,
QBS International is a structural engineering firm that designed the Forty Foot Pedestrian Bridge that was featured in your Spring issue. Our project manager, John Ruff, subscribes to your magazine and showed us his copy but we wanted to have our own copies and another subscription.

Julie R. Gangi
QBS International Inc.
Pennsauken, N.J.

Editor,
Per our conversation today, we would like to order 100 copies of the Spring 2009 issue for our 40th Street Task Force Committee members. [see PBS&J Standardizing Success, page 8, featuring the 40th Street Bridge, Tampa, Fla.]

Bridget Gordon
City of Tampa
Public Works, Transportation Division
Tampa, Fla.

EDITOR'S NOTE

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

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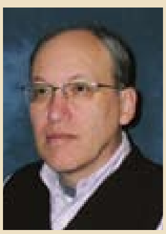
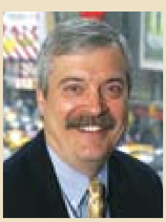
M. Myint Lwin is Director of the FHWA Office of Bridge Technology in Washington, D.C. He is responsible for the National Highway Bridge Program direction, policy, and guidance, including bridge technology development, deployment and education, and the National Bridge Inventory and Inspection Standards.



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.



Andrew W. Herrmann is a senior partner of Hardesty & Hanover LLP, New York, N.Y. He is presently the chair of the Advisory Committee for the preparation of the 2009 American Society of Civil Engineers' Report Card for America's Infrastructure.

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

MANAGING TECHNICAL EDITOR

Photo: Ted Lacey Photography.

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

CONCRETE CALENDAR 2009/2010

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

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

September 4, 2009
PCA Bridge Design Awards Submittal Deadline

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

September 21-23, 2009
Western Bridge Engineer's Seminar
Sacramento Convention Center and Sheraton Grand Hotel, Sacramento, Calif.

September 29-October 2, 2009
PCI Quality Control & Assurance Schools, Levels I, II & III
Four Points Sheraton – O'Hare Hotel, Chicago, Ill.

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.

November 12-13, 2009
Developing a Research Agenda for Transportation Infrastructure Preservation and Renewal
Keck Center of the National Academies, Washington, D.C.

January 10-14, 2010
Transportation Research Board Annual Meeting
Marriott Wardman Park, Omni Shoreham, and Hilton Washington, Washington, D.C.

February 24-26, 2010
Concrete Bridge Conference
Hyatt Regency, Phoenix, Ariz. (Abstracts due July 15, 2009)

March 21-25, 2010
ACI Spring Convention
Sheraton Hotel, Chicago, Ill.

May 29 – June 2, 2010
Third International CEB-fib Congress and Exhibition
PCI Annual Convention
PCI-FHWA National Bridge Conference
Gaylord National Resort & Convention Center, National Harbor, Md.

July 11-15, 2010
5th International Conference on Bridge Maintenance, Safety and Management
International Association for Bridge Maintenance and Safety (IABMAS)
Loews Philadelphia Hotel, Philadelphia, Pa.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DAVID EVANS AND ASSOCIATES

GOING BEYOND ENGINEERING

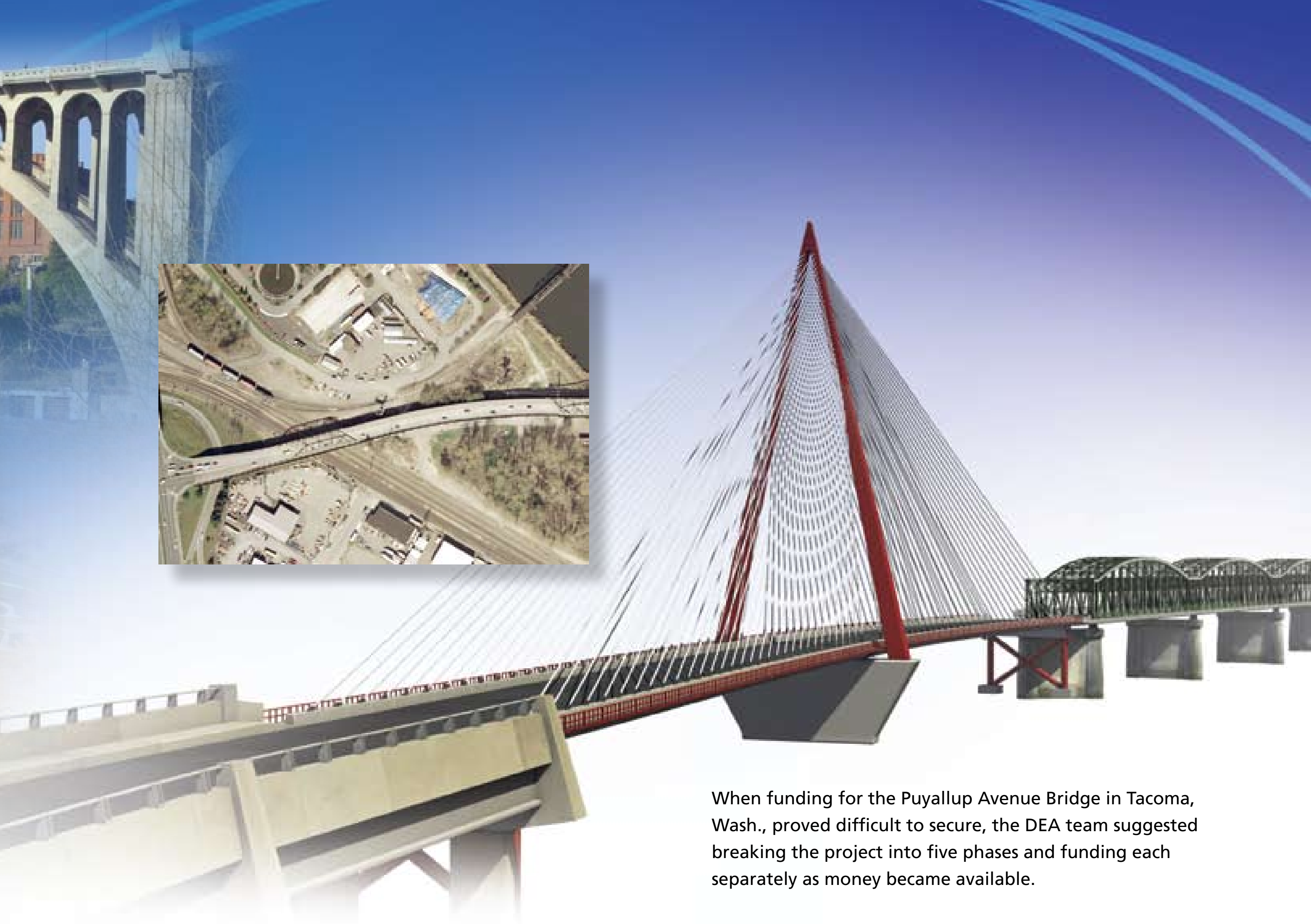
by Craig A. Shutt

A holistic commitment to owners and staff drives David Evans and Associates' success

Since its founding 33 years ago in Portland, Ore., David Evans and Associates Inc. (DEA) has focused on successfully serving an expanding array of client needs and ensuring employees share in that success. That two-pronged focus has allowed the company to grow quickly and diversify its talents, making it more of a partner with both its clients and its staff.

DEA follows two key principles, says founder David F. Evans. "Our core purpose is to improve the quality of life while demonstrating stewardship of the built and natural environments," he says. That stewardship extends to working relationships, he adds. "Our founding philosophy has been to find outstanding professionals and give them the freedom and support to do what they do best." Their reward derives in part from ownership of the firm, based on an Employee Stock Ownership Plan, which has been in place from early in the company's history.

"Our success comes from having a well-rounded team with a lot of diverse expertise that everyone will listen to," Evans says. "That helps us create projects that will cost less money, provide higher quality, and meet all of the owners' needs."



When funding for the Puyallup Avenue Bridge in Tacoma, Wash., proved difficult to secure, the DEA team suggested breaking the project into five phases and funding each separately as money became available.

'Our success comes from having a well-rounded team with a lot of diverse expertise that everyone will listen to.'

Multi-Faceted Approach

Those needs are evolving, say DEA designers, to include services that make our engineers more of a full strategic partner with clients. "We found that, today, a bridge project is not a pure bridge project any more," says Raj Bharil, DEA's director of the bridge discipline, who is based in the Olympia, Wash., office. "We aren't being asked to simply give the owner plans that can be bid and you're done. There's much more to it."

The requirements can include a range of disciplines, including environmental impacts, sustainability goals, and evaluating historical and cultural contexts, hydraulic and resource needs, constructability, and permitting requirements. "More often, we are acting as a consultant on project management, discussing how to gain funding, how best to advertise the project, which permits are needed," he says. "It becomes a multi-faceted approach." Being involved early-on in a project can reap significant results. "You can't be just a pure bridge engineer today."

The Puyallup Avenue Bridge replacement project provides a good example of how early involvement pays off. The 2453-ft-long bridge comprises seven segments that connect downtown Tacoma, Wash., to the Port of Tacoma and the City of Fife. It crosses six sets of railroad tracks as well as the Puyallup River. City officials struggled with how to fund the project, until the DEA team suggested breaking it into five projects and funding each as money became available. As a result, the design of the first two segments for a new cast-in-place concrete viaduct and a concrete box-beam bridge, are almost finished. The rest will follow as funding allows.

"This approach means that new segments can be added easily without holding up progress," Bharil explains. "We could help define what the project actually was and what would be the most successful approach from the client's perspective."

DEA engineers also are doing more high-end specialized analysis work, especially for seismic needs, as so many of their clients are located in high seismic zones along the West Coast. The San Diego office in particular performs these analyses, and it has a close relationship with the bridge seismic researchers at the University of California, San Diego. "There are many more techniques available today for seismic analysis," explains Bob Dameron, regional manager for Southern California.

DEA analyzed the 554-ft-long concrete North Torrey Pines Bridge in Del Mar, Calif. Its analysis led to partially isolating the superstructure from the highly skewed bents and jacketing columns to provide more seismic resistance.

That focus began after the 1989 Loma Prieta earthquake, which emphasized the need to upgrade infrastructure. Today, most lifeline and other major bridges in the West have been retrofitted, he notes, but there are still many more that need to be improved.

DEA performs a wide range of seismic studies, which often lead to retrofit projects. An example is the work done on the North Torrey Pines Bridge in Del Mar, Calif. The 554-ft-long bridge, built in 1933, is a multi-span cast-in-place concrete bridge, which is eligible for the National Register. It was designed with highly skewed bents on the center spans over the railroad, and these bents were a focus of seismic upgrading. As part of a Simon Wong Engineering team, DEA performed global nonlinear seismic analysis that led to a design for partially isolating the bents, post-tensioning the entire bridge for continuity, and jacketing the columns to provide more seismic resistance.

Feasibility Studies Grow

"The new tools help us analyze all types of structures, big or small," says Gernot Komar, senior bridge engineer and manager of the San Diego office. "We can examine the construction sequencing on bigger structures and look at the impacts of various combinations of materials and determine feasibility." In some cases, these studies have found that certain design approaches won't be feasible, or the construction must be performed in a specific way. "How you approach the construction can be critical."

An example can be seen in the "shear link" towers being studied by DEA for the new Gerald Desmond Bridge in Long Beach, Calif., due for completion in 2016. The 2000-ft-long steel and concrete cable-stayed structure features a 1000-ft-long center span and two 525-ft-tall shear-link cast-in-place concrete towers. The towers ensure all parts of the structure experience primarily elastic behavior during an earthquake, except for the links, which can be driven far into the inelastic range, explains Komar. This allows them to absorb large amounts of energy while the bridge's vertical load-carrying capacity remains intact. The technique previously was used on the San Francisco-Oakland Bay Bridge, he notes.

Other creative concepts also are aiding DEA's designs. For its work on the Depot Street replacement project in Jackson County, Ore., the firm replaced an existing steel-truss bridge with a 411-ft-long concrete structure. It consists of a 105-ft-long, six barrel, cast-in-place concrete, post-tensioned approach box girder span. The main span is a signature, 306-ft-long, 63-ft-tall concrete tied arch utilizing a cast-in-place "waffle" shaped deck. Advanced design analysis and high-performance concrete enabled this to be the first concrete tied arch bridge to be constructed in the United States in more than 70 years. The main span arch was constructed on a temporary offset alignment so local access to the original bridge could be provided during construction. After the bridge section was completed, it was rolled laterally 26 ft into its final position using heavy-moving technology and opened to traffic in September 2006 within a week of closure to traffic.

Innovations offer great potential, but DEA's designers are acutely aware of the need to produce designs that can be constructed efficiently. "Constructability has become a key goal for all of our projects," says Ted Aadland, bridge construction engineer and

On the Depot Street Bridge in Jackson County, Ore., DEA created a plan to replace the existing steel-truss bridge with a 411-ft-long concrete tied-arch. A unique technique allowed the 306-ft-long main span to be built alongside the bridge and then rolled into place, maintaining local access to the original bridge for as long as possible, and reopening the bridge to traffic within a week.

president of Aadland Evans Constructors Inc. (AECI), a sister company to DEA. AECI was formed in 2006 as a subsidiary of David Evans Enterprises Inc., the holding company for DEA.

DEA holds constructability reviews with contractors to review alternatives and create an efficient plan, and those often involve members of the AECI staff, even if the company isn't providing construction services. "Engineers and contractors have different mindsets on projects, and our goal is to create elegant, functional designs that are easy to build."

More Emphasis on Sustainability

Owners also are emphasizing the desire to create sustainable designs that have low environmental impact during construction. This mindset fits with DEA's stewardship, says Evans. "A lot of issues that are important today—global warming, carbon footprints, green products, and design—have always been high on our own list." A project's carbon footprint is a key factor in design for owners, he notes. "Not just the construction itself but how to build without taking anything to the landfill. We are looking at many ways to recycle materials and improve our existing techniques in those areas."

The combination of new management techniques and cutting-edge design tools is aiding DEA's capability to produce sustainable designs. The more integrated approach allows the company to leverage cost-effective sustainability opportunities into all it's projects. This is something fairly new to bridge and other infrastructure design. Factoring life-cycle costs into the design has become a key ingredient, as operating and maintenance costs, as well as long-term durability, have a great impact on a bridge's ultimate cost effectiveness.

An example can be seen in the company's work on the Columbia River Crossing connecting Washington and Oregon. The $4-billion, multi-modal project includes new bridges and light rail plus a major reconstruction of 5 miles of I-5 between Portland, Ore., and Vancouver, Wash. As lead project consultant, DEA will be publishing the final environmental-impact statement and creating a Record of Decision. It is designing more than 50 bridges, most constructed with reinforced concrete, for the major interchanges and transit extension.

Sustainable design is such a key element of the program that the design team intends for the project to be the first capable of achieving LEED certification, even though no such certification exists for bridges. They look at how those concepts for material use, construction, and use of energy can be applied to bridges. The existing 90-year-old I-5 bridge has an extraordinarily high maintenance budget. One of two bridges at the site, it was constructed in 1917 as Highway 99 and later designated as I-5. A second bridge was added in 1958. One of DEA's goals is to reduce that maintenance cost substantially through good design.

Sustainable-design concepts will be followed so rigorously on the $4-billion Columbia River Crossing project connecting Washington and Oregon that DEA designers want it to meet LEED certification standards, even though none exist for bridges.

'A lot of issues that are important today—global warming, carbon footprints, green products, and design—have always been high on our own list.'

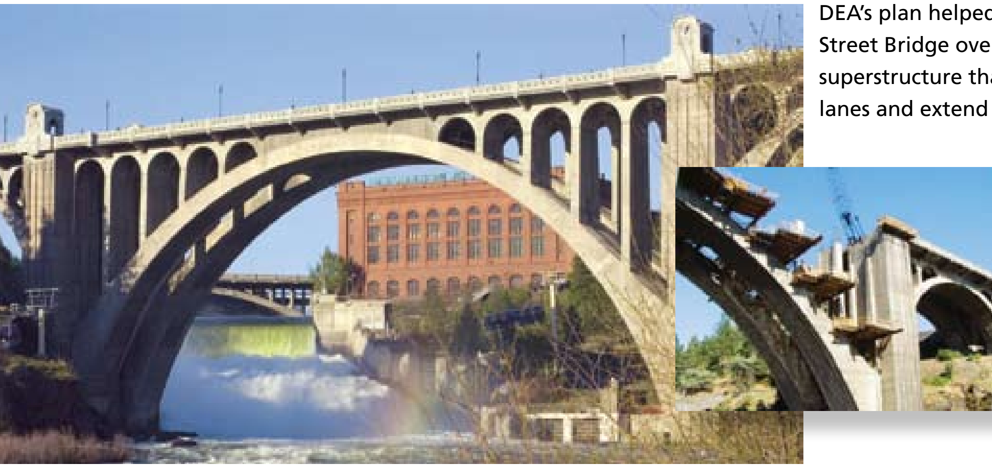
From Two Employees to over 900

David Evans and Associates Inc. (DEA) opened its doors on April 1, 1976, with just Evans and his former drafting partner, Dave Gould, who is now retired, on staff. The two had worked for a larger company where Evans served as regional manager. Soon he realized his division was successful and others were not—however, the company resisted his ideas. "I saw we should be doing things differently, but when they weren't receptive, I realized I needed to move in a different direction."

The two-man company took on a variety of site-development projects for housing developers and grew rapidly, employing 70 people by 1980. When a recession hit, Evans knew he would have to diversify and expand outside of the Northwest to retain people and keep growing.

The company, which had always shared its profits with employees, created an Employee Stock Ownership Plan (ESOP) in 1985, and has continued to grow and add new companies to its fold. Today, it operates more than 20 offices in seven states and employs more than 900 people.

DEA has won numerous awards, but it is most proud of its 2008 honors as the No. 73 best company to work for in the United States; as the No. 1 best large civil engineering firm and the No. 9 best overall firm to work for in the United States by *CE News Magazine*; and the 2007 Ethics Award from the Oregon Ethics in Business organization.



DEA's plan helped restore the look of the 97-year-old Monroe Street Bridge over the Spokane River while replacing a superstructure that will permit future widening from four to six lanes and extend the bridge's service life by another 75 years.

Rehabilitation Work Expands

Rehabilitation also offers options for sustainable design, as it drastically reduces new material use. An example of the possibilities can be seen in the Monroe Street Bridge over the Spokane River connecting the two sides of Spokane, Wash. DEA conducted a technical and economic feasibility study for restoring and modifying the existing 1911 bridge, a three-span, cast-in-place concrete, open-spandrel deck arch structure. The new superstructure was designed to allow future widening from four to six lanes and will extend the bridge's service life by another 75 years. A more detailed description is provided in *ASPIRE*™ Fall 2007.

In some cases, rehabilitation can be accomplished because original design loads were not well understood, creating over-designs that can be leveraged. "Some of the structures have never been reanalyzed, and they have a lot of reserve capacity," says Tom Whiteman, a senior bridge project manager based in the Olympia, Wash., office. "If we take the time to analyze them, we can restore them and provide a new 100-year life in addition to the years they've already served."

The company performs a variety of rehabilitation studies in addition to forensic work that helps to better understand existing structures and apply that expertise to new designs. One example is the San Diego office's forensic assessment of the I-405/55 HOV connector in Orange County, Calif., which was led by Dameron. The 2466-ft-long, 11-span bridge features curved concrete girders to accommodate a 900-ft-radius horizontal curve. When the tendons were stressed, some of the concrete on the curved portions cracked along interior girder webs, and DEA was asked to determine the cause and find a solution.

The team constructed global and local finite-element models to quantify the damage and provide analytical results. Shortly after this work, DEA analyzed generic curved girders to support the National Cooperative Highway Research Program Report 620, titled "Development of Design Specifications and Commentary for Horizontally Curved Concrete Box-Girder Highway Bridges." The 2-year program resulted in updated AASHTO guidelines for designing curved prestressed concrete girders. "Our goal is to squeeze out as much performance as possible from the materials," says Dameron.

'More times than not, the use of concrete for bridges makes sense today.'

Concrete Aids Innovation

DEA is doing more work on concrete structures these days, Bharil notes, because it has become the material of choice for bridges in the West. "The West Coast primarily uses concrete today," he says. "We have producers who give us high quality products and work closely with us on challenges; so concrete has become the predominant material."

Concrete manufacturers and fabricators have aided that process by continuing to expand its properties, he adds. "Concrete bridges can now span longer distances, and that expands its capabilities. More times than not, the use of concrete for bridges makes sense today."

The company often uses high-performance concrete, Whiteman notes, although it typically is provided without being specified because it develops strength faster and accelerates the construction schedule. "We specify concrete with a compressive strength of 4000 psi, but we often receive 6000 to 7000 psi concrete anyway." High-performance concrete and self-consolidating concrete are being considered and used more often by state DOTs as well, he says.

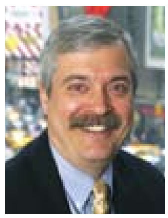
Durability is the goal more than added strength, he adds. Often, that added durability comes from the addition of fly ash, silica fume, slag, and other admixtures that also achieve sustainable-design goals.

Evolutions in concrete materials will continue, says Evans, as designers work closely with contractors and concrete companies to meet new challenges as they arise. "We expect to see more green materials being created, and as they become available, we will incorporate them," he says. Carbon fibers offer great potential, he notes, as they can provide strength and reduce the potential for corrosion in strands.

"There is a constant need for new ideas," adds Aadland, "In-water construction windows are being reduced, and it's becoming more difficult to build in the terrain that is available to us with minimal impact. New materials, such as lightweight concrete, can help us meet those challenges, which are getting more complex all the time."

Those challenges will be met with DEA's winning combination of strategic planning, involved teamwork, and concern for the entire bridge process. Going beyond the design phase to consider all aspects of the project ensures that owners receive the most efficient, highly aesthetic, and most cost-effective structure possible.

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



by Andrew Herrmann,
Hardesty & Hanover LLP

2009 ASCE REPORT CARD for America's Infrastructure

The American Society of Civil Engineers' (ASCE) 2009 Report Card for America's Infrastructure gave the nation's infrastructure an overall grade of "D" and estimated an investment need of $2.2 trillion dollars over 5 years to improve the condition from poor to good. Little to no progress has been made in the 4 years since the society released its previous report card in 2005, and the results were disappointing for the 15 categories graded in 2009—four Cs and 11 Ds. Of those grades, only one category—Energy—went up, and three categories—Aviation, Roads, and Transit—actually went down. And, the $2.2 trillion need for investment represents an increase of more than half a trillion dollars since the 2005 report estimated need of $1.6 trillion. The $2.2 trillion, which was adjusted for a 3% rate of inflation, represents capital spending at all levels of government and includes anticipated investments. Current spending amounts to only about half of this number, which leaves $1.1 trillion in needed investment for the United States over the next 5 years. As this increased investment need shows, inaction has only raised the price tag for infrastructure improvement.

More than one in four, of the nation's bridges is considered structurally deficient or functionally obsolete.

America's bridges fared only slightly better than the majority of the report card categories, receiving a grade of "C," though showing no improvement since the 2005 report. Almost 27%, or more than one in four, of the nation's bridges are considered structurally deficient or functionally obsolete. In real numbers, this means that of the 600,905 bridges listed by the U.S. Department of Transportation in December 2008, 72,868 (12.1%) were categorized as structurally deficient and 89,024 (14.8%) were categorized as functionally obsolete. Even though the number of deficient rural bridges declined by 8596 from 2005 to 2008, the number of deficient urban bridges increased by 2817 during the same time period. Considering the higher level of passenger and freight traffic on these urban bridges, the impact is significant.

According to the American Association of State Highway and Transportation Officials (AASHTO), a total of $10.5 billion was spent on construction and maintenance of bridges from all levels of government in 2004. That breaks down to $5.1 billion funded from the Federal Highway Bridge Program, $3.9 billion from state and local budgets, and an additional $1.5 billion in other federal highway aid. In 2008, AASHTO estimated that it would cost nearly $140 billion to repair all deficient bridges in the country—$48 billion to repair structurally deficient bridges and $91 billion to improve functionally obsolete bridges. AASHTO also estimated that to maintain current bridge conditions, or to simply keep the backlog of deficient bridges from growing any larger, would require a combined investment from public and private sectors of $650 billion over 50 years, an average annual investment of $13 billion. The cost of eliminating all existing bridge deficiencies over the next 50 years was estimated to be $850 billion (in 2006 dollars), an average annual investment of $17 billion.

How did the condition of the nation's bridges get to this unacceptable level? Simply put, these bridges are aging. The average age of a bridge in the United States is 43 years with a design life in many cases of only 50 years. And, while maintenance of a bridge, like the maintenance of a car, can increase useful and efficient life, postponing that maintenance generally leads to much more costly repairs in the short run and untimely replacement in the long run. Combine the age of the nation's bridges with a chronic level of under funding and the picture of how this occurred becomes very clear.

ASCE proposes five nationally focused key solutions.

What can be done to improve the state of the nation's bridges and other critical public works? In an effort to raise the grades on its infrastructure report card, ASCE proposes five nationally-focused key solutions. While these recommendations are broad in their scope, each can easily be applied directly to bridges:

- **Increase federal leadership in infrastructure**
  Bridges are a crucial part of the nation's transportation system. A new federal goal should be set to reduce the number of bridges classified as structurally deficient or functionally obsolete to less than 15% of the national inventory by 2013.

- **Promote sustainability and resilience**
  Bridges must be able to withstand both current and future challenges and be designed to protect the natural environment and withstand both natural and man-made hazards. Research and development should be funded at the federal level to develop more efficient methods and materials for building and maintaining the nation's bridges.

- **Develop federal, regional, and state infrastructure plans**
  Transportation investment at all levels must be prioritized and executed according to well-conceived plans that both complement the national vision and focus on system-wide outputs. Bridges, as a major component of transportation investment, must be prioritized and factored into overall infrastructure plans.

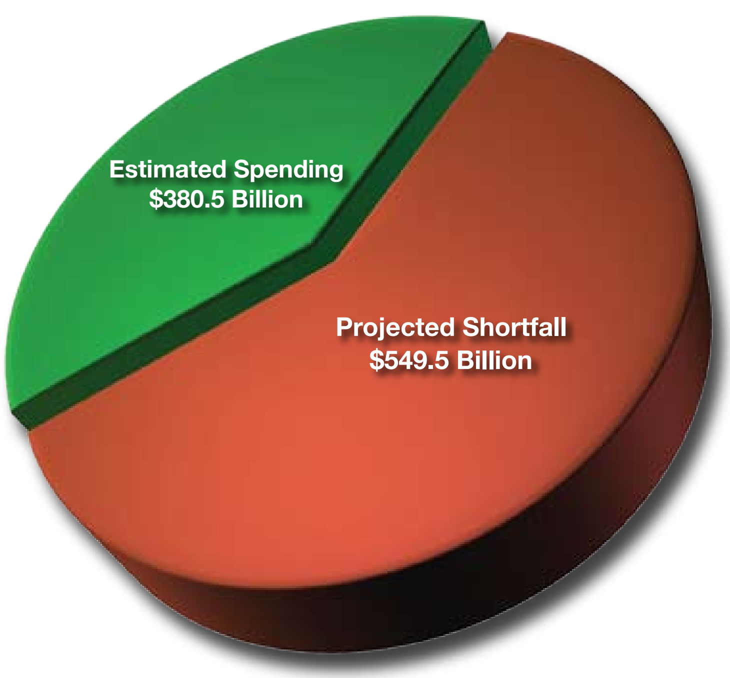
- **Address life-cycle costs and ongoing maintenance**
  Life-cycle analysis must be performed for new and existing bridges to account not only for initial construction, but also for the operation, maintenance, environmental, safety, and other costs reasonably anticipated during the life of the bridge, including recovery from natural or man-made hazards. This includes updated bridge inspection standards to determine conditions and an asset-management approach to maintaining bridges to achieve an appropriate balance between correcting immediate problems, conducting preventive maintenance, rehabilitating deficient bridges, and periodically replacing older bridges.

- **Increase and improve infrastructure investment from all stakeholders**
  All levels of government, owners, and users must significantly increase transportation investments to fund needed repair, renovation, and reconstruction of the nation's bridges. All viable financing programs must be explored and federal investment must be used to complement, encourage, and leverage investment from state and local governments as well as from the private sector.

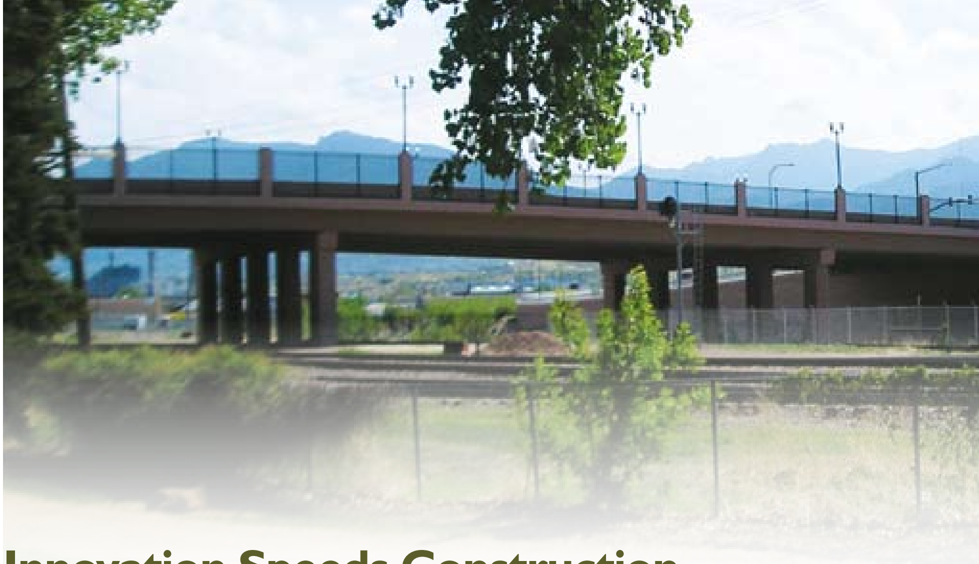
Needed Action

America's bridges are aging, and all too often are not being maintained at the necessary level of service. Adding to this, the investment gap for bridge needs is accelerating and the failure to adequately invest is leading to increased congestion and delays for motorists, wasted fuel, the further deterioration of bridge conditions, and increased safety concerns. Not only must Congress work to address these problems in the 2009 authorization of the Surface Transportation Program, but it must also set a goal to reduce the number of the nation's bridges classified as structurally deficient and functionally obsolete. Time is working against our country's infrastructure and capital is a scarce resource. However, if we do not invest now, we will end up paying more in the long run.

Estimated 5-Year Funding Requirements for Bridges and Roads
Total Investment Needs: $930 Billion



Designers of the Bijou Street Bridge in Colorado Springs, Colo., created a spliced, post-tensioned, precast concrete superstructure that features innovative prestressing layouts and variable cross-sections to accommodate the unique geometric requirements and erection scheme.



Unique precast concrete superstructure features variable cross sections to help finish complex structure in 8 months

Innovation Speeds Construction

BIJOU STREET BRIDGE OVER MONUMENT CREEK

by Gregg A. Reese, Summit Engineering Group Inc.

The bridge's seven girder lines form four continuous spans that cross Monument Creek and a rail yard with a 148-ft main span. The flared alignment was used to accommodate the variable deck widths.

Officials in the City of Colorado Springs, Colo., wanted to create a bridge that would relieve congestion and provide the major access to the downtown area, as well as project an image that allowed the structure to serve as a welcoming image for the city. To achieve these goals, designers created a bridge with a spliced, post-tensioned, precast concrete superstructure that features innovative prestressing layouts and variable cross-sections to accommodate a unique erection scheme. The approach allowed the project to be completed in only 10 months, including the demolition of the existing bridge that was necessary before construction could begin.

The bridge's seven girder lines form four continuous spans that cross Monument Creek and a rail yard. The girders vary in spacing from 13.2 ft to 22.8 ft to fit the deck width, requiring the girders to be kinked at closure joints.

The bridge's design matches the lanes from a new I-25 overpass and provides three continuous lanes of traffic into downtown, plus two lanes that cross I-25 into west Colorado Springs, two left-turn lanes to give freeway access, and sidewalks and bicycle lanes in both directions. The bridge deck's profile transitions from the at-grade roadway in the downtown area to a combined crossing over the rail lines and Monument Creek. It then blends into the I-25 ramps and overpass.

City officials wanted to improve user safety by providing a more gradual vertical curve to increase the sight distance on the bridge. This severely limited the vertical depth of the structure to ensure adequate clearance over the rail yard. In addition, the railroad wanted to limit foundations and construction access in the rail yard. A main span of 148 ft 3 in. was agreed upon to provide enough clearance for all current and future active tracks. Only one pier was placed in the yard, isolating an obsolete storage track. Access was limited to construction equipment, and no temporary supports for the girders were allowed in the yard.

profile

BIJOU STREET BRIDGE / COLORADO SPRINGS, COLORADO

ENGINEER: Summit Engineering Group Inc., Littleton, Colo.

PRIME CONTRACTOR: Rockrimmon Constructors Inc., Englewood, Colo.

PRECASTER: Encon Bridge Co. LLC, Denver, Colo., a PCI-certified producer

AWARDS: *Best Bridge With Spans Between 75 and 150 Feet, 2008 Precast/Prestressed Concrete Institute Design Awards*

Contractor Favored Precast Concrete

Preliminary design plans used to bid the project called for a steel-plate girder superstructure with a cast-in-place concrete deck to accommodate the structure's required depth limitations. The contractor requested a precast concrete girder alternate design to take advantage of his own capabilities. Even shortening the span over the rail yard slightly to accommodate pier-to-pier framing using 60-in.-deep precast concrete U-girders resulted in excessive deflections and stresses in the longer spans. So, the spliced, post-tensioned solution was ultimately selected.[1]

The precast concrete girders cantilever 15 ft beyond intermediate piers to support the free end of the adjacent girder during erection, eliminating the need for temporary supports in the rail yard. To allow this construction, designers used an innovative combination of debonded pretensioning, top flange post-tensioning, and internally thickened sections of the webs and bottom slab. Strongbacks were used at girder splices to eliminate the need for temporary shoring in the creek or the rail yard during construction. The bridge was fully post-tensioned between abutments after splices were cast and prior to placing the deck slab.

Substructure

The substructure design used the flexibility of the piers and foundation to minimize manufactured bearings. The foundations consisted of drilled shafts at the intermediate piers and the west abutment wall pier, while pilings provided a flexible abutment at the east end. Intermediate bents had four and five columns, depending on the width of the bridge. Each 4-ft by 8-ft column was founded on a single 42-in.-diameter drilled shaft.

For the crossing of Monument Creek, it was necessary to place a pier in the river basin. This pier was placed on the east bank of the normal creek channel to accommodate hydraulic design conditions for a severe flooding event.

Abutment Poses Challenges

The most challenging aspect of the substructure design involved the west abutment, which consists of a 40-ft-tall wall pier that is 180 ft wide. Along with the adjoining walls, it forms a channel liner for the creek at flood stage and provides support for the bridge. The wall pier was cast against the retaining wall of the existing bridge, and holes were cut through the existing wall to connect tie beams to the new wall pier. The top of the wall is then supported laterally by 19 reinforced concrete tie beams that connect to dead-man anchors 35 ft behind the back face of the pier in the backfill.

The superstructure was set on bearings at the top of the wall pier. A back wall was added and backfilled after the superstructure's post tensioning was completed. An expansion joint was placed between the superstructure and approach slab. The abutment wall features a full-height mechanically stabilized earth (MSE) wall panel on either side that tapers to the existing retaining walls.

The precast concrete U-girders cantilever beyond intermediate piers to support the ends of the drop-in sections during erection, eliminating the need for temporary supports in the rail yard.

The contractor requested a precast concrete girder alternate design to take advantage of his own capabilities.

SPLICED, POST-TENSIONED, PRECAST CONCRETE BRIDGE OVER MONUMENT CREEK AND UNION PACIFIC RAIL YARD / CITY OF COLORADO SPRINGS, OWNER

POST TENSIONING MATERIALS: DSI, Long Beach, Calif.

BRIDGE DESCRIPTION: Four-span continuous, spliced, precast concrete U-girder bridge, 475 ft long and 96 ft to 181 ft wide, with seven girders per span

BRIDGE CONSTRUCTION COST: $6.0 million

In keeping with CDOT regulations, epoxy-coated reinforcing bar was used for all elements of the bridge that touched the deck slab.

Superstructure

The girders for end spans 1 and 4 were erected from each abutment and cantilevered 15 ft past the first intermediate pier at each end. Girders in Span 2 spanned from a splice that was 15 ft up-station of Pier 2 and cantilevered 15 ft past Pier 3 into the west side of the rail yard. Drop-in girders were supported over the rail lines from the girders cantilevering over Pier 3 from the west and Pier 4 from the east side of the rail yard.

The ends of the drop-in girders at the splice locations were suspended from steel strongbacks that were attached to the cantilevered ends of the adjacent girders. At each splice, two 1$^3/_8$-in.-diameter post-tensioning bars were used to suspend the girders.

The design for the precast concrete girders incorporated features that were necessary to ensure smooth erection and maximize the use of existing forms. To accommodate the cantilevered erection scheme, post-tensioning tendons were placed in the webs near the top flange. A thicker web and tapered bottom flange were then necessary.

A 30-ft-long section with 10-in.-thick webs was centered over the piers. At the end of the 30-ft section, standard forms were used to transition to a typical 7$^1/_2$-in.-thick web. The section also featured a tapered bottom slab that varied from a standard 8-in. thickness to a maximum 20-in. thickness over the pier. The nonstressing end of the top flange tendons were placed at the interior end of the transition.

The longitudinal prestressing consisted of a combination of pretensioning and post-tensioning. The pretensioning was designed to optimize the prestress force in the positive moment regions. Prestressing in each section consisted of twenty to thirty-nine 0.6-in.-diameter strands in the bottom flange. Up to two-thirds of the pretensioned strands were debonded in the cantilevered section to minimize top flange tensile stresses. A seven 0.6-in.-diameter strand tendon was anchored in the top of each web in the cantilevered section and deviated to minimum cover over the piers. The top flange tendons were stressed and grouted prior to the girders being shipped and erected.

Parabolic tendons were placed in the webs and ran the full length of the bridge. The web tendons were stressed after the abutment and pier diaphragms and closures were cast and cured. The deck, which was designed to be fully replaceable, was placed after all post-tensioning was completed.

A continuous 6-ft-thick cast-in-place diaphragm section was used over the piers and abutments. Four columns of ducts were placed in the webs of the girders to provide a passage for a continuous reinforcing cage at the pier diaphragms. The girders were notched at the abutment ends to allow a continuous diaphragm and anchorage zone for the longitudinal web tendons. A thickened bottom slab section was included to temporarily support the girders at the abutments.

Deck Width Varies

The large degree of variation of the bridge deck width made it difficult to use continuous girder lines. The ultimate configuration created spans of approximately 105, 135, 148, and 86 ft, with a deck width that varied from 181 ft 1 in. at the west abutment to 95 ft 6 in. at the downtown end. To accommodate this variation, the girder spacings varied from 22.8 ft to 13.20 ft. The typical deck slab overhangs varied from 2.5 ft to 3.5 ft, increasing to a maximum of 17.4 ft on each side of the bridge at the west abutment curved turn lanes.

The bridge deck is 8-in.-thick cast-in-place concrete for Spans 2 to 4, where the girder spacing varied from 13.2 ft to 20.5 ft. The slab had clear spans of 4.2 ft to 11.5 ft. Girder spacing in Span 1 varied from 20.5 ft to 22.8 ft, with clear slab spans of 11.5 ft to 13.75 ft and a maximum overhang at the west abutment of 17.4 ft at the turnout lanes. The deck thickness in span 1 is 9 in. nominal but increases slightly due to the slope on the underside of the deck. The deck slab was conventionally reinforced for the entire length of the bridge.

City officials allowed the existing bridge to be closed during construction, to accelerate the schedule. Demolition took 2 months, after which constructing the new bridge took only 8 months, finishing 2 months ahead of schedule.

The Bijou Street Bridge used a variety of existing design technologies in innovative ways to meet a multitude of challenges that produced a cost-effective design. Its success resulted from careful consideration of every aspect of the existing conditions, methodologies, and capabilities to create a signature structure that was finished before the deadline.

Reference

[1] Reese, Gregg A., 2008, "Design and Construction of the Bijou Avenue Bridge over Monument Creek," Proceedings of the PCI-FHWA National Bridge Conference, October 5-7, Orlando, Fla., 13 pp.

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Gregg A. Reese is a principal with Summit Engineering Group Inc. in Littleton, Colo.

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

Segments were offset by one-half segment length to reduce the out-of-balance moment. Photo: Traylor Bros.

I-45 Galveston Causeway

by Jon Holt, Texas Department of Transportation and Scott Turnpaugh, Traylor Bros. Inc.

Utilizing concrete to avoid corrosion issues

The new I-45 Galveston Causeway Bridge, which crosses Galveston Bay in Texas, replaces two existing structures that had outlived their useful service life. The new bridge uses a combination of precast, prestressed concrete I girders and a cast-in-place concrete, variable-depth, double-cell, segmental box girder. Replacing the bridges, however, required overcoming some significant challenges due to the difficult site and the need to remove all existing substructure components down to 2 ft below the mud line.

By the time of their replacement, the original bridges featured a complex mix of construction materials and techniques that had been used to make economical repairs to keep the structures in service. The oldest bridge, built in 1938, featured 121 cast-in-place concrete spans plus a steel bascule span at the Gulf Intracoastal Waterway (GIWW). That bridge was supplemented in 1961 with an adjacent structure, consisting of precast, prestressed concrete girders and structural-steel plate girders for the center span at the GIWW.

At the time the second bridge was added, a portion of the original bridge had spans replaced with precast, prestressed concrete girders and a steel section to replicate the newer adjacent structure. After some years, due to the high level of exposure to chlorides in the marine environment causing corrosion and the advancing age of the structures, interim repairs to the structures were required. In 1979, footing repairs were completed, and in 1999, temporary repairs were made by installing steel girders beneath the deteriorated superstructure to provide additional support. Ultimately, it was decided that the structures could not be economically rehabilitated and needed to be replaced.

In considering options for the new structures, designers focused on the benefits and experience of the local construction community. Bridge projects in the Galveston area rely heavily on the precast concrete industry to provide materials for the bridges, which has resulted in no corrosion issues similar to those that arose on the bridges built many decades ago. The least cost construction method consists of precast, prestressed concrete I-beams, which have an approximate cost of $65/ft^2.

As a result, AASHTO prestressed concrete girders were specified for the long approaches on either side of the waterway, which make up most of the structure's 8592-ft length. A segmental box girder was used for the main spans over the waterway. Twin parallel bridges, built in multiple phases, were proposed in order to maintain traffic flow and avoid major impacts to adjacent right-of-way.

Navigation Span Features Box Girders

The main section of each bridge over the GIWW features a three-span, 740-ft-long section consisting of a cast-in-place concrete, double-cell box girder varying in depth from 8 ft to 19 ft. The three spans consist of two 195-ft-long end spans and a 350-ft-long center span. Twelve segments were used in the end spans and 19 segments were used in the center span.

The bridges were constructed using the balanced cantilever method. The design provided minimum vertical clearance of 73 ft at the edges of the 125-ft-wide navigational channel limits, and 310 ft horizontal clearance to the face of the pier bulkheads. The goal was to open the horizontal clearance as much as possible within the limits available.

profile

I-45 GALVESTON BAY CAUSEWAY BRIDGE / GALVESTON COUNTY, TEXAS

ENGINEER: Texas Department of Transportation

PRIME CONTRACTOR (INCLUDING POST-TENSIONING): Traylor Bros. Inc., Galveston, Tex.

REDESIGN ENGINEER: Summit Engineering Group Inc., Littleton, Colo.

PRECASTER: Traylor Bros. Inc., Galveston, Tex.

CONCRETE SUPPLIER: Dorsett Bros. Concrete Supply Inc., Pasadena, Tex.

POST-TENSIONING MATERIALS: VSL, Fort Worth, Tex.

The segmental unit was designed using ADAPT-ABI software with CEB-FIP factors included for shrinkage and creep. The contract plans detailed 15-ft-long typical segments, but the contractor suggested modifying that length to 5 m (16.4 ft) to optimize the benefits of their chosen form traveler and reduce the total number of segments. A production rate of two segments a week with a pair of travelers on each pier was achieved.

The three top slab cantilever tendons per segment were anchored over each web and utilized seventeen ½-in.-special strands per tendon. The bottom-slab continuity tendons were anchored adjacent to each web and utilized seventeen or twenty-five ½-in.-special strands per tendon. The concrete segmental unit was designed for a 28-day concrete compressive strength of 6000 psi.

The segmental main span pier substructure consists of two columns per bent founded on a continuous multi-pile footing. The columns are hollow, cast-in-place concrete and taper slightly. The footings are continuous between the two bents constructed in a phased sequence. They extend to the mud line. Each footing has a combined total of one hundred and fifty-four 24-in.-diameter steel pipe piles that are 109 ft long.

The design is similar to two previous bridges designed by the Texas Department of Transportation (TxDOT), in their Austin Headquarters Bridge Division office and Houston District office. This allowed the design geometry to be reused, with the number of cells in the girders doubled to provide the 74 ft width required for three lanes of traffic in each direction, an auxiliary lane, and two full shoulders.

Approach Spans Feature Precast Beams

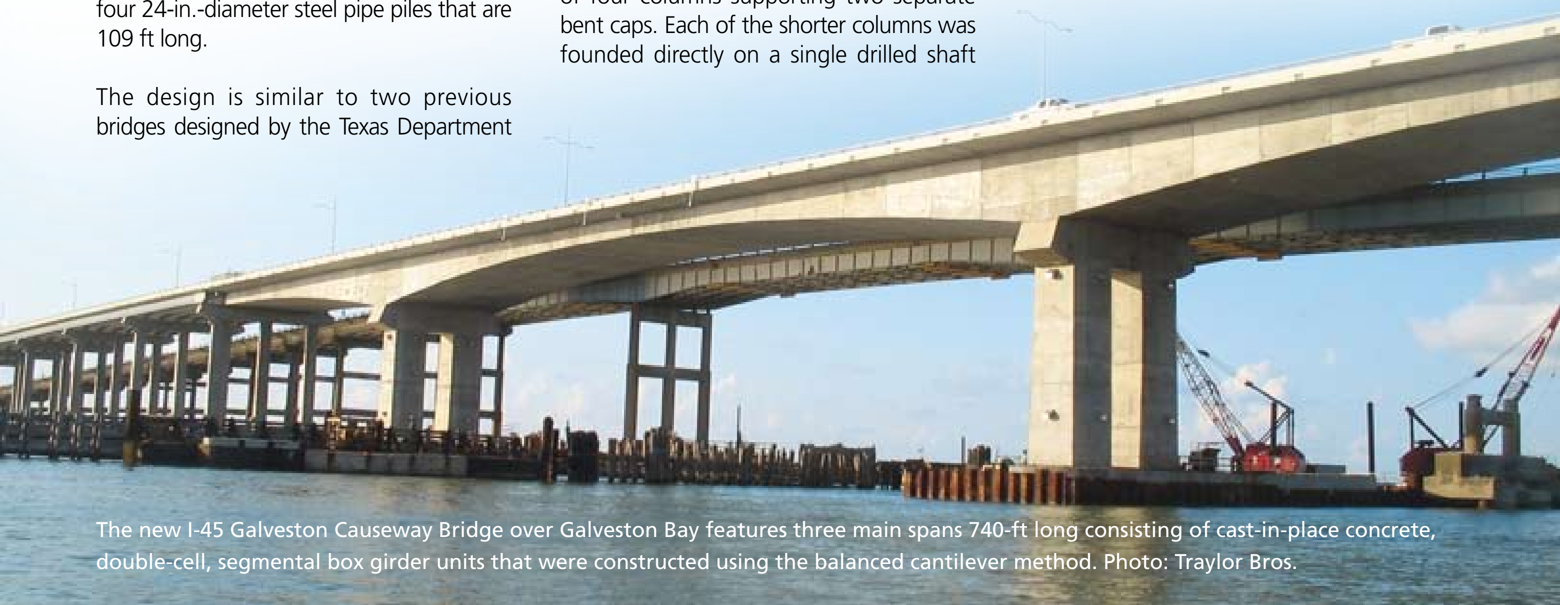
Each bridge is comprised of 35 approach spans north of the GIWW and 22 spans south of the GIWW. Typical spans consist of eight 72-in.-deep precast, prestressed concrete AASHTO Type VI beams at 9.44-ft spacing. The concrete design compressive strength is 6600 psi. The maximum bent spacing is 134.33 ft. The span lengths were based on increments of the existing bridge spans to avoid conflicts with the existing foundations. The bridge includes a 9-in.-thick deck comprised of 5 in. of composite concrete topping cast on 4-in.-thick precast, prestressed concrete stay-in-place deck panels. The deck has 2-in.-clear concrete cover over the reinforcement on top and slightly more than 1¾-in. clear cover on the bottom.

The shorter bents for each bridge consisted of four columns supporting two separate bent caps. Each of the shorter columns was founded directly on a single drilled shaft up to 78 in. in diameter and up to 108 ft in length. Taller bents for each bridge used three columns and one large hammerhead bent cap. All columns on the taller bents are founded on footings with multiple drilled shafts up to 60 in. in diameter and up to 114 ft in length. Variable-depth concrete seal slabs with steel fiber reinforcement were incorporated in the footings to help resist vessel impact.

Rigorous permitting applications were required for the project, to ensure minimum impact to the environment, maximum safety, and careful consideration of all stakeholders' concerns.

Three Phases of Construction

Construction was accomplished in three phases, to continuously maintain three lanes of traffic in each direction during the project. In the first phase, the northbound bridge was constructed, erecting the concrete approach spans north and south of the GIWW and the navigation span concurrently. Once this bridge was completed, both northbound and southbound traffic was relocated to the new structure and the existing bridges were demolished. In the third phase, the second structure was erected directly adjacent to the first.



The new I-45 Galveston Causeway Bridge over Galveston Bay features three main spans 740-ft long consisting of cast-in-place concrete, double-cell, segmental box girder units that were constructed using the balanced cantilever method. Photo: Traylor Bros.

PARALLEL BRIDGES WITH PRECAST CONCRETE I-GIRDER APPROACH SPANS AND THREE-SPAN CAST-IN-PLACE SEGMENTAL BOX GIRDERS/ TEXAS DEPARTMENT OF TRANSPORTATION, OWNER

REINFORCEMENT SUPPLIER: Sunbelt Works Inc., Dayton, Tex.

HYDRAULIC GIRDER ERECTION TRUSS: DEAL, Italy

BRIDGE DESCRIPTION: Twin, parallel concrete replacement bridges, 8592 ft long and 74 ft wide, each consisting of 57 approach spans comprising precast concrete AASHTO Type VI girders and three center spans using a cast-in-place, two-cell, segmental box girder erected using the balanced cantilever method

BRIDGE CONSTRUCTION COST: \$136 million (\$107/ft^2) that includes demolition and a small amount of roadway and landscaping to tie to the original roadway

End segments for the main spans were precast on the footing below their final location and lifted into position. Photo: Traylor Bros.

Phase 1

Multiple crews worked simultaneously, with the foundation crews followed by the substructure and superstructure crews in a fairly linear fashion. The segmental cantilever spans were cast-in-place separately, using overhead form travelers. The cantilever sections presented no unusual challenges. Each pier section was offset by one-half segment length to minimize the out-of-balance moment. The crews alternated between launching the form traveler on one side and then the other to complete each span. The two piers for these sections were placed adjacent to the GIWW, with backspan piers required on each side.

Most of the approach structures were built from barges, but nearly 2500 ft of the 8592-ft-long bridge were inaccessible by barge. The TxDOT evaluated several construction alternatives to facilitate construction in the shallow areas of Galveston Bay. Difficulties ruled out all options except construction from a temporary trestle bridge. This required permits from both the U.S. Army Corps of Engineers and the U.S. Coast Guard.

Even with the trestle bridge, the reach of the crane was limited to setting only three of the eight 155,000 lb girders in a span. For these spans, a hydraulic erection truss was used to distribute the girders on the piers beyond the reach of the crane.

Phase 2

Demolition of the existing bridge was a critical and time-consuming aspect of this project. The TxDOT required the removal of all existing structures to a minimum of 2 ft below the mud line with eight elements adjacent to the waterway removed to 20 ft below the mud line to avoid any potential conflicts with vessel traffic. Structures that had to be removed included 234 cast-in-place concrete beams and slab spans, 238 two-column bents with tie-beams, 121 footings with two 9-ft-diameter concrete caissons per footing, 117 footings with two multi-pile footings and four 4-ft-diameter cased drilled shafts, and two 40-ft by 60-ft bascule pit foundations and walls founded on piles. The TxDOT worked with the Texas Parks & Wildlife Department (TPWD) to create an option for transforming this debris into an artificial reef, but it ultimately did not prove to be cost effective in this case (see the sidebar).

Phase 3

Constructing the second bridge presented significantly more challenges than constructing the first one. The initial phase provided limited access on both sides. However, the second bridge was built with only a 1-in.-wide gap between it and the first bridge, which created difficulties for access and traffic control.

Aesthetics

Aesthetics treatments were focused on the bridge approaches in order to provide the most visual impact to the traveling public. Significant effort was put into design of the retaining wall enhancements and approaches, which had rustications added and were painted to follow the Houston District's Green Ribbon urban design scheme.

Additional visual interest was applied above the deck. This work included vertical undulations added into the bridge barrier's appearance to tie it to the district's "wave" pattern designs. Luminaires also were placed down the center of the roadway rather than at the edges, and the arms on the polls that support this lighting included the same wave designs.

The work was difficult, but necessary, and had to continue smoothly, even after Hurricane Ike hit the area. The result is two attractive, functional structures that will serve Texas and the City of Galveston for many decades to come.

Jon Holt is assistant district bridge engineer in the Houston District of the Texas Department of Transportation and Scott Turnpaugh is the project manager for Traylor Bros. Inc. in Galveston, Tex.

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

Recycled Reefs

In an effort to provide the most environmental benefits for the I-45 project as possible, the Texas Department of Transportation (TxDOT) for the first time varied from its bidding process to require contractors to supply two bids: one that included basic demolition and removal, and another one that reused a portion of the debris to create artificial reefs in the Gulf of Mexico.

The goal was to make efficient use of this mass of debris by placing it in a site in the Gulf of Mexico to create artificial reefs, as has been done in the past with other materials to good effect. The contract called for one bid to include costs for disposing of the materials as desired, while the other had to factor in dismantling 25% of the bridge materials and shipping them 25 miles offshore to be placed in the reef site.

The TxDOT worked with the Texas Parks & Wildlife Department officials as well as other organizations to determine which components could be barged easiest to the site for sinking. Designers also looked at how the components could be disassembled and placed on barges to find the most efficient approach.

Unfortunately, separating and shipping these components added costs to the project for all bidders, which caused the reef bids to be uniformly higher. As the TxDOT was required to accept the lowest bid, this artificial reef concept was not used in this case. But it remains a possibility for future bridges where environmental benefits could be achieved.

A NEW LEGACY Vancouver Land Bridge RECONNECTS LAND AND RIVER, PEOPLE AND HISTORY

by Tim Shell and Stephen Whittington, KPFF Consulting Engineers

Over 15 curved and tiered retaining walls support the approach pathways leading to the bridge. Photo: Pete Eckert.

The Vancouver Land Bridge is a landscaped interpretive work of art that reconnects the Fort Vancouver National Historic Reserve to the Columbia River over the six-lane State Highway 14 (SR14) in Vancouver, Wash. One of six art pieces comprising the Confluence Project along the Columbia River Basin, the pedestrian bridge sews together severed lands that once were the end of the Klickitat Trail—a trading center and gathering place for more than 35 Native American cultures. With the project's severe physical constraints, archeological artifacts on site, and a unique design that reflects the tribal heritage of the area, the team faced an array of complex challenges for the winding, cast-in-place concrete structure.

Siting that Respects Past, Present, and Future Concerns

The land north of the project contains the historic Fort Vancouver and Kanaka Village. Archeological excavations on site were completed prior to the start of construction. The bridge and retaining wall foundations were designed to avoid possible artifacts that may lie deeper in the soil.

The chosen site is constrained both horizontally and vertically by competing interests. An operational mainline railroad line just a few yards away runs parallel to the southwest approach. Officials of a nearby municipal airport had concerns over the long-term height impacts of the oak trees, lights, and trellises on the bridge.

The available site was restricted by SR 14 and the BNSF Railroad.

In addition, the bridge placement had to account for a variety of off-ramp alternatives being considered for the future I-5 Columbia River Crossing, a major interstate project of regional significance. (See Page 11.) The land bridge's 23-ft clearance above SR14 was needed to accommodate the future I-5 interchange ramp and helped to raise visitors away from the influence

profile

VANCOUVER LAND BRIDGE / VANCOUVER, WASHINGTON

STRUCTURAL AND CIVIL ENGINEERS: KPFF Consulting Engineers, Portland, Ore.

ARCHITECT AND LANDSCAPE ARCHITECT: Jones & Jones Architecture and Landscape Architecture, Seattle, Wash.

ARTIST: Maya Lin Studio, New York City, N.Y.

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

AWARDS: *Clark County Community Development, 2008 Community Pride Design; American Council of Engineering Companies, Oregon Chapter, 2009 Engineering Excellence Grand Award; Oregon Concrete and Aggregate Producers Association, 2009 Excellence in Concrete Award; Portland* Daily Journal of Commerce*, Top Project 2008* of the traffic below. The Washington State Department of Transportation (WSDOT) provided invaluable assistance to the team by "bracketing" the range of potential ramp alignments under consideration and helped fit the land bridge into a space that would not restrict future ramp options.

With so many critical issues at stake, the team closely coordinated with the City of Vancouver, WSDOT, the Federal Aviation Administration, the BNSF Railroad, and the National Park Service. Financed through private donations; federal, state, and local funds; and slated for opening in time for the Lewis and Clark Bicentennial, the team was charged with keeping costs down and achieving the aggressive schedule while facilitating the landmark project's unusual construction.

Complex Geometry

The circle represents the life cycle for many Native American tribes, so the designer used this symbol as the basis of the Vancouver Land Bridge's form. The project includes 3100 linear feet of pathway, and the effect creates a serpentine sculpture that meanders through wetlands, culminating in a 190-ft-long, two-span structure curving over the highway. Three overlooks provide views of Kanaka Village, Fort Vancouver, the Columbia River Waterfront, Mount Hood, and the Cascade Mountain Range.

The tight radius and semicircular shape of the bridge met project aesthetic criteria and cost objectives, but eliminated a number of conventional structural options. The team selected cast-in-place concrete for the substructure and superstructure, and developed innovative solutions for the tailored deck and bents.

Reducing the Dead Load

Intended to be an organic extension of its surroundings, hundreds of native plantings line the land bridge. Deep soils were placed on the bridge deck to support the extensive landscaping, which created heavy dead loads. The architect wanted the bridge to appear "slender," gracefully arching over the highway. The engineers had to devise a structural system that could span the six lanes of traffic below, carry significant additional dead loads, and still maintain a slender structure that provided the required vertical clearance above the existing SR14 roadway and the future I-5 interchange ramps. These conditions alone were challenging, however, the designers also had to analyze and model the complexities associated with the unique, tightly curved geometry and variable soil loading patterns.

The design team attacked the challenge two-fold: first, seek creative ways to decrease the dead weight of the structure; and second, optimize the load-carrying ability of the bridge structure through careful analysis and detailing.

Boardwalks made with recycled plastic lumber span wetlands alongside the approach pathway. Overhead steel trellises lend a more personal scale. Photo: Natural Pave Photos.

Meandering pathway leading away from the bridge. The walking surface is decomposed granite with a clear aggregate binder. Colored pavers were laid in symbolic Native American patterns. Photo: KPFF Consulting Engineers.

CAST-IN-PLACE REINFORCED CONCRETE PEDESTRIAN BRIDGE / CITY OF VANCOUVER, OWNER

CONCRETE SUPPLIER: Cemex, Vancouver, Wash.

BRIDGE DESCRIPTION: Curved, cast-in-place, 41-ft 6-in.-wide by 190-ft-long, two-span, landscape pedestrian bridge with a unique "lightweight" foam core deck, shallow longitudinal upturned edge girders, and pier walls with decorative designs

BRIDGE CONSTRUCTION COST: $12.25 million

Forms for checkered basket-weave patterns are attached to deck falsework. Photo: KPFF Consulting Engineers.

The bridge consists of a cast-in-place, voided concrete deck spanning between transverse reinforced concrete deck crossbeams laid out in a radial pattern spaced at an average of 6 ft on center. The deck crossbeams are supported by a pair of upturned cast-in-place, 6-ft 6-in.-deep, concrete edge girders to create a U-shaped cross section. The horizontally curved edge girders are continuous and frame into end abutments and intermediate pier walls founded on spread footings.

Reinforcing in place for deck soffit and radial crossbeams. Rigid foam was placed between crossbeams after the soffit was cast.

The tightly curved bridge precluded the practical use of precast or post-tensioned concrete. Steel girders with precast cladding panels were also considered. However, this option was eliminated due to long-term maintenance and inspection concerns associated with the multitude of connections required. The team selected conventionally reinforced concrete as the preferred structure type. Maintaining the thin structure depth required by the architect while using nonprestressed methods became one of the key challenges for the structural design.

The team plucked the "low-hanging fruit" first. The landscape architect was able to locate and specify a lightweight landscaping soil to be used in lieu of standard planting soils. This reduced the soil weight by approximately 50%. Next, the bridge designers developed a voided deck system consisting of foam cavities cast into the deck. Approximately thirty-five 36 ft by 4 ft by 13 in. rigid foam panels were custom-fitted and secured between the transverse deck crossbeams (horizontally) and between the bottom and top deck sections (vertically).

Furthermore, the bridge designers created detailed 3-D finite element computer models of the continuous, curved structure to optimize the structural elements. The upturned edge girders were analyzed and detailed for complex flexure and shear effects in combination with significant torsional loads generated by the bridge's unusual geometry. By accurately modeling these complex effects, the designers were able to detail the most economical reinforcing layout and minimize the members' depths. Significant deck detailing, especially in high torsion and negative moment regions was used to keep the members as small and light as possible.

The longitudinal concrete edge girders were "upturned" in order to help increase the clearance above the highway and to serve the added function of retaining the 3-ft to 4-ft depth of landscaping soils placed along the sides of the pathway across the bridge. Turning the girders upward also helped enhance the visual and acoustic separation from the traffic below.

Girders and Abutments Perform Dual Functions

The bridge's curved plan and nonparallel approaches created unique loading conditions at the support piers. Computer models including soil springs were developed to evaluate the structure's complex behavior under both gravity and seismic loads. Understanding how changes to the design affected torsion loads, lateral earth pressures, and bridge deflections were key to successfully optimizing the bridge's design and construction, as well as providing a durable structure with decreased long-term maintenance costs.

Special decorative formliner finishes were cast into certain concrete surfaces to convey the site's Native American heritage to motorists passing beneath. Intricate basket weave patterns were formed into the abutments and bridge soffit.

Curved Retaining Walls

The curvature of the path demanded special attention to achieve the desired effect. The team designed over 15 separate

Environmental Considerations

The bridge was designed to capture all rainwater runoff. A slight cross slope in the pavement surface directs excess storm water into thin channels along the edges of the pathway. On one side of the bridge, the channel leads to a rain garden and a dry well to infiltrate slowly into the ground. On the other side, the water collects in a manmade creek and inlet that lead to an underground storage pipe, which stores the water to irrigate the bridge's landscaping. A shallow groundwater well fed by the Columbia River aquifer will supplement the irrigation system during dry periods until the plants become established. The use of indigenous plants for the landscaping also reduces the need for irrigation.

In addition to incorporating innovative sustainable water quality measures into the design, the team included water meters to quantify the amount of storm water reuse compared with well-water use, and to measure their effectiveness. These meters will provide invaluable data on the performance of different types of sustainable water treatment and reuse measures.

Basket-weave pattern on bridge soffit.

retaining walls reaching up to 25 ft tall in order to satisfy architectural requirements and enable constructability within the limited available space. Each horizontally and vertically curving wall followed its own unique alignment while still needing to tie into its neighboring wall. This required multi-dimensional thinking and extensive detailing.

To maximize landscape space within the constricted project area, the design team made creative use of stepped structural mechanically stabilized earth (MSE) retaining walls with concrete formliner facings. The architect wanted to minimize the joints in the exposed walls' faces, therefore the team decided against conventional, segmented precast concrete MSE wall panels. Instead, a cast-in-place concrete facing was used on the front side of the MSE walls and the contractor successfully cast the full height of the wall facings in a single placement with no horizontal joints. Full-height precast concrete wall panels were also considered. However, they proved to be less practical and more expensive for the higher walls. The project also incorporated a series of curved cast-in-place concrete cantilever and soil-nail retaining walls, all designed to blend and integrate together.

The Vancouver Land Bridge leaves a new legacy, one that links the visitor with the Native American cultural history of the site, commemorates the bicentennial of Lewis and Clark's journey West, and restores a community connection between Fort Vancouver and the Columbia River.

Tim Shell is an associate and Stephen Whittington is a structural engineer at KPFF Consulting Engineers in Portland, Ore. Shell was project manager and Whittington was structural engineer on the Vancouver Land Bridge.

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

AESTHETICS COMMENTARY

by Frederick Gottemoeller

The Vancouver Land Bridge is a too-rare example of a crossing that is conceived as an integrated extension of a larger landscape. The bridge and the approach ramps follow a single sweeping curve. The wing walls peel away from of the main curve to follow the contours of the approach embankment. The embankment in turn blends into the natural slopes of the site. The landscape itself crosses the bridge in the edge planters. There are no obvious dividing lines between bridge and ramp or between ramp and site. The site and crossing are a single piece. It is the same quality that Frank Lloyd Wright aimed for in his "organic" architecture.

The users' experience reflects that. As they approach the crossing, they are attracted onto a ramp that appears to be a natural extension of the landscape. They cross the highway with landscape planting buffering them on both sides, then descend again into the landscape. The patterns on the walls and paving engage users interest and at the same time educate them about the site. The covered overlooks and benches recognize the common human desire to pause and enjoy the view, to rest a moment and absorb what has been seen. The experience is as seamless as the crossing itself.

LAMBERTS/BRAMBLETON VIADUCT
NORFOLK LIGHT RAIL TRANSIT PROJECT

by Jason R. Doughty, PB

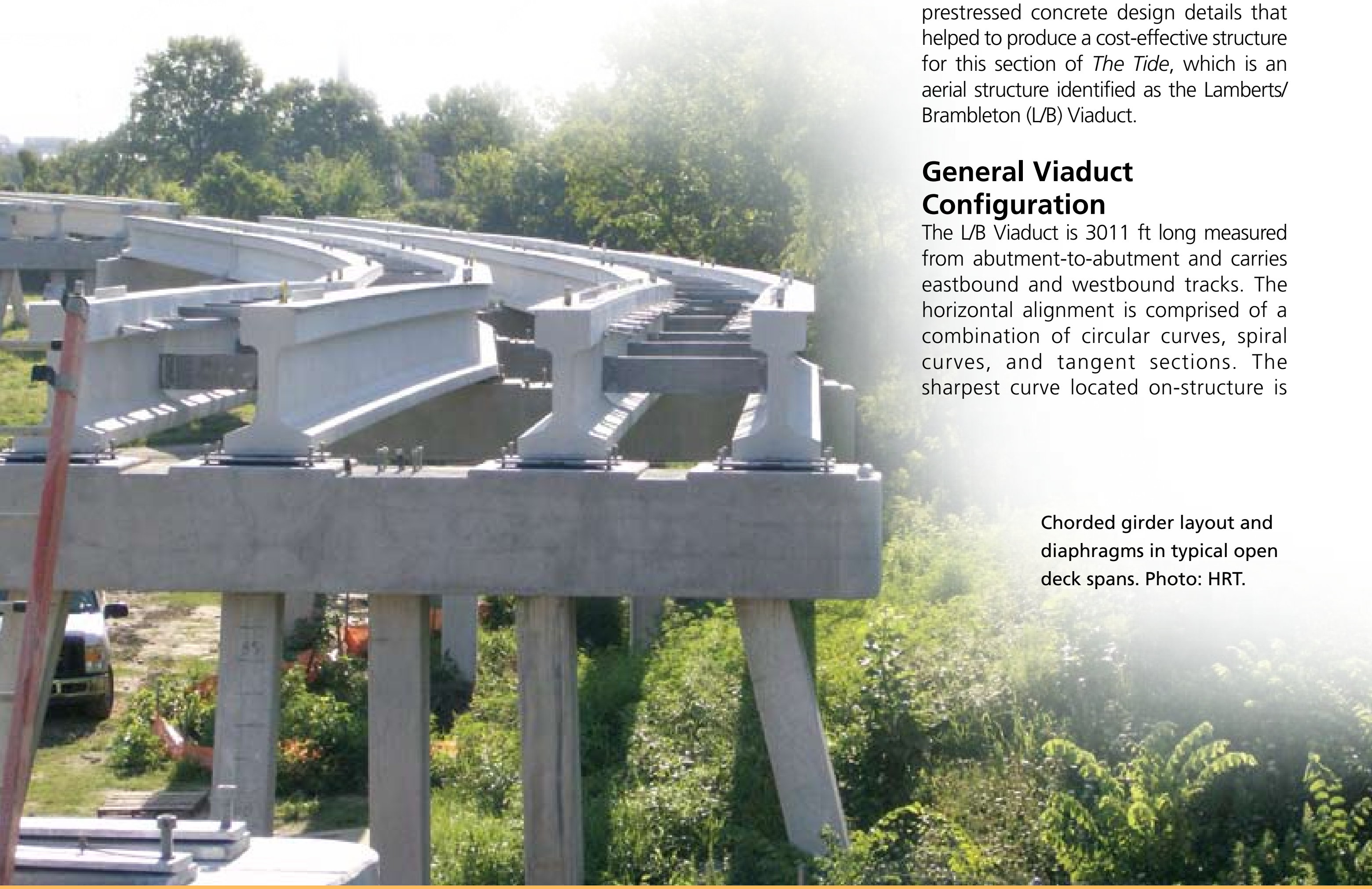
Hampton Roads Transit (HRT) in Hampton, Va., has been planning a new-start light rail system known as *The Tide* since the late 1990s. In late 2006, the General Engineering Consultant (GEC) contract was awarded to the team of Parsons Brinckerhoff (PB) and URS. The team proceeded with final design of track alignments, aerial structures, trackwork, stations, a yard-and-shop building, and a variety of other components comprising this multi-discipline project. In the fall of 2007, HRT executed a Full Funding Grant Agreement with the Federal Transit Administration, which provided necessary federal funds to begin construction activities. Construction began in late 2007 and passenger revenue operations are expected to begin in 2010. The estimated total cost for the project is $288 million and the estimated ridership is 6000 to 12,000 riders per day.

The Tide light rail line will extend 7.4 miles on a west-east alignment from the East Virginia Medical Center through downtown Norfolk, continuing along a former Norfolk Southern Railroad right-of-way, roughly parallel to I-264, to the city line at Newtown Road. Eleven stations will be constructed along the route with four park-and-ride locations that provide access to major areas such as Sentara Norfolk General Hospital, MacArthur Center, City Hall, Harbor Park, Tidewater Community College (Norfolk Campus), and Norfolk State University.

The 7.4-mile system was divided into several different construction contracts. The first contract was awarded in late 2007. This article focuses on the precast, prestressed concrete design details that helped to produce a cost-effective structure for this section of *The Tide*, which is an aerial structure identified as the Lamberts/Brambleton (L/B) Viaduct.

General Viaduct Configuration

The L/B Viaduct is 3011 ft long measured from abutment-to-abutment and carries eastbound and westbound tracks. The horizontal alignment is comprised of a combination of circular curves, spiral curves, and tangent sections. The sharpest curve located on-structure is



Chorded girder layout and diaphragms in typical open deck spans. Photo: HRT.

profile

LAMBERTS/BRAMBLETON VIADUCT / NORFOLK, VIRGINIA

BRIDGE DESIGN ENGINEER: PB Americas Inc., Norfolk, Va.

PILE-BENT DESIGNER FOR OPEN DECK SPANS: Simpson Engineers & Associates Inc., Cary, N.C.

PRIME CONTRACTOR: Bryant Contracting Inc., Toano, Va.

PRECASTER: Bayshore Concrete Products Corporation, Cape Charles, Va., a PCI-certified producer a circular curve with a radius of 166 ft. The distance between the track centers along the viaduct varies, requiring some sections of the viaduct to be a double-track structure and other sections to be separate eastbound and westbound single-track structures. The vertical alignment varies from level to grades up to 6% and the average height of the viaduct above the existing and finished ground is approximately 20 ft.

Structural Components of the Viaduct

Key objectives behind this aerial structure design were to produce a simple structure that would use repetitive details, could be constructed rapidly, would be as cost-effective as possible, and would be easily maintained in the future. Early preliminary engineering work had concluded that the sharply curved portion of the viaduct (Spans 1 through 11) was to be designed as a horizontally-curved steel plate girder superstructure with a direct-fixation (DF) deck. However, given the volatility of the structural steel market over the past few years, the high steel prices at the time of design, and the long lead times expected for these girders, a decision was made to use chorded, simple-span, precast, prestressed concrete girders with the same DF deck.

As a result of this early decision, simple-span, precast, prestressed concrete girders were used for all but two of the spans of the 43-span viaduct. Chorded span layouts were used throughout the viaduct and the girder layout was developed such that the centerlines of the girders remained aligned as close as possible with the track's running rails. The center-to-center bearing span lengths range from approximately 50 to 85 ft.

The girders are 4 ft 6 in. deep and are a modified bulb-tee section. The wide top flanges normally associated with bulb-tee sections were reduced to a width of 20 in. The girder cross section resembles a rail section, and the narrower top flange better accommodates the dapped timber ties used in the open deck spans. The compressive strength of the girder concrete at release was specified to be 6400 psi, and the 28-day compressive strength for the girder concrete was specified as 8000 psi.

Two different deck types, each with different systems of rail fixation, were used on the concrete girder spans. In the sharply curved portion of the viaduct, a direct-fixation (DF) deck was used. The reinforced concrete deck helps provide lateral stability and serves as the mechanism to distribute live load to the girders. On all other concrete girder spans, an open-deck track system with timber ties was used.

Key objectives were to use repetitive details, be constructed rapidly, be as cost-effective as possible, and be easily maintained in the future.

The girder bearings consist of a combination of steel fixed bearings, guided steel-reinforced elastomeric expansion bearings, and conventional fixed and expansion, steel-reinforced, elastomeric bearings. Constant pad and plate dimensions were used as much as possible in order to simplify fabrication and construction.

Another cost-effective, repetitive, and easy-to-build feature was the bridge piers. Pile bents, which represent one of the most economical substructure types, were used for nearly every substructure unit on the viaduct. The pile bents consisted of battered 20-in.-square precast, prestressed concrete piles and cast-in-place reinforced concrete bent caps. The end bents also are supported by the same 20-in.-square piles. The typical pile length at the pile bents was approximately 80 ft.

Lateral bracing and diaphragms in typical open deck span. Photo: PB Americas.

Open Deck with Precast, Prestressed Concrete Girders

In order to provide HRT with a cost-effective structure and to eliminate well over 1000 yd^3 of deck concrete that would have been required for a DF deck, it was decided to

PRECAST, PRESTRESSED CONCRETE LIGHT RAIL AERIAL STRUCTURE / HAMPTON ROADS TRANSIT, OWNER

BRIDGE DESCRIPTION: 3011-ft-long bridge with 43 spans ranging in length from 50 ft to 85 ft and using both direct fixation and open deck details, chorded geometry, and precast pile bents with cast-in-place concrete bent caps

STRUCTURAL COMPONENTS: 162 precast, prestressed concrete 54-in.-deep, modified bulb-tee girders, 268 20-in.-square precast, prestressed concrete piles

BRIDGE CONSTRUCTION COST: $11.7 million for bridge structures only; does not include track system


End diaphragm detail at typical open deck spans. Photo: PB Americas.

investigate the use of an open-deck system supported on precast, prestressed concrete girders. An open deck system consists of timber railroad ties spanning transversely between the longitudinal girders and represents one of the most economical deck options available for light rail or freight railroad bridges.

At the time of design, no examples of open deck bridges with concrete girders could be found in the literature in the United States. As a result, a detailed analysis ensued to investigate live load distribution, overall girder stability, and the distribution and transfer of lateral design forces such as centrifugal forces and wind loads.

The American Railway Engineering and Maintenance-of-Way Association (AREMA) requires that steel girder open deck freight railroad bridges be designed with intermediate diaphragms spaced not more than 18 ft apart, and requires that they be designed with both top and bottom flange lateral bracing. Although light rail vehicle (LRV) live loads are markedly less than the Cooper E80 freight railroad loading that AREMA employs, the AREMA philosophy related to diaphragms and top flange lateral bracing was conservatively applied to the open deck concrete girder spans. Analysis showed that this two-girder superstructure framing system comprised of diaphragms and lateral bracing with the precast concrete girders provides balanced distribution of the LRV loads, an overall stable two-girder system, and a system that can effectively transfer lateral loads to the bearings. Any contribution to girder stability from the timber ties was neglected in the analyses based on the assumption that, over time, the ties could become deteriorated and loose from the girders.

The L/B Viaduct is one of the first open deck light rail transit structures to be designed and built with precast, prestressed concrete girders in the United States.

The precast, prestressed concrete girders are spaced at 6 ft 6 in. on center in the open deck spans. Galvanized steel channel sections were used as intermediate diaphragms and were positioned approximately at the span quarter points. A top flange lateral X-bracing system was designed using galvanized steel angles. This bracing was used along the full-length of every open deck span. Due to the chorded girder layout along the complex horizontal geometry, a wide range of girder lengths was required. In an effort to standardize fabrication of the bracing panels, constant panel spacing was used in the central region of every span. The span end-panels varied to suit the variety of span lengths. This approach minimized the variation in bracing angle lengths, simplified the connection plate details, and allowed for economical repetitive details. In order to accommodate lateral load transfer to the bearings and to prevent rolling/overturning of the overall superstructure, stocky galvanized rolled steel W-sections were used as end diaphragms. Numerous threaded inserts were required to be cast into the girders to receive the connection bolts for the diaphragms and bracing. Careful coordination with the precaster was required to confirm that inserts were accurately positioned.

Typical open deck steel girder bridges use a J-bolt to connect the timber ties to the steel girder. The J-bolt passes through the tie and clips under the girder top flange. Since the top flange of the concrete girders is very thick, another unique detail was developed to receive the standard J-bolt tie connector.

A galvanized steel WT-section was cast into the outboard edge of each girder top flange for the full-length of each girder. The outstanding leg of the WT-section provides a "flange" for the J-bolt to clip under. This detail will allow the trackwork installer to use standard J-bolts to install the track on top of the concrete girders.

Conclusions

The L/B Viaduct provides an example of where it was appropriate and beneficial to the project to use precast, prestressed concrete girders. These girders can be designed and spaced to accommodate a variety of complex alignments.

Precast, prestressed concrete girders can be detailed with a wide range of inserts to accommodate connection hardware that facilitates their use in applications where they might not commonly be used. In the case of the L/B Viaduct, common diaphragm details and simple lateral bracing connections were used so the economical open deck track system could be used for the majority of the length of the structure. This deck type allowed HRT to take advantage of a significant construction cost savings when compared to using DF deck.

Designers produced a simple cost-effective structure with repetitive details that could be rapidly constructed. Aside from meeting these objectives, the design also will provide HRT with a highly durable and a low-maintenance girder structure. The L/B Viaduct is expected to be completed in mid-2009, and will represent one of the first open deck light rail transit structures to be designed and built with precast, prestressed concrete girders in the United States. In addition to the L/B Viaduct, there are several thousand linear feet of aerial structure in the Norfolk Light Rail Transit Project currently under construction with a similar open deck system with precast, prestressed concrete girders.

Jason R. Doughty is a senior structural engineer with PB, Morrisville, N.C. He served as the superstructure design engineer for the concrete girder spans of the L/B Viaduct.

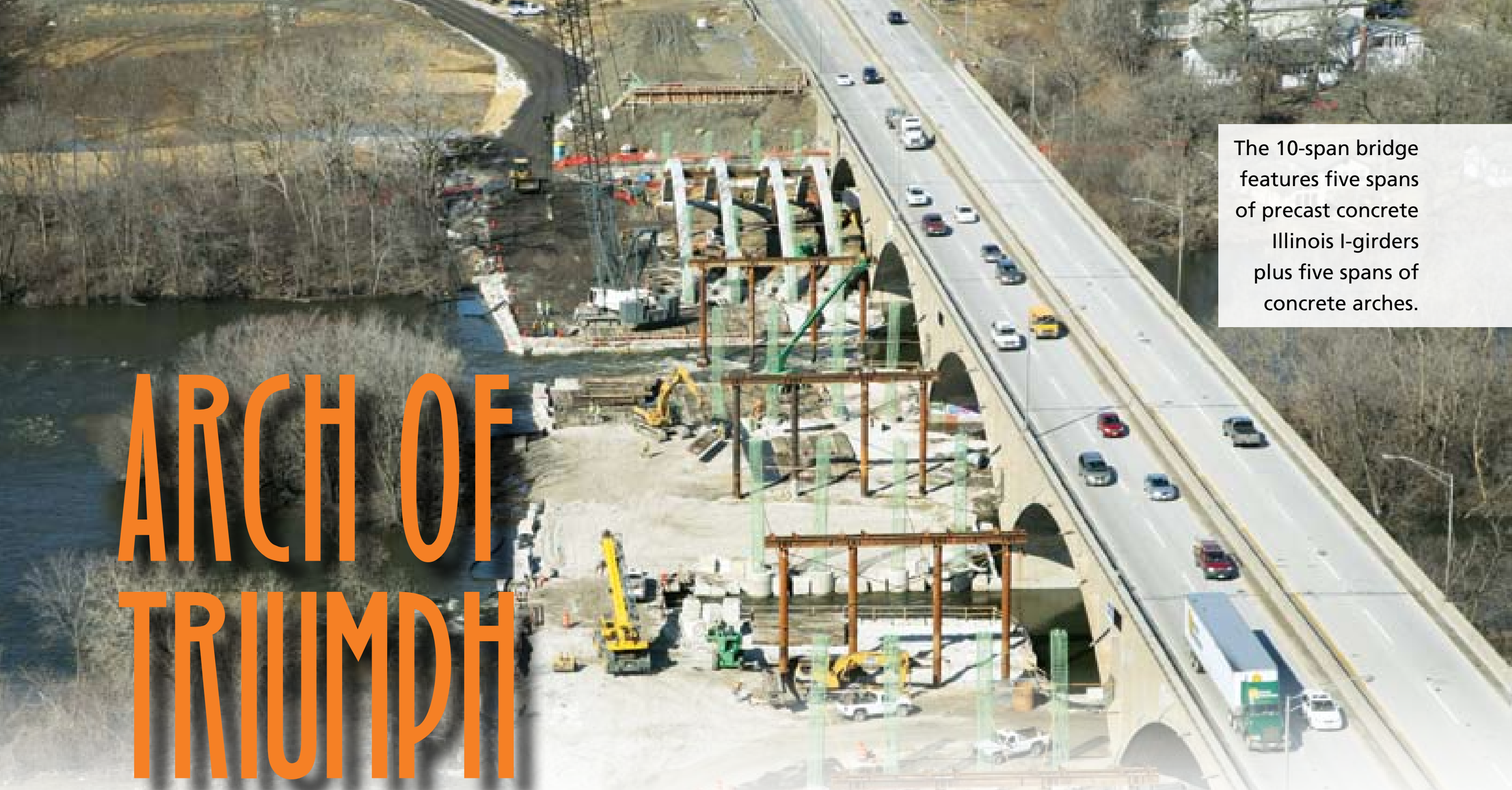
For more information on this or other projects, visit www.aspirebridge.org.

American Coal Ash Association

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

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

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



The 10-span bridge features five spans of precast concrete Illinois I-girders plus five spans of concrete arches.

ARCH OF TRIUMPH

by Brian Slagle, Janssen & Spaans Engineering Inc. and Michael Gould, James McHugh Construction Co.

Concrete design replicates existing arch bridge so well that officials also replace original

Illinois State Toll Highway Authority officials faced a key challenge in planning to widen and rebuild portions of the I-88 Reagan Memorial Tollway in North Aurora, Ill. The roadway's bridge over the Fox River featured the tollway's only arch bridge, and they hoped costs would prove economical enough that they could add a second bridge with a similar design alongside for the extra lanes. Ultimately, the selected concrete design proved so impressive that the Illinois Tollway decided to replace the existing bridge with a new one, too.

The project's goal was to increase capacity on the tollway in each direction to three lanes from two. The plan was to use the existing arch bridge, which opened in 1958, to carry three lanes of westbound traffic, while the new structure would carry three lanes of eastbound vehicles. To achieve this economically, the Illinois Tollway used a performance-based delivery system similar to the design-build format used in other states and requested two distinct bid alternatives from design-build firms.

One design bid alternate provided parameters for an arch bridge that would closely match the shape and construction of the existing arch bridge. The second design bid alternate was to focus on a simple concrete bridge consisting of typical beams and piers, with no elaborations. But that bid also had to include a \$3-million noncompensable adjustment for selecting the simple bridge type.

McHugh/Janssen & Spaans investigated both alternatives and concluded that the arch structure could be designed and constructed within the \$3-million premium allowed for the more aesthetically pleasing arch structure. They submitted this alternate in their bid package, which was selected as the best combination of aesthetics and economics. McHugh served as the team leader for the project.

Five Arch Spans

The new 1345-ft-long bridge comprises 10 spans. Five spans use cast-in-place columns and bent caps supporting 10

profile

FOX RIVER BRIDGE / NORTH AURORA, ILLINOIS

ENGINEER: Janssen & Spaans Engineering Inc., Chicago, Ill., and Bowman, Barrett & Associates Inc., Chicago, Ill.

GENERAL CONTRACTOR: James McHugh Construction Co., Chicago, Ill.

PRECASTER FOR GIRDERS: Prestress Engineering Corp., Prairie Grove, Ill., a PCI-certified producer

AWARDS: *Top 10 Bridges in North America,* Roads & Bridges *magazine*

Construction sequencing had to accommodate a very stringent set of geometric restraints.

lines of 42-in.- and 54-in.-deep precast, prestressed concrete Illinois I-girders. The other five use four lines of concrete arch ribs with a span length of 178 ft. Each arch supports two cast-in-place intermediate spandrels. Columns and bents are provided above each arch support. The bents in turn support 9 lines of 36-in.-deep precast, prestressed concrete I-girders. The bridge has nine intermediate piers including two in the river and one on an island in the middle of the river. Forty drilled caissons were used, with 28 in the river and 12 on land. Each caisson, 6 ft in diameter, was socketed into solid rock at depths up to 28 ft. The cast-in-place bridge deck has a thickness of 8 in.

Each precast concrete arch was fabricated in two pieces about 1½ miles from the site in a yard established by McHugh. The arches, which are conventionally reinforced were cast on their side and then lifted and rotated into a vertical position using a device constructed for the project. The pieces were delivered using special heavy-load semitrailers with 13 axles, rear steering, and 90-ft-long flatbeds.

Each precast arch section was cast with polystyrene at its center to reduce weight without compromising structural integrity. Even so, each arch section weighed approximately 92 tons and contained approximately 48 yd^3 of concrete with a specified compressive strength of 7000 psi.

McHugh began installing the arches from each end, eventually meeting in the center. Placement of the arched sections required a choreographed crane operation. To maintain river flow and leave the river channel open during construction, a crane-pick location plan was developed to accommodate the erection of the arches. A temporary bridge, capable of supporting more than 1 million lb, was built to give workers access to the island and to support tractors and trailers with the arch segments to the erection points.

Arch Geometry Was Critical

Constructing the arch sections required the project team to monitor each arch during every stage of erection to ensure the structure functioned properly at all times. Sequencing the construction had to accommodate a very stringent set of geometric restraints inherent in creating an arched design that acts as a true arch.

Designers ran two models, a two-dimensional analysis that took into account time-dependent properties of the concrete components, and a 3-D analysis to model the load distribution for the arches. These analyses ensured the construction team could sequence the construction process to optimize the arch design's inherent benefits during each stage by slightly manipulating the activities.

Precast concrete I-girders frame the approach spans and span between the spandrel bents. (top)

The concrete arches were fabricated in two pieces and supported on the substructure and falsework tower before closures were cast. (middle)

Precast concrete half-arch in transit to the construction site. (bottom)

10-SPAN PRECAST CONCRETE I-GIRDER BRIDGE INCLUDING FIVE PRECAST CONCRETE ARCH SPANS / ILLINOIS STATE TOLL HIGHWAY AUTHORITY, OWNER

BRIDGE DESCRIPTION: 1345-ft-long, 10-span bridge incorporating five 178-ft-long concrete arches, precast concrete Illinois I-girders, and a cast-in-place concrete deck

BRIDGE CONSTRUCTION COST: $44.5 million (including Route 31 ramps and overpass)

The new 1345-ft precast concrete arched bridge over the Fox River along I-88 in Illinois, designed to add lanes alongside an existing arched bridge, proved so successful that the project was extended to replace the original bridge, too.

As each arch half was delivered to the site, it was placed on temporary falsework, with one end supported on the substructure and the midspan end supported by a falsework tower. Cast-in-place closures at the arch crowns and thrust blocks were then added to establish continuity. The arch was released from its falsework support so it would begin to behave as an arch. After the arch deflected due to its self weight, it was shimmed tight to the falsework tower, near the center of the arch, to minimize the anticipated design moments during the stages of construction. This approach reduced the amount of structural reinforcing that was needed, saving money.

Anticipating arch deflection during the construction sequencing and establishing the necessary geometry for support elevations represented the biggest design challenge for the project. A key concern was supporting the superstructure from the intermediate spandrel supports, which also move up and down during construction. Designers had to anticipate future deflections of the arch and the movement of the supports over the arch to establish proper beam seat elevations.

Site Conditions Added Challenges

In addition to creating the unique geometry of the arched design, the project also faced key challenges due to the site. The Fox River is not navigable where the bridge crosses it, but it still is subject to strong currents and rapid water flows. During construction, McHugh's crews persevered through a 500-year flood event and two 100-year flood events. Under normal conditions, the river flows at approximately 500 to 700 ft^3/sec; during the construction period, it was measured at more than 15,000 ft^3/sec.

Even before these historic flows were reached, the team had to maintain the river's flow while ensuring it could easily transport materials, leading to the creation of the temporary bridge as well as additional temporary access structures. Environmental standards also had to be maintained, including ensuring that no construction materials or debris entered the waterway. All materials, the cranes' support bases, and other equipment had to be secured against the fast-moving and rising waters. The river's active recreational uses also meant that the team had to be cognizant of kayakers and canoers, especially those who were drawn to the river when its waters were most active.

Original Bridge Replaced

The challenges faced on this project made McHugh better prepared for understanding the changing dynamics of the Fox River during subsequent construction projects, which came in handy almost immediately. Upon seeing the quality and design of the new structure, Tollway officials decided to replace the existing arch bridge in lieu of the planned rehabilitation. This new westbound span now is scheduled for completion in summer 2010.

McHugh is acting as general contractor for the additional project, with Teng & Associates serving as engineer of record and Janssen & Spaans providing construction engineering. A key challenge for the second phase was demolishing the existing 1958 structure. To ensure balance and stability during demolition, the bridge deck's weight first was reduced as much as possible. Each arch barrel then was removed in sequence, carefully reducing each arch's width while maintaining its stability. The new bridge's design is virtually identical to the earlier structure in length and span configuration, speeding construction.

Both projects required considerable coordination among a number of public agencies and private interests, since the bridge spans areas with a variety of stakeholders. The team had to coordinate and communicate with officials from the tollway, the Village of North Aurora, City of Aurora, Burlington Northern Santa Fe Railroad, Illinois Commerce Commissions, Fox Valley Park District, Fox Metro Sanitary District, Army Corps of Engineers, and several utilities.

These two projects together expand the functionality of the crossing and extend the crossing's service life significantly. They also retain the distinctive look that the original bridge provided to this segment of the tollway, and it will continue to do so for many decades to come, even though its original inspiration has been replaced.

Brian Slagle is a vice president at Janssen & Spaans Engineering Inc. in Chicago, Ill., and Michael Gould is vice president of infrastructure at James McHugh Construction Co. in Chicago, Ill.

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

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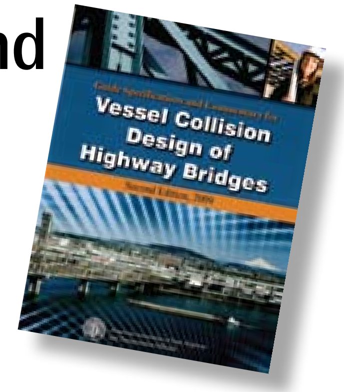
The AASHTO Guide Specifications and Commentary for Vessel Collision Design of Highway Bridges

by Michael A. Knott, Moffatt & Nichol



This 2nd Edition (2009) of the *Guide Specifications* incorporates the following enhancements:

- Lessons learned from the use of the original 1991 Guide Specifications
- Current LRFD Bridge Design methodology
- Clarification of some of the risk procedure elements
- Minor modifications and corrections
- Discussion of results from barge and ship collision research conducted since the original edition

The *Guide Specifications* now highlights procedures to evaluate existing bridges. A new example illustrates the procedure for vessel collision risk assessment.

The many subject areas covered by the 2nd Edition include deep draft and shallow draft waterways; ship and barge characteristics; vessel impact analysis methods; location of impact forces; minimum impact loads; impact load combination; design impact speed, energy, and forces; deterministic method and probabilistic method of selecting the design vessel; probability of vessel aberrancy; geometric probability of collision; probability of collapse; annual frequency of collapse; risk acceptance criteria; cost of collision; pier protection requirements; fenders, pile structures, dolphin, and island protection systems; moveable bridge protection; motorist warning systems; and navigation alternatives for bridge protection.

The manual was developed by Moffatt & Nichol (M&N) under contract to the Federal Highway Administration (FHWA). A 2-day short course to train engineers on the use of the new manual has also been developed by M&N for FHWA, state DOTs, and bridge designers.

Michael A. Knott is vice president of Moffatt & Nichol in Richmond, Va.

The AASHTO Guide Specifications for Bridges Vulnerable to Coastal Storms

by John M. Kulicki, Modjeski and Masters Inc.

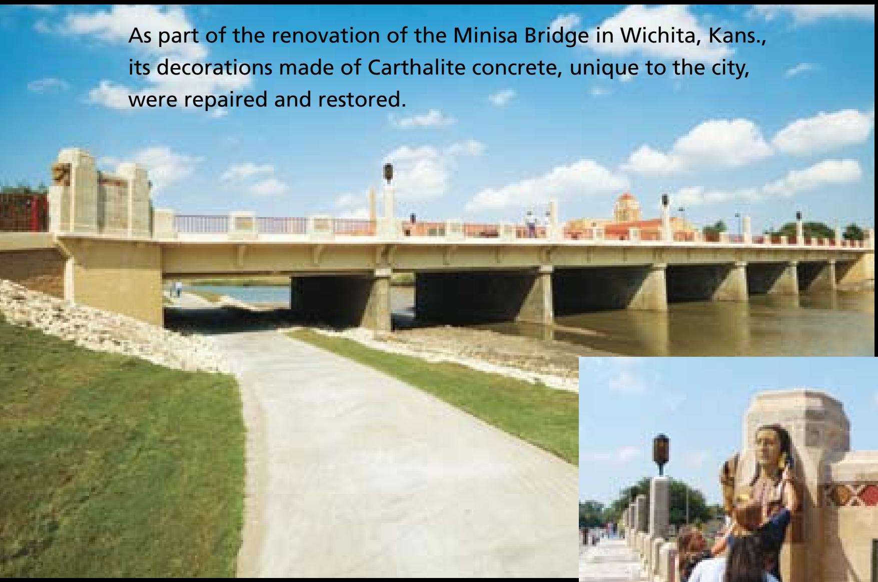
In 2004 and 2005, hurricanes caused significant damage to numerous structures in Florida, Mississippi, and Louisiana. The bridges were similar to many low-lying coastal bridges composed of numerous relatively short spans located close to the mean high water level. These types of structures are susceptible to extreme horizontal and vertical forces and moments exerted by waves brought within reach of the superstructure by storm surge. The estimated replacement and/or repair cost for four of the longer bridges (I-10 Twin Spans over Lake Pontchartrain, I-10 over Escambia Bay, U.S. 90 over Bay St. Louis, and U.S. 90 over Biloxi Bay) is $1.6 billion.

In response to the need to learn more about how to design and retrofit coastal bridges, a pooled fund study was developed by some 10 concerned states and the Federal Highway Administration (FHWA). A team led by Modjeski and Masters Inc. and including coastal engineers Moffatt & Nichol, and Ocean Engineering Associates Inc. (OEA); geotechnical experts from D'Appolonia Inc.; and assistance from Dennis R. Mertz, was selected for the project. The work was guided by the Bridge Wave Task Force chaired initially by William Nickas then of the Florida DOT and later by Gregory Perfetti of the North Carolina DOT.

Capitalizing on work previously started by OEA and the University of Florida (UF), a numerical simulation of wave action on bridge cross sections called the Physics Based Method (PBM) was developed. Results were confirmed by comparison to model test measurements in the UF wave tank and the pattern of failure and survival of the spans of the I-10 bridge over Escambia Bay. Numerous simulations with the PBM were used to develop empirical equations for vertical and horizontal forces and overturning moments acting on a cross section. These are then extended to a full-bridge span. A three-level approach based on increasingly more rigorous meteorological and oceanographic input was developed to estimate wave height. All of this was codified in the AASHTO Guide Specification, which was adopted in 2008.

John M. Kulicki is chairman/CEO of Modjeski and Masters Inc., Consulting Engineers in Harrisburg, Pa.

Both publications are available from the AASHTO online bookstore at https://bookstore.transportation.org/. The item code for the 2nd Edition of the Guide Specifications and Commentary for Vessel Collision Design of Highway Bridges *is GVCB-2 and for the* Guide Specifications for Bridges Vulnerable to Coastal Storms *is BVCS-1.*



As part of the renovation of the Minisa Bridge in Wichita, Kans., its decorations made of Carthalite concrete, unique to the city, were repaired and restored.

Community residents helping to restore some of the decorative sculptures on the Minisa Bridge.

PARTNERSHIP PAYS OFF

by Don King, King Construction Co.

Updating the 1932 Minisa Bridge along West 13th Street in Wichita, Kansas, involved a variety of unusual challenges. In essence, the bridge was torn away completely in the rehabilitation work, leaving only the sidewalks and ornamental elements on both sides supported by standalone shoring of steel and wood to provide access for children to their school on the other side. The bridge then was reconstructed beginning in January over a major river. The work not only preserved the historic portions of the bridge but opened less than 6 months later, ahead of schedule.

All of the stakeholders, including designers, contractors, city officials, city engineers, public-works employees, historical experts, and local school officials realized that partnering would be a key element of the project if it was to succeed. Engineers at Parsons Brinckerhoff had to recreate the plans for the bridge, as the originals were 76 years old and in bad condition. The designers and city both provided great latitude to make formwork and construction decisions, with their approval, so construction could proceed quickly.

The ornamental elements were rebuilt using a cast-in-place concrete mix that replicated the original material used for the construction, consisting of Carthalite concrete. Carthalite is essentially white portland cement concrete with colored glass aggregates. The material was made by the Cement Stone & Supply Co. in Wichita and was used to create ornamental sculptures, such as buffaloes and Native American images, as well as unique colors for the bridge. The material appears to have only been used in Wichita, where it was incorporated into 13 buildings, a flagpole base, and the Minisa Bridge. The company still operates, but it does not make the Carthalite concrete, requiring a new approach for the repairs.

I-Beams Installed

Structural integrity was first restored to the bridge, using precast, prestressed concrete I-beams. Seven spans of nine girders each were erected, ranging in length from 33 ft to 41 ft. A conventional cast-in-place composite concrete deck was used on the girders. Once the main structure was completed, restoration of the historic concrete wingwalls and piers supporting the balustrades was performed. Under consultation with historic-masonry experts, the historic Carthalite mortars and materials were replicated.

Restoration work consisted of four phases: joint and crack repair, sculpture repair, recasting, and cleaning. Joints and cracks were repointed and injection-patched with less-dense mortar to allow the concrete to "breathe." Then the historic colored mortars were analyzed and recreated. The original castings had featured crushed-glass aggregates, which required incorporating glass made prior to 1950 to obtain pigments stable enough to withstand future weathering. Local citizens donated family treasures, old bottles, and even bought and donated antiques to aid in creating the glass aggregate.

During the removal of the original materials, a wide variety of mortar-patch materials were uncovered that had been applied over the years. These consisted of epoxies, plasticized mortar mixes, silicon and butyl rubber caulk, and other unknown materials. These inappropriate mortar-joint materials caused additional problems and had to be removed by hand to avoid causing further damage.

A calcium hydroxide-based lime mortar was used to replace all existing mortar, providing a strong bond that would remain sufficiently porous to allow rapid water migration. Crew members monitored the joints for approximately 5 hours per application, taking moisture and temperature readings. Each reading indicated a joint noticeably harder than before.

Broken caps on some pillars were patched or recast with the historic-mortar formula. Some areas that had become stained from pollutants resisted typical cleaning methods, so a diluted solution of muriatic acid was applied with a bristle brush, immediately neutralized, and rinsed with water.

The bridge was reopened to traffic in 5½ months, some 32 days early, earning a substantial bonus. After opening, some of the historic preservation work continued and a new bike path was added under the bridge to connect an existing bike path to a new area two blocks away. All of the work was completed on budget and with no lost-time accidents.

Don King is president of King Construction Co., Hesston, Kans.

Precast concrete components, including columns and spandrel walls were carefully fabricated to replicate the look of the original concrete pieces replaced on the historic Spring Street Bridge in Floyd and Clark Counties, Ind.

PRESERVING HISTORY

by Kevin R. Loiselle, Farrar, Garvey & Associates, division of Clark Dietz Inc.

The Spring Street Bridge over Silver Creek in Clark and Floyd Counties, Ind., built in 1926, is eligible for inclusion in the National Register of Historic Places due to its engineering significance. Local officials wanted to ensure it maintained that eligibility while updating it to increase its load capacity to HS 20 and lengthen its service life. The design team at Clark Dietz Inc.'s Farrar, Garvey & Associates division worked with a variety of local and federal officials to preserve the four-span, reinforced concrete, open-spandrel arch bridge.

The proposed improvements included replacing the entire bridge deck, railings, floor beams, and stringers to upgrade the deteriorating components to meet current safety standards. The columns were repaired or replaced, while the arches were repaired.

Coordination began early in the design phase due to the historic nature of the project. Engineers at Farrar, Garvey & Associates coordinated communications with Floyd and Clark Counties, the adjacent towns of New Albany and Clarksville, the Indiana State Historic Preservation office, the Indiana Department of Transportation, and the Federal Highway Administration. They also worked closely with the general contractor, Gohmann Asphalt & Constructors Inc.

This detailed coordination was required to ensure that any removed structural elements were reconstructed to match the existing elements' sizes and shapes. Precast concrete components were used extensively to save construction time and eliminate the need for additional formwork and bracing. It also eliminated any extra construction dead loads applied to the arch ribs.

Precast columns were attached to pedestals on the arch ribs with grouted NMB splice sleeves. These sleeves also were used to tie the floor beams to the tops of the columns. The precast spandrel walls were constructed to the same size and shape as the existing ones, as these were the most visible elements from below the bridge. The spandrel walls were attached to the columns using a Halfen anchor channel cast into the column and a Halfen tee-head bolt cast into the spandrel wall.

Several challenges arose due to the open-spandrel arches and the bridge's location. The 150-ft main span rises 38 ft above the springline and 50 ft above the flowline. That made it difficult to inspect the arches, columns, and underside of the deck. A snooper truck was used to provide access for inspecting and sounding the individual elements.

The loading and unloading sequences had to be carefully analyzed and planned to ensure portions of the arches were not asymmetrically loaded, which could cause a collapse. To eliminate the time and expense of creating supporting falsework during rehabilitation of the columns and deck, construction unloading and loading were evaluated. It was determined that no more than two adjacent sections of the arch could be unloaded at once to keep the arch in compression.

Precast, prestressed concrete deck panels were used to span the floor beams instead of metal-deck forms; thereby, maintaining the appearance of the concrete deck. Using the deck panels provided permanent formwork that did not have to be removed.

The historic railing did not meet current standards because the pilasters located within the rail protruded 4 in. into the driving area. The new railing was modeled from the crash-tested Texas type bridge railing, but it was modified along the exterior face to replicate the appearance of the historic bridge railing.

The rehabilitation work increased the load rating and lengthened the bridge's service life while maintaining its historic character. The goal was to use techniques to maintain the history while increasing load capacity and providing ease of construction. Using precast concrete construction saved time and eliminated the need for additional bracing. That resulted in safer construction and a reduced schedule, which helped minimize costs. The project met the owners' goals and will enhance its community for many decades to come.

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Kevin R. Loiselle is senior project manager with the Farrar, Garvey & Associates, division of Clark Dietz Inc., Indianapolis, Ind.

SETTING THE STANDARD

by Nate Scigliano, Nathan Contracting Co. and Will Gold, BASF

When officials at the Pennsylvania Department of Transportation (PennDOT) decided to make repairs to the bridge on State Route 4012 in Northumberland, Pa., they made it more than a stand-alone rehabilitation project. They designated the procedures applied to the repairs to serve as the specifications for future repairs on other bridges. That put more pressure on this project to be completed in ways that maximized savings on time, labor, and material.

The bridge, built in the 1940s, consists of a 48-ft-long span using six reinforced concrete tee beams. By 2008, the bridge was showing signs of corrosion damage and could not support the loads required for modern truck traffic. PennDOT officials worked with researchers at Penn State University and West Virginia University to evaluate the bridge's condition and investigate repair options.

The officials ultimately selected two key products from BASF to be used to restore the bridge and chose Nathan Contracting in Allison Park, Pa., to perform the work. PennDOT set loading criteria and performance standards and arranged for Nathan to work with university researchers to uncover the full extent of the repairs needed to achieve the set goals. Nathan, operating under a subcontracting agreement with Gregori Construction Co. in Sarver, Pa., exposed damaged portions of the bridge to give West Virginia University and PennDOT officials better access to the deteriorated areas.

BASF then provided in-house engineering services to determine how best to address the conditions with the selected products of MBrace Composite Strengthening System and Emaco S-88 CI Concrete Repair Mortar. Nathan and BASF had worked together for more than 10 years on projects and were familiar with each other's approaches. This project required a lot of out-of-the-box thinking to determine the best approach to the conditions to ensure they could be addressed in ways that other bridges could use. BASF provided theoretical design options that Nathan then evaluated for in-field feasibility to maximize constructability.

The strengthening system consists of carbon-fiber sheets that are applied to the surface of the concrete structure to restore or increase its strength without changing the dead load. After the extent of the deterioration in the concrete was determined, each area to be addressed was prepared by sandblasting the surface. Then a two-part epoxy coating was applied with a roller. The MBrace sheets, which have the thickness and texture of denim, were cut to size and applied to the affected area. Another layer of epoxy was then added over the sheets.

The repair mortar was applied to damaged concrete areas and to the cross section of the bridge beams where needed. A special corrosion inhibitor also was included in the mix to provide additional protection.

The carbon-fiber installation took only 3 days to complete and was accomplished with no unusual challenges once the specifics of the plan were worked out. The work allowed the bridge to carry modern HS20 loading with an inventory rating of 1.0. This timely procedure will provide key benefits to many bridges that require repairs and rehabilitation to ensure they continue to offer long service to the public.

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Nate Scigliano is president of Nathan Contracting Co. in Allison Park, Pa., and Will Gold is the project's technical service representative at BASF in Evans City, Pa.

Repairs to the bridge on State Route 4012 in Pennsylvania, which used carbon-fiber reinforcement and cementitious repair mortar, will serve as the standard by which other bridges will be repaired in the state.

PERFORMANCE OF
BRIDGE DECK SEALANTS AND CRACK SEALERS

The Minnesota Department of Transportation has released a report defining the state-of-the art regarding the use of bridge deck sealants and crack sealers to extend the life of reinforced concrete bridge decks. Based on information collected from a literature review and survey of 16 state departments of transportation, the best sealant materials and application practices are recommended for use throughout the Midwest.

Deck Sealants

The research on deck sealants suggests that a number of measures can be taken prior to application of the sealers to improve their effectiveness. The initial moisture content of the deck should be as low as possible because a higher moisture content can hinder penetration of the sealer. Also, curing compound should be removed from the deck prior to application of the sealer.

The researchers noted large variability present in the data collected for deck sealants. Many times, observations made in the laboratory could not be reproduced in the field and different laboratory studies yielded conflicting results. Nevertheless, the researchers were able to make some specific observations and recommendations including the following:

- Silane products typically outperform siloxane products.
- Solvent-based products typically outperform water-based products.
- Water-based products are not suitable for reapplication.
- High solid content is typically desirable.
- A solvent-based silane with 40% solids is the commonly produced sealant that best fits the criteria above.
- Sealants should be applied between temperatures of 40 °F and 100 °F.
- A drying period of at least 2 days before application of the sealant should be enforced if the deck is moist from rainfall or washing.

Crack Sealers

Information collected in the literature review and performance survey indicated that epoxy crack sealers tend to have the highest bond strength as well as a good resistance to freezing-thawing. However, high molecular weight methacrylates (HMWM) are much less viscous, which enables them to achieve a larger penetration depth. Because of this property, product selection may need to depend on specific project conditions. If very narrow cracks are present in the bridge deck, depth of penetration may be deemed more important than bond strength indicating that an HMWM product is the best choice. However, if the bridge deck cracks are large, bond strength may become a more important criterion indicating that an epoxy crack sealer is the best choice. Additionally, HMWM products are typically applied in a flood coat and epoxy products are generally applied to individual cracks. This means the extent of cracking on the bridge deck may also be a factor in the decision.

Specific observations and recommendations from the researchers included the following:

- HMWM products typically provide better penetration and are better suited for narrower cracks.
- Epoxy products typically provide higher bond strength.
- Although test results are varied, epoxy sealers tend to demonstrate good resistance to freeze-thaw effects.
- Cracks sealers should be selected with
    1. viscosity less than 500 cP (or 25 cP for HMWM sealers),
    2. tensile strength more than 1160 psi, and
    3. tensile elongation larger than 10%.
- Some form of surface preparation should be used to clean the cracks.
- Crack sealers should be applied between temperatures of 45 °F and 90 °F.
- If possible, crack sealers should be applied between 11:00 p.m. and 7:00 a.m.
- A drying period of 2 to 3 days before application of the sealer should be enforced if the deck is moist from rainfall or washing.

Further Information

The full 268-page report titled *Crack and Concrete Deck Sealant Performance* by the Department of Civil Engineering at the University of Minnesota is available at http://www.cts.umn.edu/Publications/ResearchReports/reportdetail.html?id=1754 and click on download pdf.

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://books.trbbookstore.org/nr620.aspx
Visit this website to order a copy of the National Cooperative Highway Research Report 620: *Development of Design Specifications and Commentary for Horizontally Curved Concrete Box-Girder Bridges* mentioned on page 12.

www.infrastructurereportcard.org/fact-sheet/bridges
This website contains the American Society of Civil Engineers' Grade C report card for bridges summarized in Perspective on pages 14 and 15.

https://bookstore.transportation.org
Visit this website to order copies of the AASHTO *Guide Specifications for Bridges Vulnerable to Coastal Storms* (Item Code BVCS-1) and *Guide Specifications and Commentary for Vessel Collision Design of Highway Bridges* (Item Code GVCB-2), other AASHTO publications, or just to browse the bookstore.

http://www.cts.umn.edu/Publications/ResearchReports/reportdetail.html?id=1754
Visit this website to down load a copy of the report titled *Crack and Concrete Deck Sealant Performance* mentioned on page 42.

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.

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

Bridge Technology

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

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

www.hpcbridgeviews.org
This website contains 55 issues of *HPC Bridge Views*, an electronic newsletter published jointly by the FHWA and the NCBC to provide relevant, reliable information on all aspects of high-performance concrete in bridges. Sign up at this website for a free subscription.

www.nhi.fhwa.dot.gov/about/realsolutions.aspx
Presentations from a monthly seminar series offered online by the Federal Highway Administration National Highway Institute are available to listen to or download from this website. Guest speakers discuss challenges they have faced in the field and innovative solutions used to address those challenges. Seminars relevant to bridges include I-70 Overpass Beam Failure, New Technologies in Driven Piles, and Use of Self-Propelled Modular Transporters.

www.specs.fhwa.dot.gov
This site serves as a clearinghouse and electronic library where users can search, review, cross-reference, and download the most current specifications, construction manuals, and drawings. Materials on the site have been submitted by state departments of transportation and other agencies and include access to specifications, construction manuals, and standard drawings.

Bridge Research

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

http://www.trb.org/news/blurb_detail.asp?id=8718
NCHRP Report 609, *Recommended Construction Specifications and Process Control Manual for Repair and Retrofit of Concrete Structures Using Bonded FRP Composites* explores recommended construction specifications to facilitate highway agencies' use of bonded fiber-reinforced polymer (FRP) composites for the repair and retrofit of concrete structures. The specifications cover the construction of FRP systems used as externally bonded or near surface-mounted reinforcement to enhance axial, shear, or flexural strength of a concrete member.

http://www.trb.org/news/blurb_detail.asp?id=10217
NCHRP Synthesis 393, *Adjacent Precast Concrete Box Beam Bridges: Connection Details* explores current design and construction practices that are reported to reduce the likelihood of longitudinal cracking in box beam bridges.

http://www.trb.org/news/blurb_detail.asp?id=9627
NCHRP Report 628, *Self-Consolidating Concrete for Precast, Prestressed Concrete Bridge Elements* explores recommended guidelines for the use of self-consolidating concrete (SCC) in precast, prestressed concrete bridge elements. The report examines the selection of constituent materials, proportioning of concrete mixtures, testing methods, fresh and hardened concrete properties, production, and quality control issues, and other aspects of SCC.

Global Efforts on GREEN Highways and Bridges

by M. Myint Lwin, Federal Highway Administration

On April 22, 1970, millions of Americans of all ages and from all walks of life, from coast to coast, participated in the first Earth Day celebration—a celebration of the enactment of a very important legislation, the National Environmental Policy Act (NEPA) in January 1970. On that day, millions of Americans made it clear that they were deeply concerned over the deterioration of our environment and the dissipation of our natural resources. That was the time when rivers caught on fire and cities were covered with dense clouds of smoke.

The first Earth Day had brought about major and lasting changes in improving and protecting our environment and our natural resources. The U.S. Environmental Protection Agency (EPA) was established on December 2, 1970, to provide stewardship and oversight of environmental protection standards and national environmental goals. Congress passed legislation and enacted into law: the Clean Air Act, the Water Quality Improvement Act, the Water Pollution and Control Act Amendments, the Resource Recovery Act, the Resource Conservation and Recovery Act, the Toxic Substances Control Act, the Occupational Safety and Health Act, the Federal Environmental Pesticide Control Act, the Endangered Species Act, the Safe Drinking Water Act, the Federal Land Policy and Management Act, and the Surface Mining Control and Reclamation Act, new emission standards, cleaner fuels and engines, and so on. (Please see *ASPIRE*™ Fall 2008 for more details on the missions and accomplishments of the EPA).

On April 22, 2009, people from around the world celebrated Earth Day with a common hope of creating a greener, cleaner, and healthier environment.

Partners in Green Highways and Bridges

FHWA is one of many partners, including federal and state regulatory and transportation agencies, consultants, contractors, industry groups, academic institutions, and nongovernmental organizations, working on improving the natural, built, social, and environmental conditions, while addressing the functional requirements of the highway infrastructure. The key is to meet the mobility and safety needs of the traveling public, while protecting or enhancing the environment and assuring the livability and sustainability of our communities.

In the design, construction, operation, and maintenance of highway facilities, it is suggested to consider at least the following in the promotion of and the development of guidelines for "green highways and bridges":

- Improving highway safety for motorists and wildlife by reducing collisions with wildlife
- Maintaining wildlife habitat connectivity across highway facilities
- Attention to safety, durability, mobility, and economy
- Compliance with environmental and preservation laws and regulations
- Application of context-sensitive solutions
- Sustainable site selection and planning
- Utilization of high-performance and environmentally friendly materials, and quality workmanship
- Safeguarding air, water, soil, and wetland quality
- Conservation of materials and resources
- Avoidance of negative impacts on the ecosystems

Green Highways and Bridges in Europe

An interdisciplinary delegation of federal, state, and conservation group representatives visited some European countries including Switzerland, Germany, and France. Although each country uses different approaches to address "green highways and bridges" issues, they have formed an international network to share information. The Infra Eco Network Europe (IENE) is an initiative for creating a transport infrastructure that harmonizes with the surrounding landscape. Here are some approaches to "green bridges" in some European countries.

Pond and vegetation on a swiss green bridge.

Switzerland

Switzerland's transportation and environmental programs have a long history of research and actions related to wildlife. Swiss actions are scientifically based, supplemented by hunter information. Swiss scientists have completed geographic information system-based identification of wildlife habitat and corridors nationwide, pinpointing bottlenecks and voids in connectivity. They characterize the wildlife corridors as impacted, impaired, or interrupted, with only one-third categorized as intact.

The Swiss use a variety of structural and nonstructural measures. Vegetated overpasses, called "green bridges" or "ecoducts," are a preferred structure for maintaining habitat connectivity. Swiss research demonstrates that the diverse habitats on "green bridges" provide important connectivity for a broad spectrum of species.

Many of the "green bridges" are of multiple uses, accommodating forestry roads and wildlife. The structures are monitored using standard approaches, such as animal tracks and photography, and evolving technologies including infrared video. The video makes it possible to record the behavior of the animals while using the structures. The Swiss research indicates that "green bridges" with a width of 164 ft or greater are used by the widest variety of species and the animals exhibit natural behavioral characteristics when using the structures.

Germany

Landscape planning plays an important role in identifying protected flora and fauna and mitigating impacts to the natural environment. The Germans apply landscape ecology principles to highway planning in areas where adjacent land use and distribution can be expected to change because of highway development. All proposed detrimental changes to natural areas require compensation measures. Three kinds of compensation are possible: in-kind, off-site, and compensation fees (in-lieu-fees), in that order of preference.

Legal requirements in Germany necessitate wildlife fencing (needed because many highway stretches have no speed limits), signing, underpasses, green bridges, and land conservation as mitigation for highway facilities. Germany has one of the largest numbers of "green bridges" in the European countries. The overpasses vary in width from 28 ft to 2854 ft. Forest and agricultural roads cross about half of Germany's "green bridges."

Germany's green bridges.

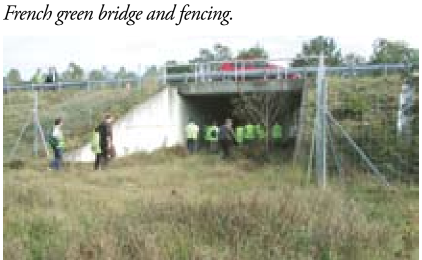
Germany builds extensive projects, such as fences and crossing structures to keep amphibians and other small animals away from roads. More than 100 such projects for small animals were completed nationwide. The Germans also report that more than 130 "green bridges" over rivers were designed to accommodate wildlife passage and keep the animals away from the traffic lanes. The Germans are very thorough in considering every detail in determining what and where to construct a "green bridge."

France

The French Transportation Ministry's primary objective when looking at transportation and wildlife issues is to increase motorist safety. Approximately 30 deaths per year result from collisions with animals. The French consider motorist safety as a major reason for measures to keep animals off the highways.

The French have taken numerous measures to reduce wildlife collisions. Fencing for wildlife is required on all federal highways. Permanent signage has not been effective in reducing wildlife mortality, and measures such as reflectors and vehicle-mounted whistles generally are ineffective. "Green bridges" are used as structural alternatives. France has been developing and building "green bridges" for wildlife since the 1950s.

French green bridge and fencing.



China's Green Highways and Bridges

China's green highways and bridges are integrated into the master plans for their eco-cities. Integration is the theme in planning the eco-cities. Roads and bridges are considered at the same time as parks and health care. They are interrelated—the more convenient and attractive to walk or bicycle to parks or work, the less air pollution, the healthier the people, the lower the health care costs, and the more productive in the factories.

China's developer, Shanghai Industrial Investment Corporation (SIIC) contracted with Arup, the British engineering consulting firm, to design and master plan Dongtan, an eco-city on Chongming Island close to Shanghai. Dongtan is one of four eco-cities envisioned in China. The cities are planned to be ecologically friendly, with zero greenhouse-emission transit and complete self-sufficiency in water and energy, together with the use of zero-energy building principles. Energy demand will be substantially lower than comparable conventional cities due to the high performance of buildings, roads, and bridges, and a zero-emission transport zone within the city. Waste is considered to be a resource and most of the city's waste will be recycled.

Dongtan proposes to have only green highways and bridges along its coastline. People will arrive at the coast and leave their cars behind. The people then travel on foot, by bicycle, or on sustainable public transportation vehicles. The only vehicles allowed in the city will be powered by electricity or hydrogen. When completed, this eco-city will house up to 500,000 inhabitants.

The development of Dongtan will incorporate all of the economic, social, and environmental principles, and the "green highways and bridges" concepts. This will reduce the impact on the natural environment and provide a model for healthy living for future development across China. Dongtan aims to be a post-industrial, sustainable city of the highest quality.

Closing Remarks

Great global efforts are devoted to applying the concepts of "green highways and bridges" to design, construction, operation, and maintenance of transportation facilities to improve livability and sustainability of the communities and wildlife habitats. "Green" or "sustainability" is everywhere. Nearly all current concrete seminars or conferences focus on "green" or "sustainability." The owners of bridges are demanding it.

The Precast/Prestressed Concrete Institute (PCI) has an educational seminar on sustainability. It provides training on sustainability and stresses its importance to the construction industry. In the PCI Annual Bridge Design Award Competition, there is an award category on "Best Sustainable Design" to bring awareness of the significance of sustainability in concrete construction, and promotes the use of "Green Bridges" concepts in concrete bridge design.

The American Concrete Institute (ACI) dedicated the February 2009 edition of Concrete International to "Green Concrete." In October 2008, ACI conducted a survey of over 1100 members to obtain more information on involvement and interest in sustainability. Sixty-seven percent of the respondents indicated they were professionally involved with sustainability and related issues, while 89% were personally interested in sustainability and related issues. Seventy-seven percent of the respondents thought sustainability design and construction would become increasingly important and would be required globally at increasing rates.

One of the four FHWA strategic goals is on System Performance: the nation's highway system provides safe, reliable, effective, and sustainable mobility for all users. FHWA is committed to improving the performance of the highway system—as part of a fully integrated, multimodal transportation system—to levels needed to achieve national economic, security, energy, environmental, and other goals.

In his confirmation hearing in February 2009, the new Secretary of the U.S. Department of Transportation, Ray LaHood, outlined four key themes for his tenure as Secretary. In addition to economic recovery, which is of primary immediate concern, and safety, which is always an important part of the mission of the department, Secretary LaHood suggested that sustainability and livability would be hallmarks of his policies.

Finally, we must use green design and construction principles in the building of new highways and bridges and in the rehabilitation of existing highway facilities for the benefits of the present and future generations!

U.S. Department of Transportation
Federal Highway Administration

Research Drives Designs in

Louisiana

by Arthur D'Andrea, Paul Fossier, Ray Mumphrey, and Kian Yap,
Louisiana Department of Transportation and Development

The 18-mile-long bridge being built on the LA 1 Highway near Leeville, La., will be one of the longest bridges in the Americas when completed. It spans a sensitive wetlands area that has been subjected to coastal erosion and ground subsidence.

The new bridge on the LA 1 Highway is being constructed from the top down to minimize impact on the coastal wetlands areas over which the bridge is being constructed.

The Louisiana Department of Transportation and Development (LADOTD) has built its bridges predominantly with cast-in-place and precast concrete for decades, especially for short- and medium-span designs. That decision has been driven both by environmental conditions that require high durability and by long-running studies that have made the state a leader in techniques and research involving high-performance concrete (HPC).

The state has unique conditions that create challenges, including a large number of waterways and hurricane issues (storm surge, wave forces, and high winds). The state's bread-and-butter design consists of precast, prestressed concrete girders and cast-in-place concrete decks for short- to medium-span length structures.

The bridges north of I-10, which account for about 80% of the state's bridge area, are similar to concrete structures designed in other states. However, there are a host of extremely long bridges along and south of I-10. Although the state ranks 21st in total number of bridges, it ranks fourth in total bridge area, indicating the large length of many of its bridges. The region south of I-10 features many navigational crossings and a tremendous number of waterways. For this reason, Louisiana has a large number of movable bridges. In all, the annual budget for fixed- and movable-bridge replacements is about $140 million.

An example of the extraordinarily long projects that arise is the replacement work underway on an 18-mile-long bridge on the LA 1 highway near Leeville, La. Currently 9 miles are under construction and 9 miles are

Nine miles of the LA 1 Highway Bridge are currently being constructed, while an additional 9 miles are being planned and designed. Here a precast concrete pile bent cap is being moved into position for installation.

under planning and design. The project spans a sensitive wetlands area that has been subjected to coastal erosion and ground subsidence, resulting in the existing highway literally sinking.

When complete, the structure will be one of the longest bridges in the Americas, nearly as long as the Pontchartrain Causeway north of New Orleans. That precast concrete structure is generally regarded as the world's longest bridge at 23.87 miles. The LA 1 project will be built in phases as funding permits, with the most critical sections built first.

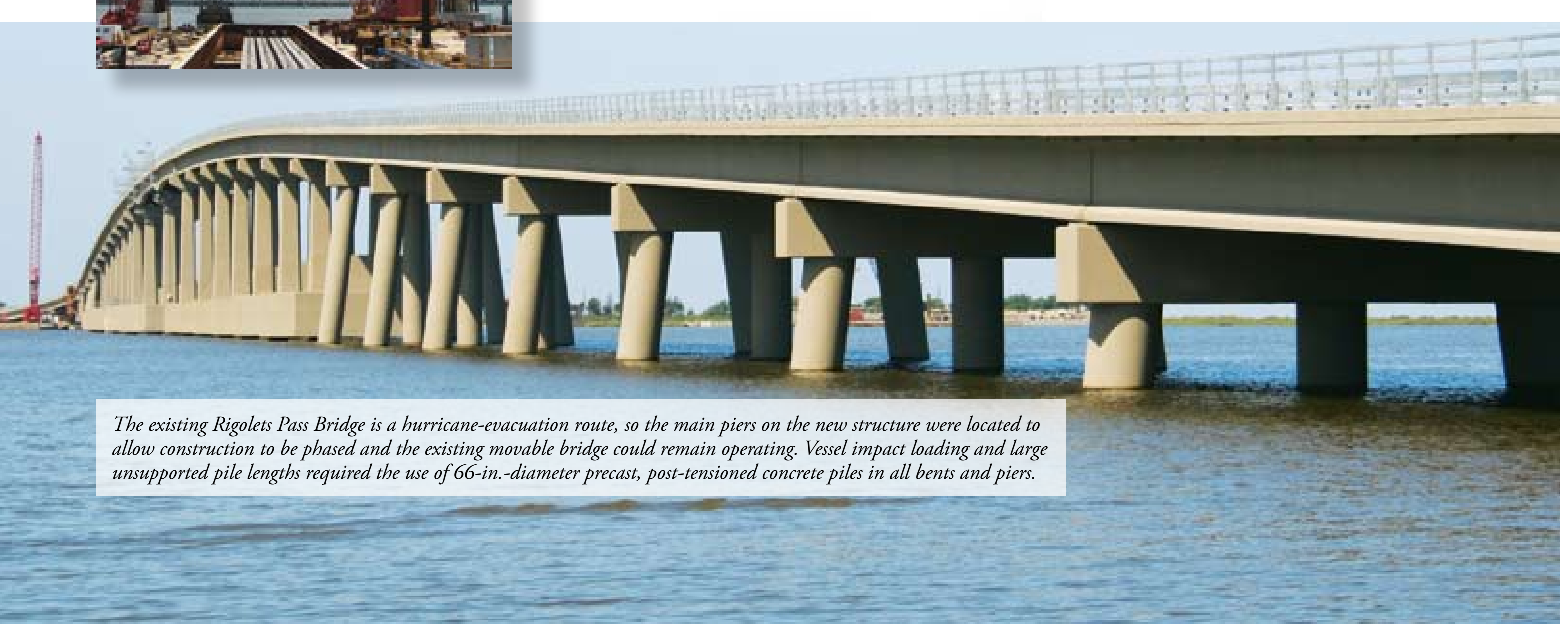
Concrete Replaces Steel

A majority of projects, as in other states, are replacement bridges and upgrades to existing structures, including a variety of widening projects. In some cases, an existing steel bridge is replaced with a more durable and efficient concrete design. That was the case with the Rigolets Pass Bridge recently completed near Slidell, La. The $50-million bridge replaced an existing main steel truss swing span with a high-level spliced girder concrete bridge that provided 65 ft of vertical and 200 ft of horizontal clearance for marine traffic.

The pass itself created an unusual challenge for design and construction. It is one of two main passages between Lake Pontchartrain and the Gulf of Mexico, with the main tidal flow through this narrow channel and one at Chef Menteur Pass. To meet the requirements of unsupported pile length and vessel-impact loadings, 66-in.-diameter precast, post-tensioned concrete cylinder piles were used in all bents and piers located within the channel.

Precast concrete forms were used to support the low-clearance slab span construction. This eliminated the need for falsework during construction. For other approach spans, both

The $50-million Rigolets Pass Bridge replaced a steel-truss swing-span structure with a high-level spliced girder concrete bridge that provided 65 ft of vertical and 200 ft of horizontal clearance for marine traffic.



The existing Rigolets Pass Bridge is a hurricane-evacuation route, so the main piers on the new structure were located to allow construction to be phased and the existing movable bridge could remain operating. Vessel impact loading and large unsupported pile lengths required the use of 66-in.-diameter precast, post-tensioned concrete piles in all bents and piers.

The I-10 Twin Spans as they approach the main channel. The goals for these replacement structures include better storm protection, safe accommodation of six traffic lanes, enhanced barge collision resistance, and utilization of well-known materials and techniques to provide for low maintenance and long service life.

AASHTO Type II and 78-in.-deep bulb-tee precast, prestressed concrete girders were used with stay-in-place steel forms to support the cast-in-place concrete deck. The typical bulb-tee girder spans were designed with optimum span lengths of 131 ft and girder spacing of 9.4 ft with concrete compressive strengths of 6000 psi at strand release and 7500 psi final. The main spans consist of a three-span continuous unit (with individual spans of 201 ft, 254 ft, and 201 ft) of spliced, post-tensioned, precast, prestressed concrete girders.

A precast concrete bent cap being set on precast concrete piles for the I-10 Twin Spans Bridges over Lake Pontchartrain.

Concrete Designs Vary

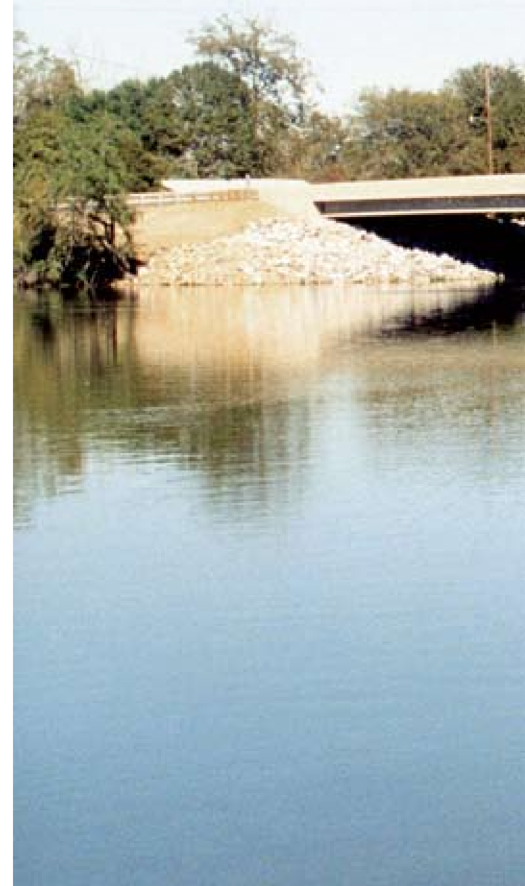
Designers use a combination of cast-in-place and precast concrete depending on the specific circumstances and the capabilities that each provide. Precast concrete provides efficient, fast construction while cast-in-place concrete provides added sturdiness and flexibility. Precast concrete panels require added attention to handle crossloads and camber, but those can be worked out to make the components quite efficient.

A recent example of concrete and steel construction is the $803-million I-10 Twin Spans structure crossing Lake Pontchartrain between Slidell and New Orleans. The crossing is approximately 5.5 miles long, with a total length of 11 miles of bridges on an offset alignment. The main channel provides 73 ft of vertical clearance and 200 ft of horizontal clearance, with the bridges offering three lanes in each direction and serving as one of the main evacuation routes for New Orleans.

In consideration of their location, size, and functional requirements, the bridges were designed to take advantage of precast concrete components for the bulk of the construction. The precast concrete elements include 36-in.-square precast, prestressed concrete piles, with 4-ft-deep by 5.5-ft-wide by 59.25-ft-long precast concrete bent caps and 135-ft-long, 78-in.-deep Florida bulb-tee girders. Stay-in-place precast concrete slabs were used to form the footings.

High-Performance Concrete Research Projects

One of the key reasons that Louisiana has turned to concrete for so many bridge designs comes from its long-standing research work in the field. Since the 1980s, LADOTD has



worked with the Louisiana Transportation Research Center (LTRC) in Baton Rouge and the Department of Civil Engineering at Tulane University in New Orleans, under the direction of Dr. Robert N. Bruce Jr., to evaluate HPC and create standards that can be used nationwide.

This work began in the 1970s, when the West Bank Expressway in New Orleans incorporated a HPC mixture with concrete compressive strength of about 6500 psi. That created interest in improving strength and durability capabilities, which led to a formal program that experimented with various methods, including variations with fly ash and silica fume. A variety of studies followed, such as examinations of fatigue endurance, curing temperatures, and concrete compressive strengths as high as 10,000 psi in combination with 0.6-in.-diameter prestressing strands.

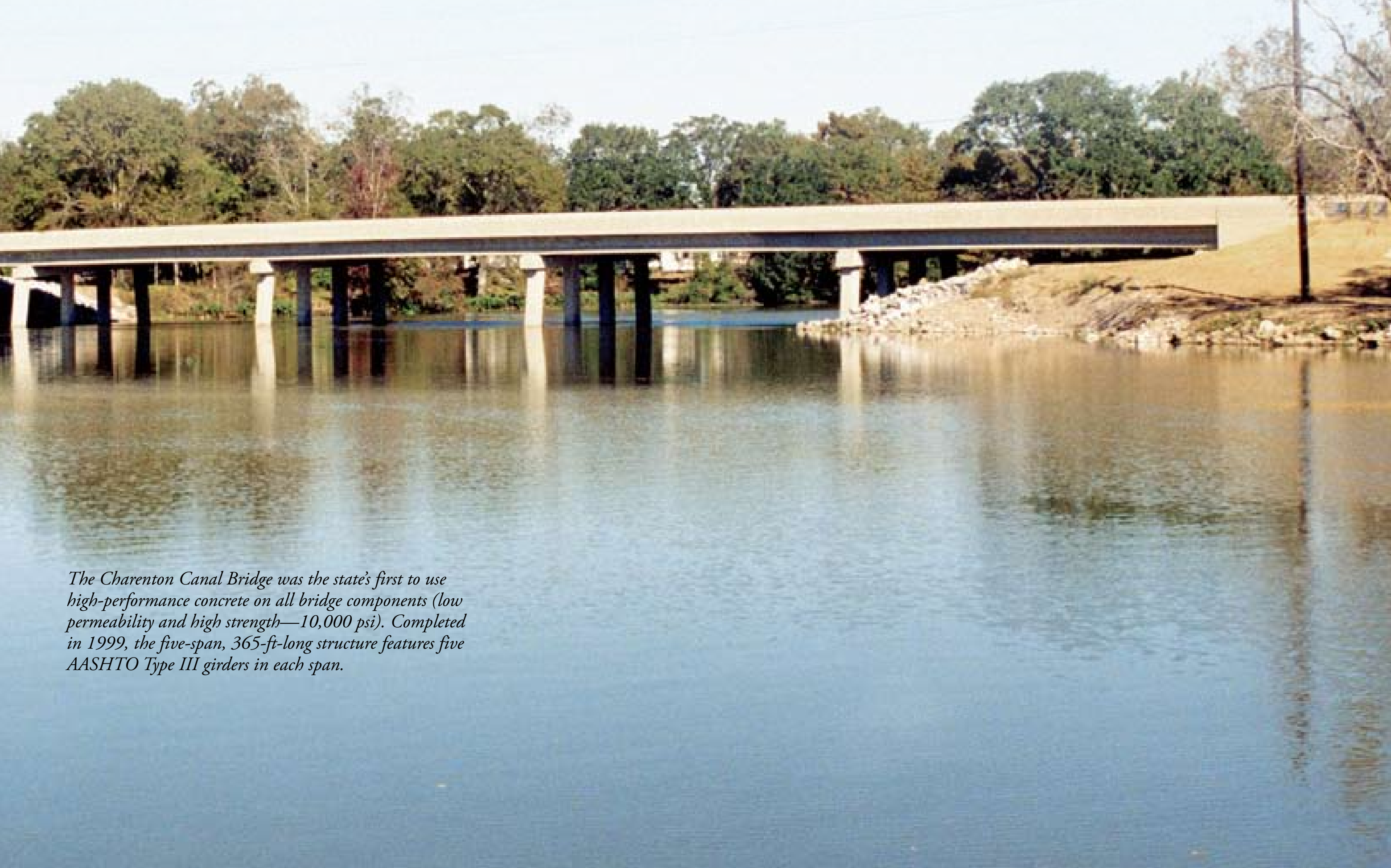
The continuing research led in 1999 to the opening of Louisiana's first bridge built with HPC, the Charenton Canal Bridge on LA 87 in St. Mary Parish. The project replaced a 55-year-old reinforced concrete bridge with a five-span, 365-ft-long continuous prestressed concrete structure using five Type III AASHTO girders. The girders on the 73-ft-long spans were spaced at 10-ft centers supporting an 8-in. cast-in-place concrete deck. The substructure of the bridge consisted of cast-in-place concrete bent caps supported on 24-in.- and 30-in.-square precast, prestressed concrete piles.

Specified concrete compressive strengths were 10,000 psi for the girders and piles and 4200 psi for the bridge deck and bent caps. All members had a chloride permeability of less than 2000 coulombs for durability. The use of HPC allowed the bridge to be designed with one fewer lines of girders than would have been required with normal strength concrete. The added pile strength also increased their ability to resist compressive- and tensile-driving stresses and allowed them to be cast to longer lengths. A 75-year to 100-year design life is expected compared to the 50-year limit that was more traditional at the time.

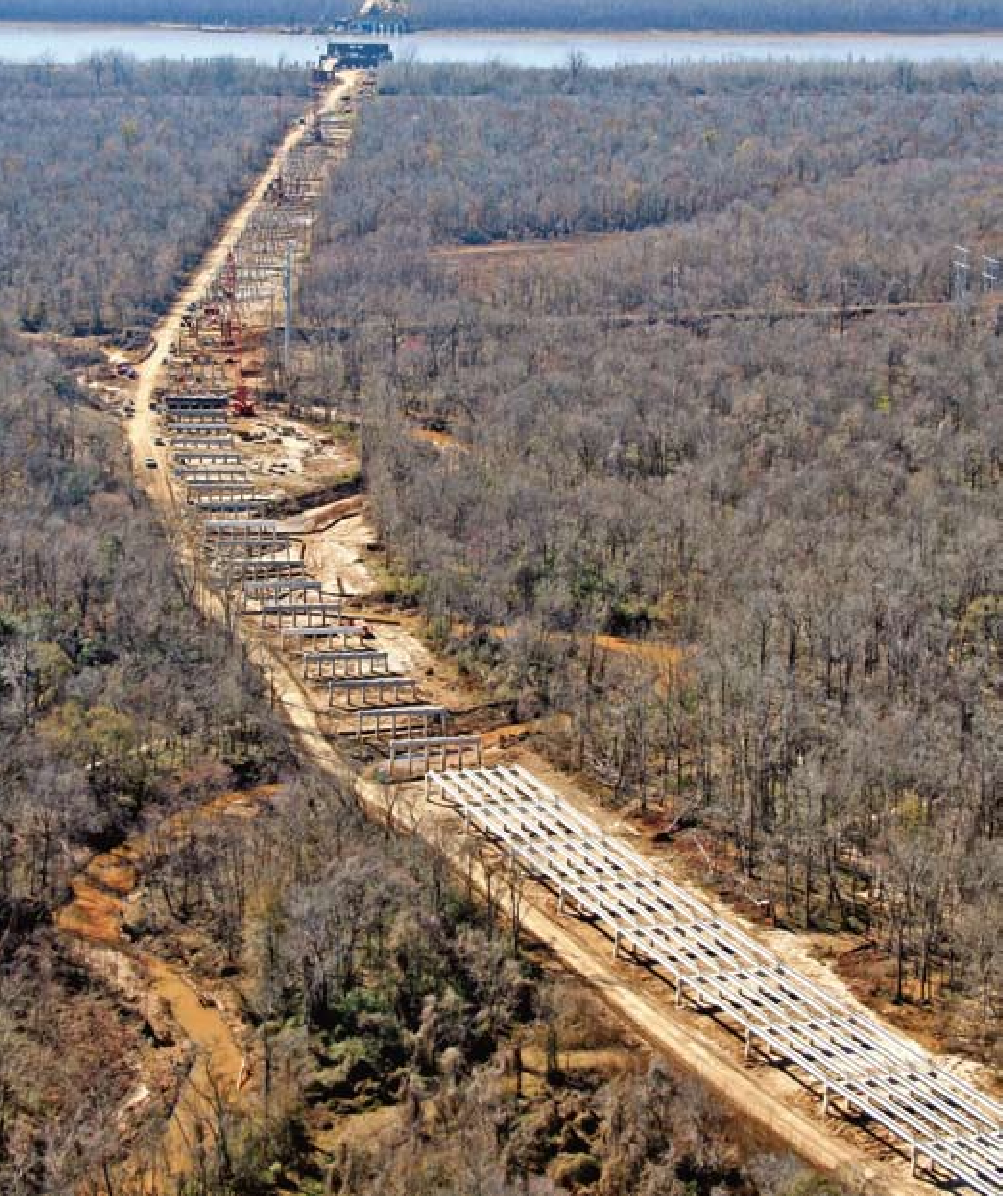
New Crossings Created

New crossings, although rare, continue to emerge. An example, which also shows how designs continue to improve, is the John James Audubon Bridge crossing the Mississippi River between Pointe Coupee and West Feliciana parishes in south central Louisiana. The project, to be completed in late 2010, will be the longest cable-stayed bridge in North America and replaces a ferry service. It will be the only structure across the Mississippi River between Natchez, Miss., and Baton Rouge, La. This will be the 10th bridge in Louisiana to cross the Mississippi River.

Twenty-four-inch- and 30-in.-square piles were cast with high-strength concrete permitting longer individual lengths.



The Charenton Canal Bridge was the state's first to use high-performance concrete on all bridge components (low permeability and high strength—10,000 psi). Completed in 1999, the five-span, 365-ft-long structure features five AASHTO Type III girders in each span.



The 2.44-mile-long John James Audubon Bridge crossing the Mississippi River, to be completed in late 2010, will be the longest cable-stayed bridge in North America. In addition to the precast concrete structure, the project involves seven other bridges featuring Type III AASHTO precast, prestressed concrete girders and 72-in.-deep bulb-tee girders with cast-in-place decks.

The project consists of approximately 12 miles of roadway with seven bridges in addition to the 2.44-mile-long main bridge. A key element unique to this design is the construction of the coffer-boxes used to create the tower foundations for the main cable-stayed spans. Instead of the traditional approach, in which cofferdams are driven into the river, the coffer-boxes are being constructed on top of the drilled shafts and then lowered into place prior to final concrete placement.

The coffer-boxes measure 160 ft long and 64 ft wide, weighing about 500 tons. The contractor used precast concrete side and bottom panels to form the coffer boxes. The panels will remain in place with the permanent concrete piers. The concrete main towers for the cable-stay span will be 500 ft tall to support the record 1583-ft-long main span.

The project's seven other conventional bridges and most of the approaches to the main span use AASHTO Type III precast, prestressed concrete girders typically about 70 ft to 75 ft long. Precast, prestressed concrete, 72-in.-deep bulb-tee girders are also used for the longer 140-ft spans.

Prestressed girders are made continuous using a new positive-moment continuity detail, which is being evaluated on a skewed span with instrumentation for a research project with the Department of Civil and Environmental Engineering at Louisiana State University. The program will test the value of positive-moment continuity, which is not used frequently. The bridge was designed and constructed as part of Louisiana's TIMED (Transportation Infrastructure Model for Economic Development) Program.

The monitoring work being performed on the bridge is not unique in the state. A number of current or under-design structures include monitoring and evaluation programs to aid in better understanding concrete applications. For instance, the Rigolets Pass Bridge features two 131-ft-long spans with HPC with a 56-day concrete compressive strength of 10,000 psi and release strength of 6800 psi to aid with LTRC studies. Girder spacing in these spans is 12.6 ft. Four of these girders were monitored from time of fabrication until the bridge was in service to evaluate their performance.

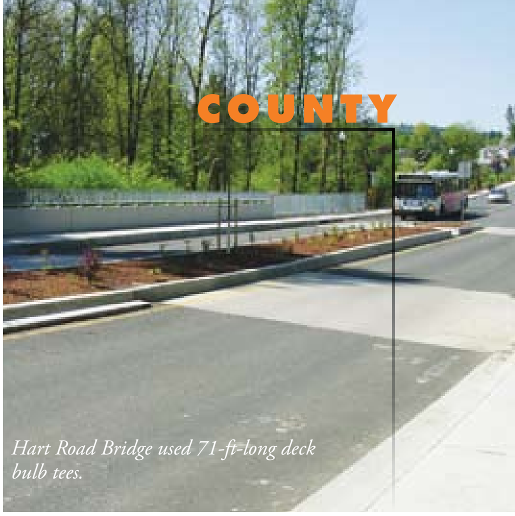
Tests also were performed on the I-10 Twin Spans to test lateral resistance. The footings were subjected to 2000 kips of lateral loading to simulate a ship collision and evaluate response. This is the first time such footing studies have been conducted in a full-scale test, which will allow designers to validate requirements for future designs. All of the precast concrete piles feature moment connections and studies will determine how they behave, while all columns, girders, and diaphragms are being continually monitored. In addition, corrosion meters in the footings and all spans will validate the ability of the HPC to protect the reinforcement.

New techniques continue to be tried, as well. The Caminada Bay Bridge Replacement on LA 1 in Grande Isle is the first bridge in the state to incorporate stainless steel reinforcement in the precast concrete components. It is being used in the substructure areas and spans in the transition area near water elevations, to provide additional protection against the marine environment.

Such efforts will continue as Louisiana studies alternatives and examines new concrete techniques to meet on-going challenges. The combination of new programs, Katrina-repair funding, the TIMED program, and funding from the American Recovery and Reinvestment Act of 2009, have created the largest amount of bridge construction in Louisiana's history. The goal is to use those programs to better serve citizens today and for the next 100 years, while incorporating monitoring equipment and research programs that will improve on today's designs to create even more efficient structures.

Arthur D'Andrea, Paul Fossier, and Ray Mumphrey are assistant bridge design administrators and Kian Yap is a bridge design manager, all with the Bridge Design Office of the Louisiana Department of Transportation and Development, Baton Rouge, La.

For more information on Louisiana bridges, visit www.dotd.louisiana.gov



Hart Road Bridge used 71-ft-long deck bulb tees.

CONCRETE BRIDGES IN WASHINGTON COUNTY, OREGON

by Jim Perkins, Washington County, Ore.

Washington County, Ore., just to the west of Portland, has been very fortunate that its citizens have supported several serial levies since 1986 to improve major streets. With that funding, the county has been replacing one to three bridges each year. Currently there are 187 bridges in the county, with 105 of those having concrete superstructures and 75 being timber structures. The lengths range from 15 ft to 684 ft.

The majority of bridge replacements have used concrete bridge components. Greg Clemmons, the county operations engineer, says that he prefers concrete bridges for their longevity, ease of maintenance, and versatility.

In 1999, the county designed the Germantown Road Bridge consisting of 65-ft-long precast, prestressed concrete box beams. Prior to the project, Oregon performed a bat study. It noted that the Washington County had one of the lowest bat populations and that concrete bridges are prime bat habitats. The county devised a simple means of providing bat habitats on this bridge. It consisted of a short piece of plywood placed on the side of the precast form during casting. This creates wider joints or roosting slots when the beams are abutted in the bridge. The design is cheap and has now been used throughout the state.

In 2004, the county designed the Hart Road Bridge to replace an existing culvert. The roadway consisted of two lanes with a planted median that continued across the bridge. The bridge was constructed using 71-ft-long deck bulb tees with an asphalt overlay. Deck bulb tees are precast, prestressed concrete bulb tees with an integral full-depth deck cast during prefabrication. The sections are abutted during installation. Bridge construction is accelerated and simplified since there is no deck to cast on site.

In 2007, the county replaced the Greener Road Bridge, which was a timber structure. The bridge is in a remote area of the county and is the only public access for a dozen homes and a business. The new 82-ft-long bridge consisted of precast, prestressed concrete box beams. To speed construction, the pile caps used precast concrete, but that is not what made the project so interesting. Site conditions required that one end of the bridge be fully superelevated, while the opposite end needed to have a typical center crown. To accomplish this, each box beam had a different running slope and end bearing elevation. This added to the complexity of the precast cap and its construction. The precaster was heard to say, "I had many a sleepless night over that one!"

The county is now reconstructing 0.8 miles of River Road. This project includes replacing an existing 125-ft-long, timber, multi-span bridge with a new 183-ft-long single span bridge. The new bridge consists of eight 84-in.-deep deck bulb tees supporting a cast-in-place concrete deck. The deck bulb tees are the longest non-segmental, precast prestressed beams in Oregon. Construction is to be completed this year.

The county looks forward to continuing to replace its old deficient bridges and to constructing more concrete bridges due to their long life and low maintenance performance. Washington County is excited about its efforts in being innovative in meeting the many challenges it faces in this work.

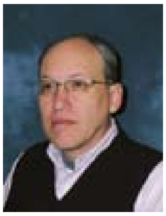
Jim Perkins is a structural engineer with Washington County, Ore.

Greener Road Bridge used precast concrete pile caps to speed construction.

River Road Bridge is a 183-ft-long single span bridge that uses 84-in.-deep bulb tees supporting a cast-in-place concrete deck. The deck bulb tees are the longest in Oregon.

Development of the HL-93 Notional Live Load Model

by Dr. Dennis R. Mertz



The development of probability-based design specifications, in the form of the *AASHTO LRFD Bridge Design Specifications*, highlighted the need for an updated live load model for the design of our nation's highway bridges. The HS20-44 live load model of the *AASHTO Standard Specifications for Highway Bridges* served the bridge-design community well since its original adoption in 1944, but the calibration of the LRFD Specifications revealed its shortcomings. In calibration, the uncertainties of loads and resistances are used to develop load and resistance factors, which result in uniform reliability for the various load combinations of the LRFD Specifications. These uncertainties are quantified as a bias and coefficient of variation for each load and resistance.

For the live load, the bias is the relationship between the most likely live load a bridge will experience in terms of moment and shear and the predicted live load from the design model. The coefficient of variation reflects the spread of the distribution of the live load moments and shears that the bridge is expected to experience.

The bias must be relatively constant over all span lengths for a single live load factor to be used for all span lengths. The bias of the HS20-44 live load model is illustrated in Figure 1 taken from the commentary for Article 3.6.1.2.1 of the LRFD Specifications. In this figure, various moment ratios (simple-span positive moments and positive and negative moments along continuous spans) are plotted for span lengths from zero to 150 ft. The moment ratios are the moments due to heavy trucks on our nation's highways today divided by the moments due to the HS20-44 live load model.

To calibrate the specifications to yield uniform reliability over all span lengths, a varying load factor would need to be applied to the HS20-44 live load model as the ratios tend to grow with increasing span length. Clearly, this solution would have been less than ideal. Thus, a new live load model was developed for the LRFD Specifications.

By chance, a superposition of components of the HS20-44 live load model combining vehicles and lane load produced more uniform moment ratios, or a more constant bias, over all span lengths. Trial and error revealed this elegant solution to defining the live load. Thus, the HL-93 notional live load model of Article 3.6.1.2 of the LRFD Specifications was born.

Figure 2, taken again from the commentary for Article 3.6.1.2.1 of the LRFD Specifications, illustrates the bias of the HL-93 notional live load model of the LRFD Specifications. The model is termed a "notional" model as it is not simply a truck but a superposition of vehicular and lane loads that approximates the moments and shears of a heavier truck.

The moment ratios for the HL-93 notional live load model now cluster much more closely around a single value of one. Thus, the bias is more uniform across all span lengths and the calibration can be accomplished with a constant load factor.

Future articles will continue the discussion of the development and application of the HL-93 notional live load model.

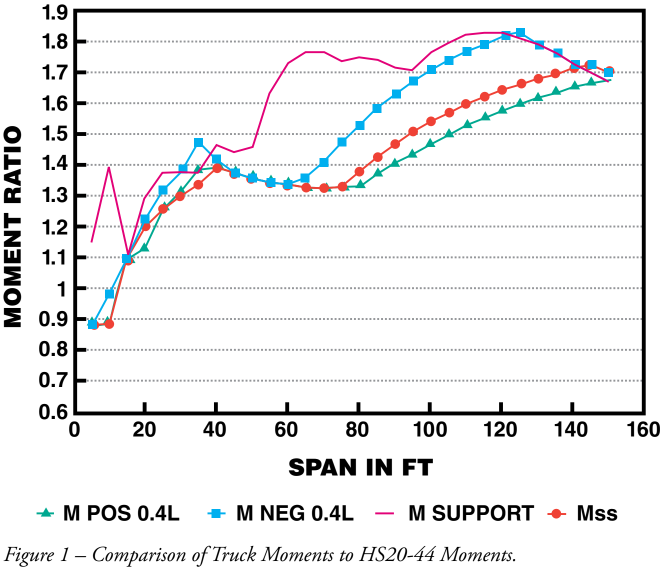


Figure 1 – Comparison of Truck Moments to HS20-44 Moments.

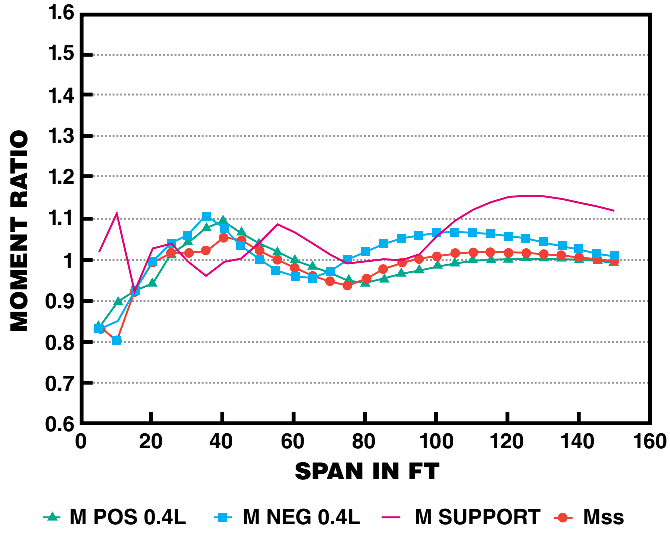
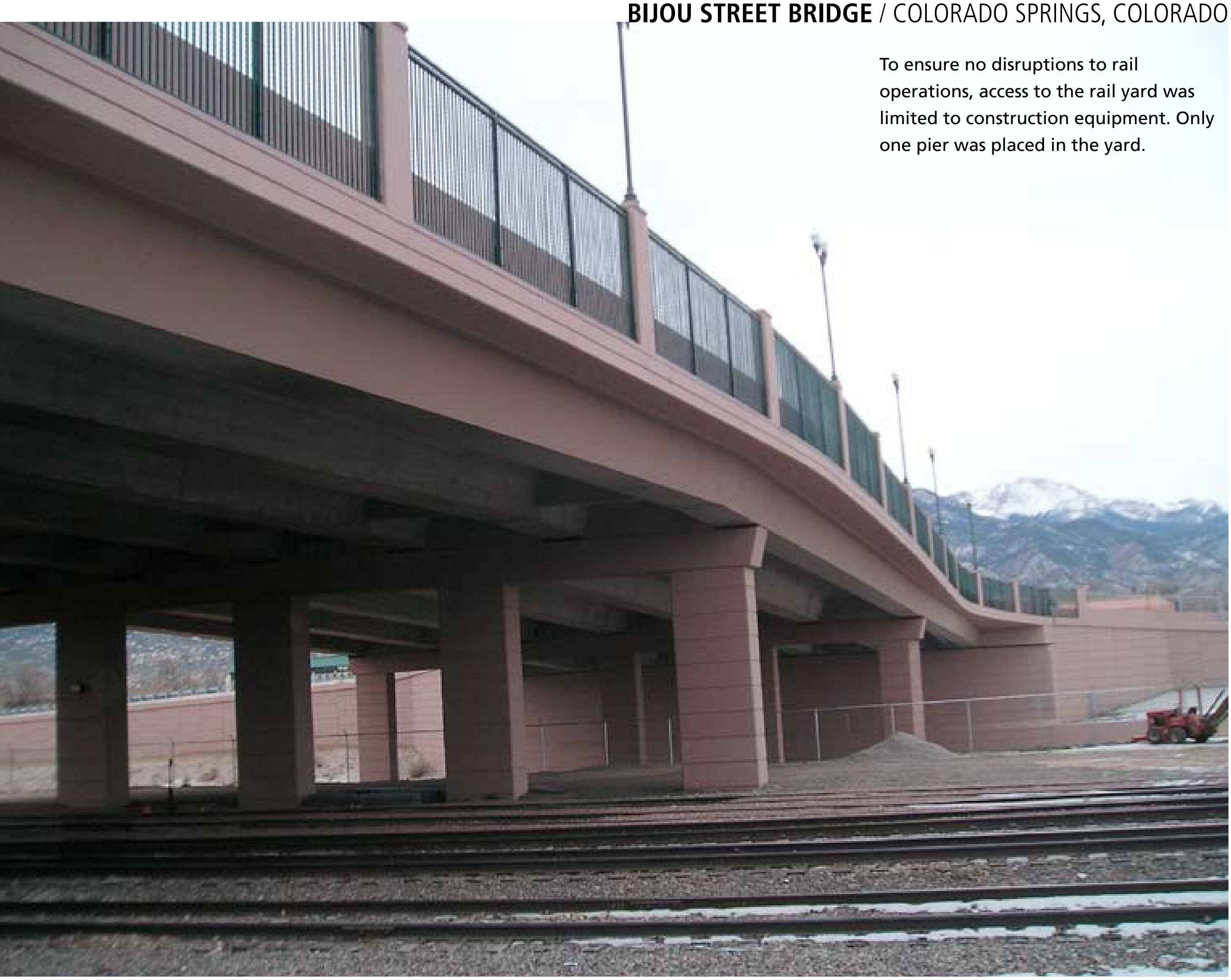


Figure 2 – Comparison of Truck Moments to HL-93 Moments.

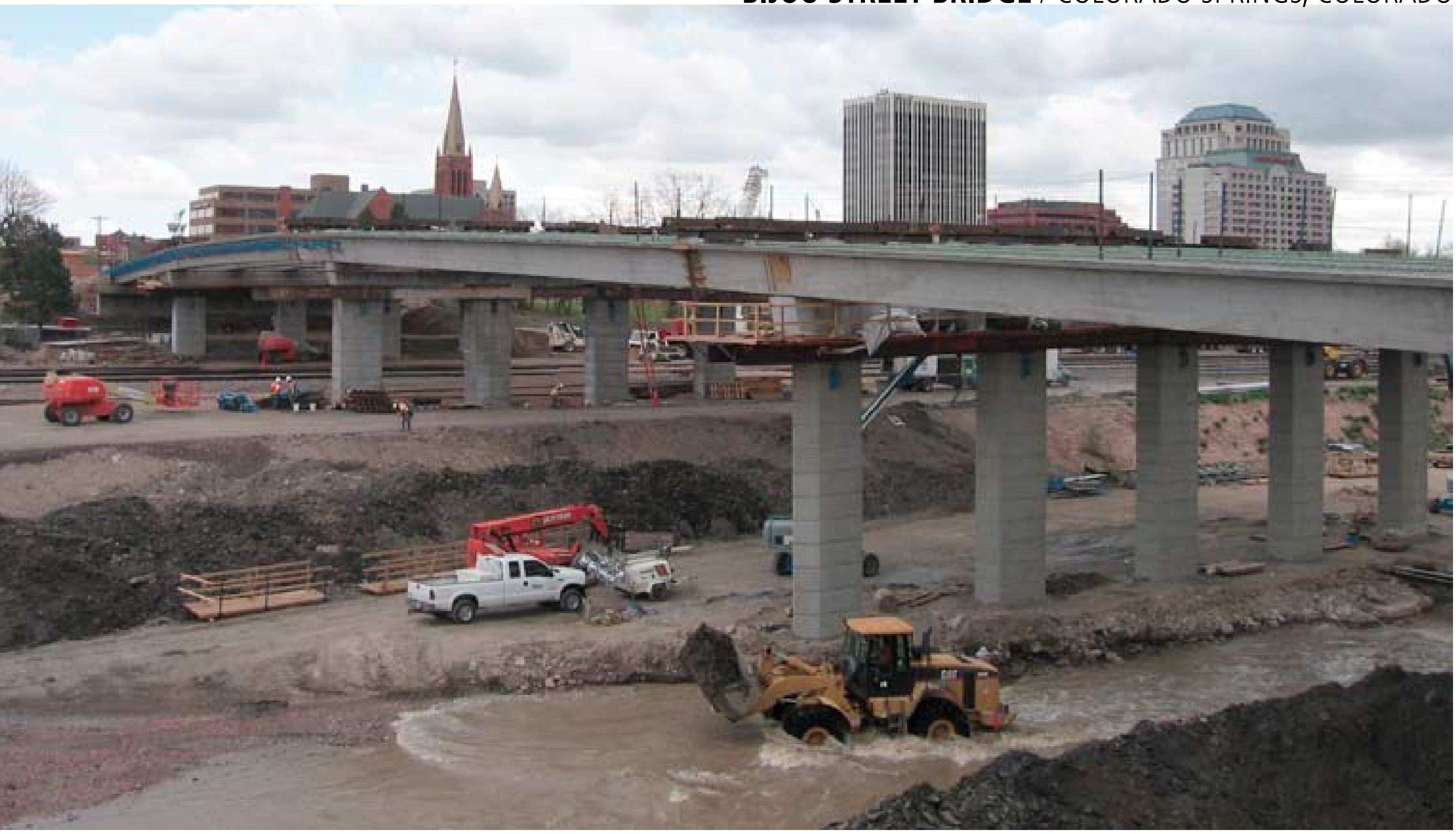
photo courtesy of PCI and Mid-States Concrete Industries



To ensure no disruptions to rail operations, access to the rail yard was limited to construction equipment. Only one pier was placed in the yard.

The substructure design used the flexibility of the piers and foundation to minimize the need for manufactured bearings.

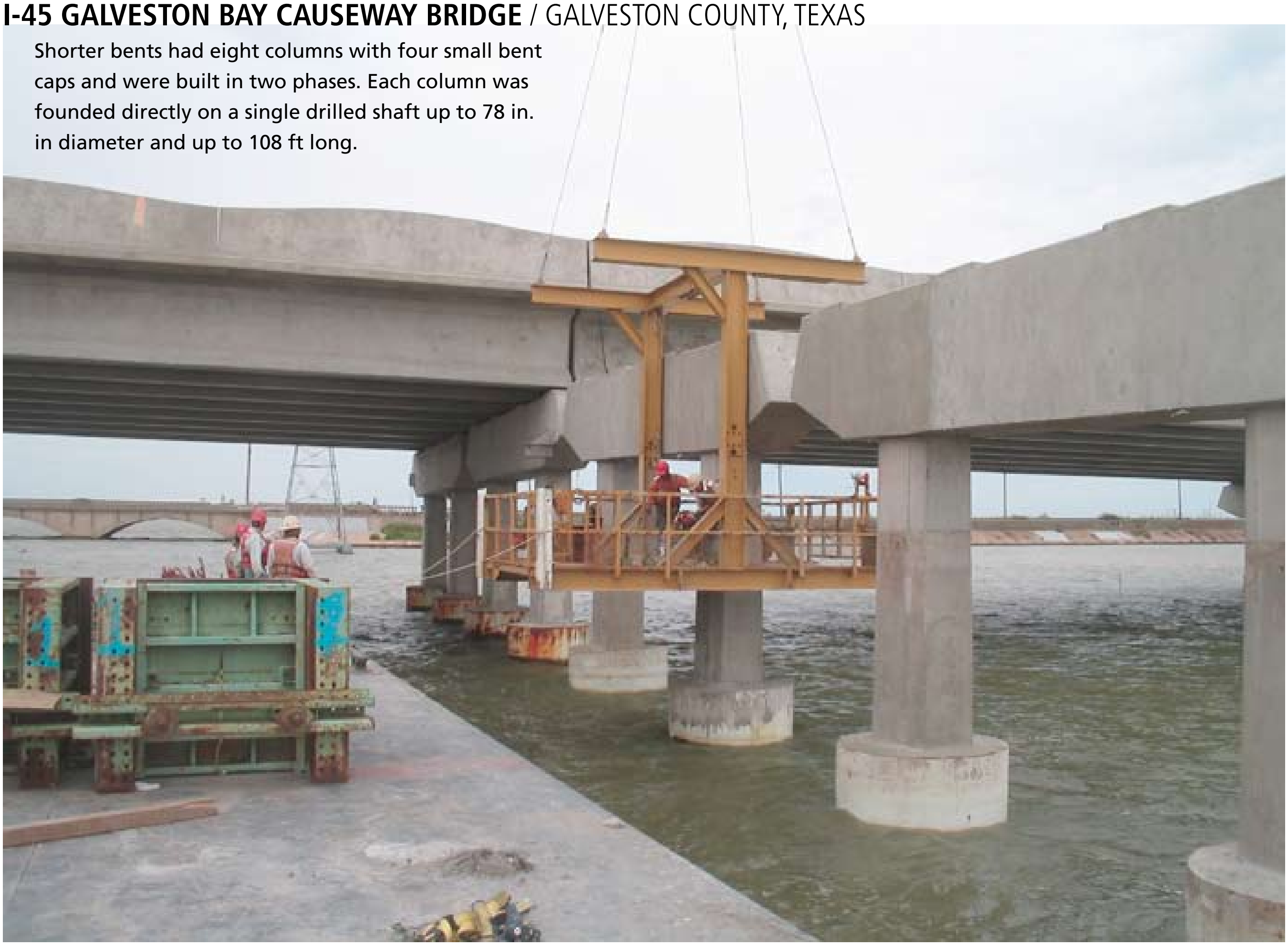
The longitudinal prestressing consisted of a combination of pretensioning and post-tensioning.



The large degree of variation of the bridge deck width made it difficult to use continuous girder lines.

The new I-45 Galveston Causeway Bridge over Galveston Bay features three main spans 740-ft long consisting of cast-in-place concrete, double-cell, segmental box girder units that were con-structed using the balanced cantilever method.
Top left photo was courtesy of Traylor Bros in ASBI SEGMENTS Vol. 48.

The main spans were constructed using the balanced cantilever segmental method.



Shorter bents had eight columns with four small bent caps and were built in two phases. Each column was founded directly on a single drilled shaft up to 78 in. in diameter and up to 108 ft long.

In areas where precast girders were erected from the temporary trestle bridge, a hydraulic girder erection truss was used to distribute girders laterally on the piers to compensate for the crane's limited reach.

Rigorous permitting applications were required to minimize environmental impact and maximize safety.

The bulk of the structures were built from barges, but some areas of Galveston Bay near the embankment were inaccessible, requiring a temporary trestle bridge.

There were a total of 57 approach spans, with eight 72-in.-deep AASHTO Type VI girders comprising each span..

The construction was accomplished in three phases, to maintain existing traffic.

Visual interest was concentrated along the deck and approaches, including incorporating a wave pattern in the retaining walls that reflects the district's core design scheme.

The new bridges are shown with the temporary trestle bridge during demolition of the old bridge to a minimum of 2 ft below mud line.

General view of the aerial structure looking west at a typical pile bent and the open deck spans. The embedded WT steel section can be seen in the outside edges of two of the girders.
Photo courtesy of HRT.

Construction of the spans over Lamberts Point Branch Line.
Photo courtesy of PB.

Girder erection in open deck spans.
Photo courtesy of HRT.

The girders can be designed and spaced to accommodate a variety of complex alignments.

Separate single track open deck spans, looking east from bent 38.
Photo courtesy of Bryant Contracting.

Two bids were requested, one based on a typical bridge design with a second using an arch design similar to the existing bridge.

Nine piers were built, including two that were located in the river and one on an island in the middle of the river. The existing bridge is in the background.

Constructing the arch sections required the project team to monitor and survey each arch during every stage of erection to ensure the structure functioned properly at all times.

FOX RIVER BRIDGE / NORTH AURORA, ILLINOIS

Construction crews persevered through a 500-year flood event and two 100-year flood events.