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THE CONCRETE BRIDGE MAGAZINE

SPRING 2008

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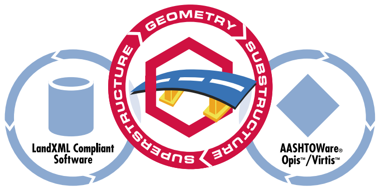

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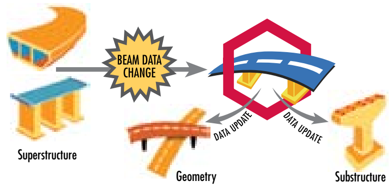

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Social Benefits of Sustainable Concrete Bridges

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Photo: Illinois State Toll Highway Authority.

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Benicia-Martinez Bridge
Photo: CH2M Hill.

EDITORIAL

Photo: Ted Lacey Photography.

Bridge Sustainability, Part Two: Societal Issues

John S. Dick, *Executive Editor*

In this issue of *ASPIRE,*™ we continue our year-long program to define sustainable issues in bridge design and construction. On page 16, Kevin Eisenbeis, a Principal with Harrington & Cortelyou Inc., Kansas City, Missouri, outlines the "societal" aspects of sustainability: life safety, accelerated bridge construction, context sensitive designs, long service life, and aesthetics.

One life-safety issue impacting bridges is their fire resistance. Fire is an ever-present concern of all owner agencies. As more and more flammable materials are carried over the highway system, fires will continue to occur with increased frequency.

Accordingly, this issue contains two articles on fire that should be of interest to owners and designers alike. In the first, on page 18, we report on eight concrete bridge fire events that occurred in recent years. The bridges covered illustrate that even after exposure to fires of various intensities, concrete can remain in service, circumventing long-term closures or long-distance detours. The primary beneficiary of this concrete-bridge capability is the traveling public, who can continue to use these important arteries while owners consider alternatives for repair or replacement.

That raises a frequent question addressed by our second fire-resistance article, on page 24: How can fire-damaged concrete be evaluated? From the Pacific Northwest, the Washington State Department of Transportation (WSDOT) provides details of their investigation into a 3000 °F bridge inferno. Richard Stoddard, Bridge Design Engineer with the Bridges and Structures Office of WSDOT, offers important information about what they did when tragedy struck. Without precedent, they quickly established definitive analytical methods and determined that the bridge could be reopened to traffic while more long-term solutions were sought. A more complete report on their work is available at *www.aspirebridge.org/resources/*. Additional photos are also available on the website following the article.

Further expanding on the sustainability theme, M. Myint Lwin, Director of the Office of Bridge Technology at the Federal Highway Administration, describes the FHWA "green" programs now underway (see page 54). FHWA is actively participating in the Green Highways Partnership, a voluntary public/private initiative.

Sustainable Bridge Design Awards

Also in the sustainable-bridge area are two award programs announced in this issue. The Precast/Prestressed Concrete Institute (PCI) is soliciting entries for its Bridge Design Awards program (see the notice on page 43). One category available to designers is the Sustainability Award. The purpose is to recognize the construction of responsible, innovative designs that are sensitive to the environment while meeting the needs of the public and the owner. Deadline for entries is May 23, 2008. Details are available on the PCI website (*www.pci.org*, select "News and Events").

Also, the Portland Cement Association (PCA) has created the Sustainable Leadership Awards. PCA developed these awards to honor public officials who utilize concrete and other cement-based products in public works projects such as highways, streets, bridges, dams, pipe, or water systems that are energy efficient and beneficial to the community. Be sure to notify your colleagues about this opportunity for agency recognition. Deadline for entries is May 30, 2008. Details are available at *www.cement.org/sustainableleadership/*.

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Cover: Puyallup River Bridge (main photo) Wash.
See "Protecting Against & Evaluating Fire Damage" articles beginning on page 18 for additional credits.

Long Span Bridge Landmark

Twin wall piers are cast with an inlaid stone pattern.

The curved rectangular piers reflect the curved shape of the superstructure.

The completed superstructure box girder pier table is revealed with removal of formwork (02.18.08).

PENNA TURN-PIKE

Pennsylvania Turnpike Commission continues their capital plan with the replacement of the I-76 bridge at Oakmont, Pennsylvania, across the Allegheny River. Pennsylvania's first cast-in-place concrete segmental bridge was designed by **FIGG** and is being built by **Walsh Group**. Twin 2,350' long structures are being constructed from above to preserve and maintain vehicular, river and rail traffic below. Spans of 285'/380'/380'/444'/532'/329' cross the river and Fourteen Mile Island. The bridge is on schedule to open in 2010.

If you share our passion for creating bridge landmarks, join the **FIGG** Team. For an exciting career as a Bridge Design Engineer, CADD Designer, Construction Site Engineer or Inspector, please contact us at 1.800.358.FIGG (3444) or www.figgbridge.com.

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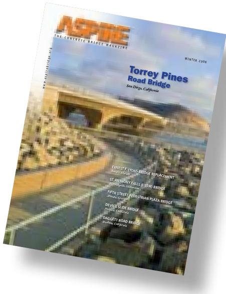


Dr. Ahlborn's Perspective on Sustainability correctly champions the role of education in the realization of a sustainable future. Innovative solutions are definitely needed; however, none of the three "tenets" of sustain-ability (environmental, social and economic) deserve relegation to a diminutive role. Will merely shifting the focus of engineering education to social and economic tenets rather than environment issues solve our problems? Another question concerns whether an economic cost-benefit analysis accurately reflects environmental values. Social and economic well-being of our species, as we know life, depends on a healthy, sustainable environment . . . Engineering education must not restrict itself to the free-body diagram boundaries within an engineering project. It may not be appropriate to only examine efficiencies of a bridge joint when we need to holistically examine the entire transportation system and its relationship to our other life-support systems.

Roger Patocka
Estherville, Iowa

[Editor's Note: Mr. Patocka raises significant issues concerning our standard design practice for transportation systems and our focus toward the environment. Individually, we may not have direct control over long-range solutions needed to affect change for the planet, but we do have choices in our design solutions and the materials that we select on a daily basis that will have positive impacts. This is one of the ultimate challenges of sustainability, changing our design philosophies to truly think holistically. See the article on page 16 that provides another installment in our goal of environmental awareness.]

Congratulations on a great inaugural year and your vision that has been realized. This is a great magazine that allows the bridge professional to review the state-of the-art of concrete bridges in one publication. One of the few that I put in my briefcase to read whenever I have a moment.

Jon Grafton
President, Pomeroy Corporation
Perris, Calif.

The number of deficient bridges in most states . . . makes the focus of ASPIRE™ magazine very timely. ASPIRE gives us a good tool to learn from each other: about what works, what looks good, and what can get the job done with the least impact on the traveling public. Please keep it going!

Hank Bonstedt
Executive Director
Central Atlantic Bridge Associates
Allentown, Pa.

First of all, I wanted to congratulate you on the quality of ASPIRE magazine. I thought the first issue was great and it just seems to get better with every issue! The latest issue of Aspire has PB as its company highlight. I'm especially interested in this issue because I've recently relocated to PB's Honolulu office and the cover shot is of Keehi Interchange just down the street from us.

Taka Kimura
Principal Engineer, PB
Honolulu, Hawaii

CONTRIBUTING AUTHORS

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

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

Kevin Eisenbeis is a Principal with Harrington & Cortelyou Inc., Kansas City, Mo. His responsibilities include management of major highway and railway projects including the design of eight Missouri River bridges.

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.

James M. Barker was Vice President with HNTB Corp. and is currently teaching at the Civil Engineering School of Purdue University.

MANAGING TECHNICAL EDITOR

Photo: Ted Lacey Photography.

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

CONCRETE CALENDAR 2008

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

April 14-15
ASBI Grouting Certification Training
J.J. Pickle Research Center, University of Texas at Austin, Austin, Texas

April 24-27
PCI Annual Committee Days
Includes meeting of PCI Bridge Committee and AASHTO Technical Committee on Concrete Design (T-10)
Westin Hotel. Chicago, Ill.

May 4-6
PTI Technical Conference & Exhibition
Hyatt Regency St. Louis, St. Louis, Mo.

May 4-7
NCBC-FHWA 2008 Concrete Bridge Conference
Hyatt Regency St. Louis, St. Louis, Mo.

May 5-10
PCI Quality Control & Assurance Personnel Training & Certification Schools
Embassy Suites Hotel - Nashville Airport, Nashville, Tenn.

May 18-22
AASHTO Subcommittee on Bridges and Structures Meating
Hilton Omaha and Qwest Center, Omaha, Neb.

May 20-22
NRMCA Concrete Technology Forum: Focus on Sustainable Development
Marriott Denver Tech Center, Denver, Colo.

June 2-4
International Bridge Conference & Exhibition
Pittsburgh Convention Center, Pittsburgh, Pa.

July 27-30
Sixth National Seismic Conference on Bridges & Highways
Organized by the Federal Highway Administration (FHWA), the Transportation Research Board (TRB), the South Carolina Department of Transportation (SCDOT) and MCEER, University at Buffalo, N.Y.
Francis Marion Hotel, Charleston, S.C.

July 28-29
ASBI Seminar on Segmental Construction Practices
Hilton Sacramento West and Arden West, Sacramento, Calif.

August 4-6
PCI Quality Control & Assurance Personnel Training & Certification Schools
Embassy Suites Hotel Nashville Airport, Nashville, Tenn.

October 6-8
PCI-FHWA National Bridge Conference
Rosen Shingle Creek Resort, Orlando, Fla.

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

November 3-8
PCI Quality Control & Assurance Personnel Training & Certification Schools
Embassy Suites Hotel Nashville Airport, Nashville, Tenn.

November 17-19
ASBI International Symposium on Concrete Segmental Bridges
Fairmont Hotel, San Francisco, Calif.

CH2M HILL'S HOLISTIC APPROACH

by Craig A. Shutt

Combining design and construction services helps firm meet owners' growing needs for speed and constructibility

CH2M Hill's engineering, construction, and operations capabilities have served a large variety of clients throughout the world since the firm's founding in 1946. Those skills are being integrated closer than ever today, especially as the company meets a wider array of needs from owners of bridges and other transportation structures throughout the United States.

"We are a full-service provider," explains Joe Showers, Chief Bridge Engineer. "We have the depth and breadth of capabilities under one roof to provide flexibility to the client as we participate in a project. These range from the environmental document and planning stages through the final design stage and include being a designer-constructor. We span the length of the project from concept to completion.

"Design-build is a delivery method that we use frequently, and we consciously developed consulting and construction methods to allow it to happen. More owners are growing comfortable with the design-build format, because they recognize that the benefits can help achieve their goals. Design-build has been used with buildings for some time, and it's moving into the transportation field today, because owners are being driven by pressure on schedules in particular."

The design-build format can condense the time needed for the project, as construction can commence before all the design is completed. That not only saves time but can save money, shorten labor schedules, and reduce user costs incurred through detours and congestion delays. "A cost savings often is produced, but design-build definitely creates a savings in the schedule, which is the critical component in most cases."

The Kathleen Road Bridge over I-4 in Florida was created under a design-build approach and consists of a cast-in-place concrete deck, pretensioned concrete beams, cast-in-place concrete piers, prestressed concrete piles, and concrete panels for the mechanically stabilized embankment walls. The structure replaced a smaller 1958 design.

'More often today, the engineer and contractor work closely together rather than separately.'

Designs Are More Complicated

Owners are looking for new ideas to aid designs in every way possible, because bridge construction has become more complicated in the past 20 years, he adds. "Owners are very cost-conscious today, due to increases in costs for materials and labor." With cost escalations as high as 10 percent per year, it can be difficult to create budget estimates for bridges that will be constructed well after the design and material choices are finalized.

"Design-build formats in particular bring design engineers and constructors together on the same team, working toward a common goal, as opposed to being adversaries," he says. "More often today, the engineer and contractor work closely together rather than separately." The functions used to be fairly split apart, but now owners understand the value of marrying the two closer to aid communication and input.

"We have to look at the total project for savings and constructibility, and the emphasis has become the total project cost, not just savings in design or construction. Our designs definitely focus on creating the most cost-effective bridge to be constructed, not just designed."

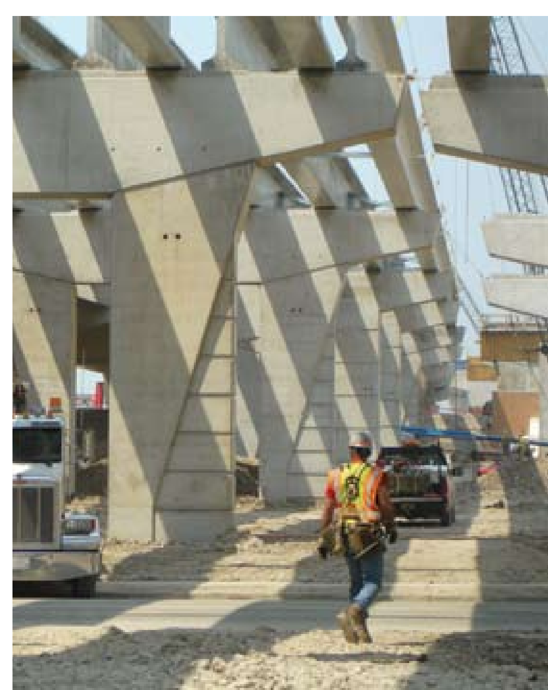
Traffic Control Key Ingredient

Owners also are putting an emphasis on traffic control, a result of projects becoming more congested as infrastructure expands outward from cities and becomes more complex. "There are few green-field sites today," Showers says. "Many of our projects involve rehabilitation and widening of corridors under traffic, and we have to deal with those challenges. They definitely are affecting how we plan projects."

An example of the attention paid to this factor is the Marquette Interchange upgrade in Milwaukee. The $1-billion project encompasses 12 miles of urban freeways, including the design of 50 ramps and construction of more than 180 bridge structures. It also features five levels of roadways and 300,000 vehicles per day. The project, a joint venture of CH2M Hill and HNTB, features 72-in.-deep precast, prestressed concrete I-girders for the bridges.

The four-year reconstruction was the largest and most complex transportation project ever undertaken in Wisconsin, Showers says. As a result, "Public perception of impacts and alternative routes around the construction were

Some of the 72-in.-deep precast, prestressed concrete I-girders are delivered and set for the I-794 bridges at the east end of the Marquette Interchange project in Milwaukee. The project was designed for the Wisconsin Department of Transportation by Milwaukee Transportation Partners, a joint venture of CH2M Hill and HNTB.
All photos: CH2M Hill.



As the largest highway-construction project in the Colorado Springs' history, the $150-million COSMIX project involved reconstruction of 16 bridges and widening four more. Rockrimmon Constructors, a CH2M Hill-led joint venture with SEMA Construction, also provided design-build services to expand 12 miles of highway capacity and reconfigure two major interchanges.

identified as extremely important to the overall project's success." The Wisconsin Department of Transportation committed to keeping two lanes open in each direction during construction.

To achieve that, CH2M Hill developed a detailed schedule to clarify ramp and lane closure times and locations. In addition to creating disincentives for missing the schedule, the team also introduced a "lane rental" program, which gave contractors an allotment of hours in which to close freeway and ramp lanes without disincentives. "The lane-rental program was an effective tool to reduce unneeded lane closures and minimize disruptions to the public." The team also found paths for temporary roadways to pass under existing structures through the core of the interchange.

Aggressive communication with businesses about detours also has become commonplace on projects, Showers says. That was a key element in the success of the $150-million Colorado Springs Metro Interstate Expansion (COSMIX) project, which reconstructed 16 concrete bridges and widened another four. CH2M Hill created a joint venture with SEMA Construction to provide design-build services.

Those services included weekly meetings with local business owners, as well as maps and signage placed along the routes to ensure changes were well known. More than 20 informal and formal town-hall meetings were held during the project's course, which used more than 300,000 cu yd of concrete to rebuild I-25 through the metro area.

Durability Is Stressed

Durability also has come to the fore, as owners look to decrease costs and create added safety. "Owners are focusing more on life-cycle costs today and understand that it's worth spending more upfront, because it's a good investment if you don't have to

Owners are more willing to spend another dollar today to save $10 down the road.

Working with the Idaho Transportation Department, CH2M Hill strengthened and restored the concrete-arched Rainbow Bridge between Boise and Cascade in Idaho. Key elements included replacing ornate concrete bridge rails, repairing corrosion-damaged stringers, and repairing and replacing corrosion-damaged columns.

spend money on maintenance later on. They realize the key is total costs, not necessarily just initial costs, and they're more willing to spend another dollar today to save $10 down the road."

Current specifications for a 75-year life contain "the rules of the road," he notes, "but some bridge owners are asking us to design for service lives of 100 to 150 years." European engineers already are evaluating ways to create such service lives routinely and are developing models for it. "We'll see some of that here in the coming years."

Likewise, sustainability is gaining ground, although Showers notes that it hasn't become as major a concern in America for bridges as it is in Europe already. "It's growing in interest here, certainly. Energy costs are becoming a key aspect of designing bridges, and the project's 'carbon footprint' is being discussed more."

Emphasizing Context Sensitivity

Along with sustainability is the need for context-sensitive solutions (CSS), which CH2M Hill emphasizes in its designs. The company literally wrote the book on this concept, as its staff served as primary authors on National Cooperative Highway Research Program Report 480: *A Guide to Best Practices for Achieving Context Sensitive Solutions.* "CSS is an emerging trend and requirement in the planning and design of highways, and CH2M Hill has been at the forefront," says Showers. The goal is to bring clients, stakeholders, agencies, and the public together in the earliest phases of projects to achieve sustainable solutions sensitive to the project context. This approach addresses safety, mobility, aesthetics, and other community values prior to design being finalized rather than reacting to issues later in the process. "This need has been driven by the public," he notes. "People are becoming more sensitive to the infrastructure and the public involvement in designing highway and railroad bridges in their communities." He likens it to the early 1900s "City Beautiful" movement, when emphasis was put on a city's physical state and how it could be improved. That urban-architecture movement found its way into bridge designs, and a similar movement seems to be underway today.

"Recreating bridges that have become local landmarks poses challenges," Showers adds. "To make an exact replica of a 100-year-old bridge is tough today, because we don't build like that anymore. If we can create a design that harmonizes with that style, new technologies and advances in concrete materials give us far more capabilities for achieving a high-quality, functional, and still complementary design."

An example can be seen in the Rainbow Bridge project, in which a 1933 concrete

CH2M Hill has been at the forefront of using context-sensitive solutions to meet challenges.

Sharing the Wealth

CH2M Hill opened its doors in Corvallis, Oregon, in January 1946 as a partnership among three Oregon State College engineering graduates and one of their professors: Holly Cornell, T. Burke Hayes, James Howland, and Fred Merryfield. Some 25 years later, the company merged with Clair H. Hill & Associates to create CH2M Hill.

The founders' concepts were simple but unusual: Grow the company by solving clients' problems, hire creative people to find new approaches to those challenges, and share the benefits of the company's success with them. The employees own the company through a stock-sharing program.

The company has won a number of awards for being employee-friendly. For instance, it was named one of *Fortune* magazine's "100 Best Companies to Work For" in 2006, one of "Denver's Best Places to Work" by the *Denver Business Journal*, and one of the "Top 50 Companies to Work For" by *Woman Engineer* magazine.

By the end of the 1960s, the company had achieved revenues of $6.2 million, generated by 310 employees. The firm gained momentum with the 1971 Hill addition and publicity from their partnership on a ground-breaking wastewater treatment facility. One decade later, the company had revenues of $95 million and 1800 employees.

Ralph Peterson was elected president in 1991, ushering in a period of rapid growth and diversification. By the mid 1990s, CH2M Hill's 6000 employees produced revenues close to $1 billion. In 2006, the company reported revenues of $5 billion achieved with 23,000 employees from activities in 31 countries.

'Designers are starting to treat concrete as a highly engineered material.'

CH2M Hill supplied design-build services for the new I-5/41st Street Interchange (at center) and a new flyover bridge (far left) that replaced an outdated left lane exit in Everett, Washington. The project included the widening of about 10 miles of highway and rebuilding bridges and interchanges.

spandrel-arch bridge over the Payette River between Boise and Cascade, Idaho, was rehabilitated. CH2M Hill provided both design and construction services for the $2.9-million project, which involved reconstruction of corrosion-damaged deck-stringer ends and repair of columns, piers, and arches. Existing decorative bridge rails also were replaced with an identical railing. Throughout the design, the original historic fabric of the bridge was retained whenever possible.

Concrete Helps Meet Challenges

Concrete materials can help meet a number of the challenges presented by these trends—and that, too, has been a trend for some time, he states. "The industry has been headed toward more concrete designs for the past 30 or 40 years." Earlier, virtually every interstate overpass, especially spans of more than 100 ft, was constructed with steel girders.

"Everything is changed now. We're seeing precast, prestressed concrete used much more often, with box girder spans as short as 80 ft. At the same time, some prestressed spliced girders are extending to 350-ft-long spans. Spliced-girders and segmental technology have expanded the use of concrete in bridges, and post-tensioning is more widespread than ever."

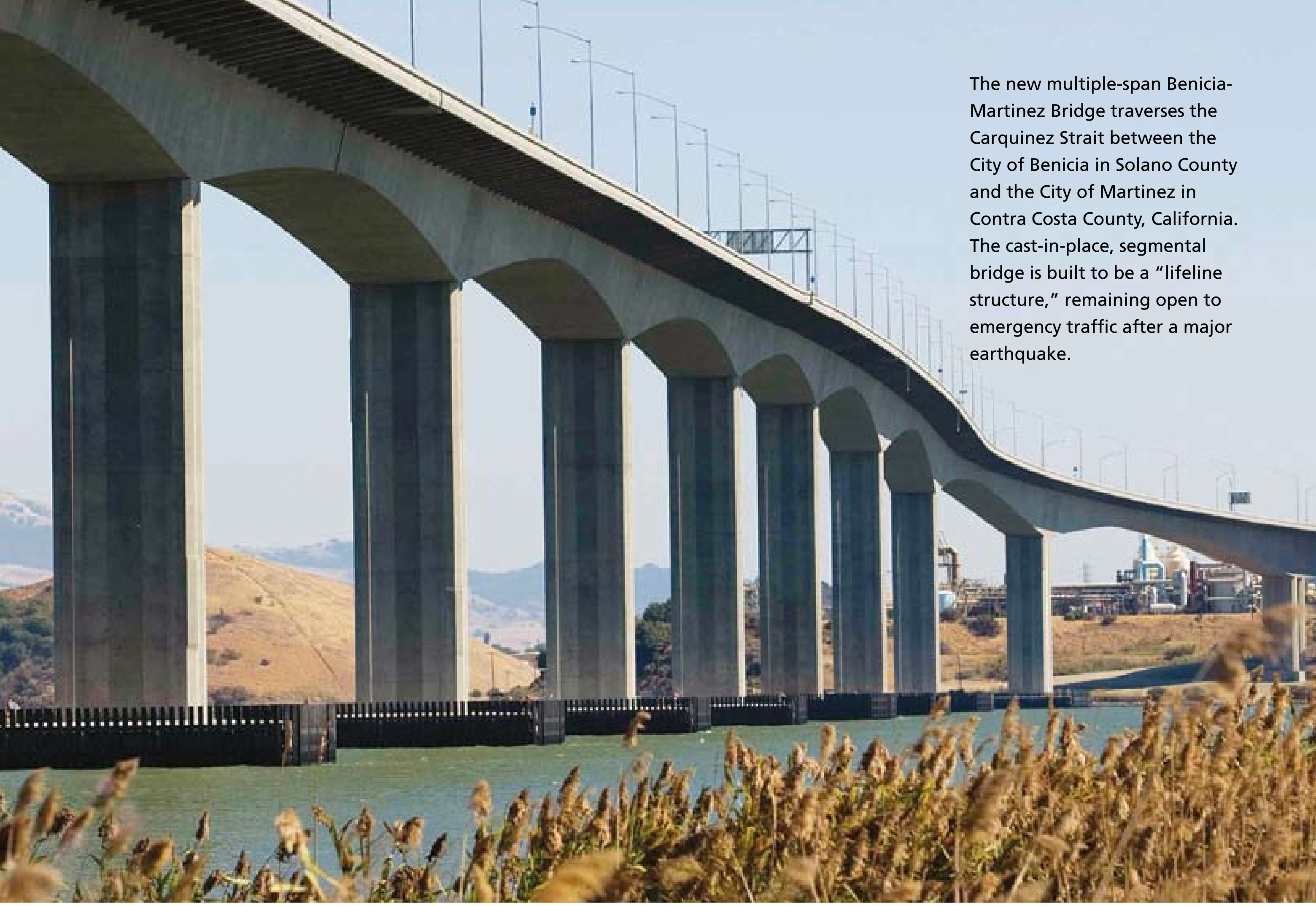
The concrete industry has changed dramatically in recent years, he adds, increasing its capabilities significantly. In the 1980s and 1990s, many of the advances in bridge engineering could be attributed to computer software that allowed designs to be modeled and better forecasts and calculations to be created. "But in the last 5 to 10 years, the changes we've seen have been due to changes in materials and better performance, and that includes concrete."

High performance concrete is a key example. "Designers are starting to

treat concrete as a highly engineered material, and that's an evolving change. These advances affect what can be accomplished with bridge engineering, and that's really exciting." The changes have been particularly notable in the precast concrete field, with techniques achieved with formliners, coloring, and other aesthetic options. "There really are a lot of new options being created."

It's up to designers to stay up to date and incorporate new ideas when applicable, he stresses. "Designers are gaining awareness, and they're asking questions about what can be accomplished." For that reason, CH2M Hill works closely with concrete suppliers early in the design process. "We don't want to overspecify materials, so we work closely with concrete producers, and they're very constructive with help at the concept level. And since we also are contractors, we can integrate the ideas throughout the process."

The new concepts are expanding concrete applications in new directions,



The new multiple-span Benicia-Martinez Bridge traverses the Carquinez Strait between the City of Benicia in Solano County and the City of Martinez in Contra Costa County, California. The cast-in-place, segmental bridge is built to be a "lifeline structure," remaining open to emergency traffic after a major earthquake.

he adds. For instance, the firm has worked with the Colorado Department of Transportation on one of seven bridges the department has developed using a curved, spliced-girder system. "They've pioneered this design and led the way, which is really an interesting approach. Owners are definitely sold on concrete concepts and are leading its use."

Lightweight Concrete Evolving

Concrete mixtures that have led to more lightweight concrete also are changing design concepts, he says. "Lightweight concrete is fast becoming a standard, and it has a tremendous influence on design."

An example can be seen in the company's work in a joint venture with T.Y. Lin International on the Benicia-Martinez Bridge in California. The project used "sand-lightweight" prestressed concrete box girders constructed primarily by the segmental, balanced cantilever, cast-in-place construction method. The sand-lightweight concrete uses normal weight sand and lightweight coarse aggregate to produce concrete that is lower in density than normal weight concrete. (For more on this project, see the Summer 2007 issue of *ASPIRE*.™)

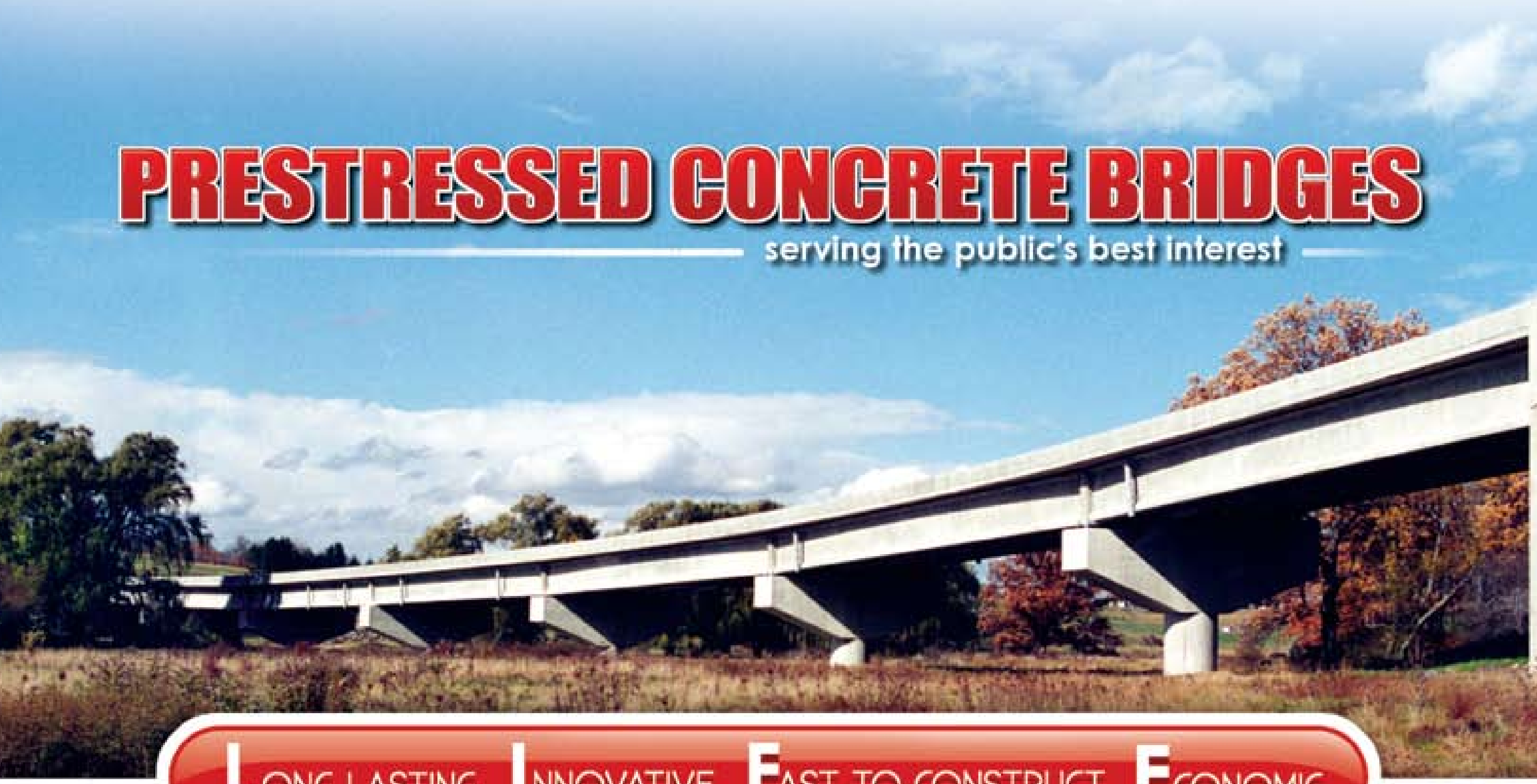
"We needed to use concrete that was lightweight but that also offered other properties related to modulus of elasticity and creep," he explains. "We stretched the capabilities in that design, and that is happening more often all the time."

The design for the new 3175-ft-long concrete crossing of the Fraser River near Vancouver, British Columbia, Canada, features a much lower profile due to the concrete material and a new foundation design, which uses large-diameter bored piles to provide cost-effective construction in the deep layers of soft silt. The project also features an emphasis on aesthetics, using decorative eagles as a recurring theme on bridge towers and other locations.

Self-consolidating concrete also is being used more often, most usually to aid contractors in speeding construction rather than for design purposes. Showers notes. He also has great hopes for a variety of new reinforcement materials, such as fiber reinforced plastics or carbon fibers.

"A number of states have created demonstration projects with these materials, and there is some work being done in Europe," he says. "I haven't seen a massive breakthrough yet, but there could be one in the next few years. It would be ideal if the material could be put into slabs and wouldn't corrode. An indefinite service life would be the Holy Grail."

As concrete producers work with CH2M Hill toward that goal, the firm will continue to improve on its own design and construction processes, as well as their integration, to help cut costs and create designs that meet the more diverse, specialized, and challenging needs of all types of bridge clients.



POST-TENSIONING INSTITUTE®

Post-tensioning is being utilized on bridges in increasingly varied ways, including cable stays for long-span applications, segmental construction, bridge decks, strengthening, and on spliced girders to extend the capabilities of precast elements. Post-tensioning offers some unique advantages that have lead to rapid growth in its usage around the world.

Post-tensioned bridges have performed extremely well, but reliability and performance are dependent on quality construction and good design. Education and training is one of PTI's strategic goals. PTI's initiatives to assist designers and to help assure a high quality workforce, include the following:

Bonded Post-Tensioning Certification

This 3-day training workshop is a comprehensive course on all aspects of bonded post-tensioning installation. It is intended for construction personnel, inspectors, and construction managers. Attendees are certified following successful completion of the training and subsequent examination. The next course is planned for May 28-30, 2008, in Gainesville, Fla.

2008 PTI Technical Conference

The 2008 conference will be held May 4-6, 2008, in St. Louis, Mo., and will feature technical sessions, committee meetings, and PTI's 2008 Design Awards. It will be held jointly with the NCBC's Concrete Bridge Conference—PTI registrants can attend all the bridge sessions.

Design Guides

The updated 5th Edition of PTI's ***Stay Cable Recommendations*** is now available. In addition, PTI's Bridge Committee is working on two design guides: 1) update of PT Bridge Manual, and 2) Guide for PT Bridge Decks. Post-tensioned bridge decks offer potential benefits such as reduced cracking and improved durability, lighter superstructures, and fewer girders.

For more information, contact PTI or visit our website at www.post-tensioning.org.

SUSTAINABILITY

Social Benefits of Concrete Bridges—How Green is Our Valley?

by Kevin R. Eisenbeis

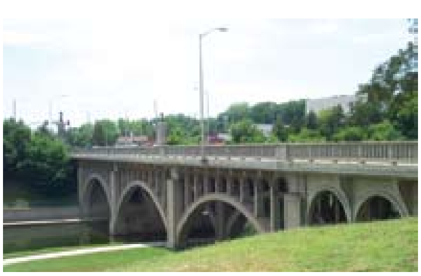
Is sustainability merely a fad or a concept whose time has come? At every turn, we are exposed to print media, industry dialog, political stumping, and even Hollywood celebrities promoting sustainability and the value of going green. What is this all about, and how does the concrete bridge industry relate? And perhaps of greater significance, why should we care?

This issue of *ASPIRE*™ focuses on the social benefits of sustainable concrete bridges. Social benefits, including life-safety issues, accelerated bridge construction, context-sensitive designs, and aesthetics are just one aspect of the overall theme of sustainable design as it relates to highway bridges. Future issues of *ASPIRE* will delve into the economic and ecologic aspects of sustainable concrete bridges.

In this article, we will examine the social benefits of sustainable concrete bridges and how we can balance the impact of our choices on society.

What is a Sustainable Structure?

For a better understanding of the subject, some definitions are in order. To the casual observer, a sustainable structure will last a long time and have minimal negative impact on our environment. However, to the environmental advocate,



Rehabilitation of the Benton Boulevard Bridge in Kansas City, Mo., allowed preservation of an existing arch bridge originally constructed in 1923.
Photo: Harrington & Cortelyou Inc.

The excellent fire and seismic resistance characteristics of these structures further ensures the public well-being.

sustainability connotes a much deeper intent. To be truly sustainable, all aspects associated with a structure including design, location, materials utilized, construction techniques, maintenance, impact on the environment, overall energy consumption, and effect on future generations must be considered. All elements should be coordinated in a manner to benefit society. The consequences of our decisions now may affect our children's future. To put it another way, a sustainable bridge design accomplishes our needs now without compromising the ability of future generations to meet their own needs.

Much of the concern in the field of going green relates to carbon emissions in the atmosphere. A reported three-fold increase in carbon dioxide in the atmosphere since 1977 prompts the global warming concern. One aspect of sustainability is the minimization or elimination of carbon emissions to reduce the portion of climate change that may be caused by this phenomenon. Locating bridges where drive times and travel distances are minimized can reduce overall carbon emissions from vehicles.

Social Benefits of Sustainable Concrete Bridges

Society is the benefactor when our industry provides safe, long-term, durable structures. Even more so when economical, attractive, and low-maintenance describes our bridge. Sound familiar? Additional benefits occur when construction minimizes site disruption, environmental impact, and traffic congestion, again, all common benefits inherent to current bridge construction.

Let's look at various social benefits of concrete bridges as they relate to sustainability.

Life Safety

Concrete bridges, with their typically redundant structural systems, are safe bridges. The excellent fire and seismic resistance characteristics of these structures further ensures the public well-being. In seismic zones, confinement and corresponding ductile behavior in plastic hinge regions provides for minimal earthquake damage, low repair costs, and immediate post-earthquake use. With accelerated bridge construction, rapid replacement of other bridges that may have been damaged is also beneficial. Concrete bridges also demonstrate outstanding performance when exposed to fire as illustrated by other articles in this issue. The necessity of safe bridges is fundamental to our industry.

Accelerated Bridge Construction

Precast components allow rapid construction of bridges to occur. With the advancement of rapid construction techniques, construction time previously measured in weeks and months is now measured in hours and days. Minimal lead times, locally manufactured products, and standard shapes make this method economically feasible. Deck formwork for cast-in-place concrete can be eliminated when adjacent precast members are used. Combined with the reduced disruption to traffic, shorter detour times, and minimal site impact afforded, the social benefits are significant.

Context-Sensitive Design

A context-sensitive design utilizes a

Aesthetic requirements played a key role in selecting the type of bridge for the 27th Street Bridge, Kansas City, Mo. Photo: Harrington & Cortelyou Inc.

collaborative approach involving all key stakeholders when considering the total setting in which a project will exist. Concrete structures adapt well to various physical settings often preserving scenic, aesthetic, historic, and environmental resources. The advantage of concrete bridges is apparent in the number of communities improved by their use.

Aesthetics

Concrete bridges blend well with their surroundings. The simple, clean shapes provide attractive spans in individual or multiple arrangements. Low span-to-depth ratios create slender lines and enhance their graceful appearance.

Long Service Life

Another key aspect of sustainability is longevity. When maintenance requirements are minimized, the amount of effort and energy required to repair the bridge in the future is minimized.

The Route 100 precast box beam bridge provides a shallow structure depth over I-44 near St. Louis, Mo. Photo: MoDOT.

Recent advancements in the use of higher strength concretes combined with prestressing provide for extremely durable concrete structures. Where corrosion of reinforcement is reduced, future maintenance requirements diminish accordingly. Durable concrete bridges are long-term structures, minimizing the cost of future repairs and life-cycle energy consumption.

Where Do We Go from Here?

We should first answer the question, why do we care? Regardless of personal feelings about global warming, carbon credits, LEED certifications, or any of a myriad of "green" terms, it is important to realize our decisions have consequences, and our actions can make a difference. It seems safe to say we all want to preserve or improve our environment, and we want our children and our grandchildren to have a better environment than we enjoy. As practitioners in our industry we can take steps that may make a difference.

With a few minor variations in current mindset and practice, we can continue to improve on our bridge sustainability. Advocates for sustainability promote designing, building, and maintaining with overall energy consumption in mind. For example, providing solar powered lighting can reduce power requirements while still meeting safety needs. Many traffic signals and message signs utilize this technology, why not bridge lighting? Lowering the power consumption for the life of the bridge, including energy used in fabrication, distribution, installation, and maintenance, reduces its "footprint" in the realm of carbon dioxide emissions. Designing with "local" in mind can cut transportation costs and fossil fuel consumption in shipping materials and products. This aspect often comes into play now resulting in lower costs for construction, but what about on a macro level. Should we consider the consequence in carbon emissions for shipping a product a long distance, from overseas for instance, just because it had the lowest initial cost? Remember, our decisions have consequences. A reasonable balance between economy and environmental concern is in order.

As summarized above, concrete bridges provide many social benefits. From fire-resistant and seismic-resistant structures, to rapid construction and attractive, long-term installations, concrete bridges provide sustainable solutions that benefit society. In our quest for continual improvement, we should ask ourselves: Can we do more? Because our decisions have consequences, we can decide to make our children's valley greener as we continue to realize the benefit of sustainable concrete bridges.

Protecting Against FIRE

by Craig A. Shutt

Concrete can help bridges resist a blaze's high heat and return quickly to service

On June 20, 2007, a fuel tanker truck rear-ended a loaded dump truck on State Route 386 under the Stop Thirty Road Bridge north of Nashville, Tennessee. The tanker erupted into flames beneath the 233-ft-long structure, a two-span, two-cell, hollow box-beam bridge. Fearing damage that would interrupt traffic for many months, both on and below the bridge, inspectors, and maintenance crews rushed to the site to conduct studies on the concrete once the fire cooled. After analyzing the bridge and finding no problems, traffic was restored under the bridge to the busy state route as soon as pavement repairs were completed. Traffic returned to service on Stop Thirty Road after core samples were evaluated.

'The analysis showed that the bridge endured much heat but sustained very little damage.'

"The analysis showed that the bridge endured much heat but sustained very little damage," says Wayne Seger of the Office of Bridge Inspection and Repair at the Tennessee Department of Transportation. The affected span was 120-ft long. The bottom slabs of the hollow box-beams are 7.25-in. thick, and the sides of the box sections along with the common wall between the cells are 1-ft thick with two mats of reinforcement. Class A, 3000 psi concrete and epoxy-coated

Photo: U.S. Fish & Wildlife Service

Following a fire on the Bill Williams River Bridge in Arizona, it was determined that the girders could be repaired. Photo: Arizona Department of Transportation.

reinforcement had been used to construct the bridge in 1981.

After the bridge cooled, potential spalls were chipped off and concrete cores were cut to allow engineers at CTLGroup in Skokie, Illinois, to perform petrographic analysis. "The evaluation showed that the concrete was in good shape, so we removed the restricted load posting signs and returned the bridge to service," he says.

Keeping Cool

Engineers are well aware of the strength and durability that concrete can offer for bridge designs, allowing longer spans and long-term life cycles with minimal maintenance requirements. But the material offers considerable resistance to fires that could otherwise render other bridge types unusable.

The key problem is that bridge fires tend to be exceptionally hot, as they're caused by an external source of intense heat, such as fuel from an overturned truck or tankers carrying chemicals, says Richard B. Stoddard, Bridge Design Engineer with the Washington Department of Transportation, who inspected a fire-damaged bridge in his region (for more on this project, see the following article).

"Tanker fires caused by highway fuel-trucks or railway tanker cars are explosive in nature and greatly exceed the temperatures and rate of heating

Concrete can better endure these relatively short-duration, high-temperature fires.

prescribed in the ASTM fire-resistance test," he said in his report. "Additionally, the heat-transfer mechanism in tanker fires is dominated by radiant energy as opposed to hot-air and heat convection." Concrete, with its high specific heat, can better endure these relatively short-duration, high-temperature fires.

The heat from the Puyallup River Bridge fire was intense enough to cause damage to all 15 lines of girders.

Bridges Survive Fires

A variety of bridges around the country have suffered spectacular bridge fires yet have been able to return to service quickly due in part to the use of concrete. For instance, on July 28, 2006, a fuel truck crossing the Bill Williams River Bridge on Route 95 in Parker, Arizona, crashed about halfway across the structure. Built in 1967, the bridge spans the Bill Williams Wildlife Refuge, which receives about 70,000 visitors per year.

The tanker spilled approximately 7600 gallons of diesel fuel onto and under the bridge, which then ignited and burned on the bridge's AASHTO Type III precast, prestressed concrete girders and composite reinforced concrete deck. The fire-damaged girders did not show visible signs of loss of prestress but experienced varying degrees of spalling. A reduced girder section was rated for flexure and shear and compared to a prefire condition. It was determined that the fire resulted in a 6 percent reduction in the bridge load rating for the short term and a 12 percent reduction for the long term. Based on these results, and following a study of multiple alternatives, it was determined that the girders could be repaired. Both lanes on the bridge have remained open to traffic since the accident.

"The damage wasn't as bad as we initially feared," says Martha Davis, Structural Engineer for HDR Engineering Inc. in Tucson, Arizona. The firm worked with CTLGroup to identify the depth of the fire damage in structural elements, determine the extent to which spans were damaged, and note any reductions in section properties and material strengths.

Their assessment found that the overhang and shoulder in three spans, especially the ninth span, needed to be replaced. "The fuel spilled through the deck drains and expansion joints, spreading the fire under the bridge, and the wind whipped the fire along

Although flame temperatures at this methanol-fueled tanker fire under the Puyallup River Bridge, Wash., reached 3000 °F, the precast concrete bridge was reopened to traffic the next day.

The prestressing steel did return to its full strength without causing any deformation in the bridge girders following the fire.

The blackened beams of the Bell Isle Bridge, Oklahoma City, Okla., were cleaned and the bridge was reopened.
Photo: Oklahoma DOT.

the bridge's barrier and overhang," Davis explains. But the girders in those spans, and in all of the others, retained their structural integrity. Transportation officials closed the shoulder on the affected span to keep vehicles off the overhang and to protect the barrier until repairs could be completed.

Those repairs are still to be scheduled, she notes. The plan is to save as much of the existing reinforcement as possible and rebuild the overhang, repair damage to the girders where reinforcement was exposed and concrete spalled, and add a protective coating to the deck to inhibit corrosion. The bridge also is being monitored to ensure no signs of additional damage arise.

An even faster return to service took place for a ramp to the Northwest Expressway in Oklahoma City, Oklahoma, when a truck crashed on the nearby Belle Isle Bridge on January 28, 2006. A portion of the truck became airborne and crashed to the ground near the ramp, where the resulting fire blackened the ramp's AASHTO Type II prestressed concrete beams. But after evaluation, the blackened beams were cleaned and the bridge was reopened.

"There was superficial damage that we repaired," explains Walter Peters, Assistant Bridge Engineer for Operations in the Bridge Division of the Oklahoma Department of Transportation. "It was mostly smoke damage and minor spalls."

A similar result occurred at a precast concrete bridge in Washington County, Oregon, in November 2004. A derelict car was abandoned in an area beneath the bridge and set on fire, causing charred concrete on the bridge above and disruption to traffic. The damage occurred at about midspan on a 37.5-ft-long span using 18-in.-deep voided slabs. "The fire was hot enough to melt aluminum and leave it puddled on the ground nearby," reports Greg Clemmons, Operations Engineer for the Washington County Land Use and Transportation Department.

An inspection of the bridge showed that spalling occurred in an approximate area of 2 sq ft and was 1/2- to 3/4-in. deep. In several areas, the concrete also turned pink, indicating it had been exposed to heat of at least 500 °F. Following pressure washing to remove soot, a detailed inspection took place, including hammer tests at various locations.

Following the inspection, the bridge was reopened to traffic. "The prestressing steel did return to its full strength without causing any deformation in the bridge girders following the fire," Clemmons reports. Debonding of the strand possibly took place at the center of the component, he notes, but central debonding would not produce any significant concern if the ends remain intact. "There was localized damage, but it did not impact the bridge's operation."

Although the department considered cleaning and repairing the spalled areas immediately, the damage was determined to be so minor that the bridge instead was put onto the county's accelerated inspection list.

Fast Replacement is Option

Another approach to maintaining traffic on a precast concrete bridge was used by the Connecticut Department of Transportation. A tanker truck carrying 8000 gallons of gasoline jack-knifed during an accident, spilling its contents over and under the 80-ft-long bridge over the Norwalk River near Ridgefield, Connecticut. The resulting fire exposed the precast concrete bridge to severe heat and fire damage.

A blazing car fire caused damage to a bridge in Washington County, Ore., but the affects were minimal and the bridge was reopened to traffic after an inspection.

Some spalling and exposed aggregate were noted during the inspection of the Washington County, Ore., fire, but it was not sufficient to require repairs.

After a tanker truck overturned, caught fire, and burned out on a bridge spanning the Norwalk River near Ridgefield, Conn., engineers decided to resupport the 50-year-old precast concrete bridge with intermediate supports. The bridge reopened to traffic in four days.

Gasoline that spilled from the tanker-truck accident on the bridge over the Norwalk River caused spalling on the precast concrete but left it in "reasonably good shape," engineers reported.

The 50-year-old bridge, one of the first precast concrete bridges built in the United States, suffered significant amounts of spalled concrete on its beams, reports Arthur Gruhn, Chief Engineer. Reinforcement was exposed in a number of locations. "We really had no idea how strong the bridge still was," he says. Despite its age, the bridge had been in good condition, and there had been no plans to replace it.

The design team moved into action quickly, setting up a detour and providing an initial inspection on the day of the accident. On day two, a contractor and remediation crew examined the bridge to determine its status. The team decided that the bridge was still structurally sound but needed some temporary intermediate support to ensure its stability.

Two heavy steel support beams were added, one under either edge for the length of the span, and three additional, shorter beams were inserted perpendicular to these at the one-quarter and one-half points. In addition, a Jersey barrier was placed along the damaged bridge railings.

"We really couldn't gauge how much damage the fire had done, but we could see the bridge still was in reasonably good shape," he says. "We were confident that if we shortened the spans of the precast concrete beams, enough strength remained to support the loads until a replacement could be built."

Installing the support beams took two more days, and the bridge reopened to traffic only four days after the fire occurred. A temporary bridge was created adjacent to the bridge, and once it opened, work on replacing the original bridge with another precast concrete version began. That work was completed a few months later, producing a brand new bridge to replace the fire damaged one in only four months.

In fact, a later evaluation of the beams performed at the FHWA Turner-Fairbank Highway Research Center showed that concerns over the short-term structural integrity of the beams were groundless. "The investigation found that the flexural capacity of the beams had not been degraded significantly as compared to their anticipated capacity," wrote Gary L. Henderson, Director of the Office of Infrastructure at the Federal Highway Administration in his report dated February 2007. However, their long-term durability may have been degraded by the fire, he noted, so replacement would have been needed eventually. See *Concrete Connections* on page 52 for the website address with the full report.

Avoiding such replacements can ensure budget and time are spent on projects where they are needed. HDR's Davis knows the balance that must be obtained. "If there was a close detour for the Bill Williams River Bridge, and money was no object, we might do more to improve the bridge, just to be on the safe side," she says. "But the closest detour is 100 miles away."

Even to do the work that will be needed on the overhang will require closing one lane and operating alternating-direction access during construction. "Work like this totally impacts traffic, especially in an environmentally sensitive area," she says. But that disruption is nothing compared to what would be required had the bridge been unusable and users had to drive 100 miles out of their way until a new bridge was completed.

Two major fires on highway structures in California last year demonstrated the disruption that they produce. The first in April was caused by a gasoline tanker truck that crashed and exploded into flames at the MacArthur Maze—one of California's heavily traveled freeway interchanges in the San Francisco Bay area. Although the steel superstructure of one connector collapsed, only 4 ft of concrete at the top of two columns supporting one outrigger bent were replaced. The original steel bent cap was replaced with a concrete one because it could be manufactured more quickly.

The second event in California occurred in October when a truck exiting a 550-ft-long truck-bypass tunnel on I-5 near Santa Clarita lost control resulting in a multi-vehicular collision and massive fire in the tunnel. Although the collision occurred at the exit from the tunnel, the winds drove the flames so that most fire damage occurred at the tunnel entrance. The tunnel structure consisted of concrete box girders supported on top of concrete strutted abutments. Repairs consisted of building a new wall in front of portions of the wall that were damaged and replacing approximately one-sixth of the total superstructure with precast girders and a cast-in-place concrete deck. This solution was adopted as the most conservative approach and allowed the tunnel to open 15 days ahead of the deadline.

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SUSTAINABLE

A CASE STUDY

Evaluating FIRE DAMAGE

by Richard B. Stoddard, Washington State Department of Transportation

In December 2002, a railroad tanker collision caused a fire under a prestressed concrete girder bridge crossing the Puyallup River in Tacoma, Washington. The bridge, constructed in 1997, had span lengths of 146 ft with W74 girders spaced at 5-ft 0-in. centers. Specified 28-day concrete strengths were 7000 psi in the girders and 5000 psi in the columns and bridge deck.

The fire consumed 30,000 gallons of methanol, engulfed Span 8, and maintained a high flame temperature for approximately 1 hour. The bridge was closed immediately pending further inspections. The bridge displayed no unusual deflections or misalignments and was reopened to commuter traffic and legal weight trucks on the morning after the fire.

Visual Inspection and Mapping

Visual inspection of both columns at Pier 9 approximately 60 ft from the source of the fire, showed 2-in.-deep spalls that exposed spiral reinforcement for the full height of the column. The concrete inside the spiral sounded like delaminated concrete. Further investigation revealed delaminations

within the concrete just inside the spiral cage and vertical reinforcement. The crossbeam above the columns had several areas of spalling but no reinforcement was exposed.

All 15 lines of girders in Span 8 were damaged and the corners of the bottom flanges could easily be removed to expose the outermost strands. The soffit of the concrete deck displayed no evidence of spalling.

Visual inspection of the damage in Span 8 included recording the concrete color variations on the soffit of the bottom flanges that corresponded to changes in concrete condition. The color regions were described as extreme-white, ash-white, white-gray, and soot. The different colors corresponded with different exposures to the fire with the extreme-white region representing the most intense exposure directly over the fire source.

Concrete Hardness Mapping

In accordance with the recommendations for Post Fire Examination of the PCI *Design for Fire Resistance of Precast, Prestressed Concrete*, hardness testing was performed on the bottom flanges and webs of the girders using a Schmidt hammer. The purpose of the tests was to map relative changes in concrete hardness along the length of each girder. The rebound hammer readings for the soffit of the bottom flanges in Span 8 ranged from 42 to 61 compared to 61 in girder concrete not affected by the fire. The minimum hardness occurred directly over the heat source and in general, hardness increased with distance away from the heat source.

The web hardness readings did not follow a pattern of regular change because shadowing by the bottom flange affected the distribution of web damage. The bottom flange protected some parts of the webs from severe fire damage.

Prestressing Strand

The prestressing steel in the girders consisted of 1/2-in.-diameter 270 ksi strands. Concrete surrounding the straight strands in the bottom flange was easy to remove with a light rock hammer. Because of the high temperatures, there was concern that the strands could have lost strength and that relaxation of the prestress force could have occurred.

Prior to removing samples of prestressing strands for material testing, simple deflection tests were performed to calculate the prestressing force. The tests were conducted before the strands were cut and after the strand replacement splices were tensioned. The strand deflections were induced by hanging a 173 lb weight on the strand. Deflections were measured multiple times by two inspectors using a dial caliper with a measurement accuracy of 0.001 in. This method was estimated to have a probable accuracy of 5 percent and was certainly accurate to within 10 percent of the actual tensile force. Based on this approach, the strands in the hottest zones appeared to have retained 100 percent of their design force.

Three samples of strand were removed and tested for yield strength, tensile strength, and modulus of elasticity. The strand samples met the requirements for 1/2-in.-diameter uncoated seven-wire prestressing strands per ASTM A 416-96 indicating that no metallurigical changes occured.

The fire engulfed Span 8 and maintained a high flame temperature for approximately 1 hour.

Spalling of concrete cover on the columns resulted in areas of exposed spiral reinforcement.

The pink color shown in this girder from the Puyallup bridge fire indicates that the concrete was exposed to temperatures higher than 500 °F.

Concrete Core Samples

Eight vertical concrete cores from the hot zone, two vertical cores from the coolest zone, and eight horizontal cores from the hot zone were removed from the prestressed concrete beams. Seven cores were examined petrographically in general accordance with ASTM C 856. The extent and severity of fire damage was based on observed changes in aggregate and cement paste color, mineralogy, and microstructure. Based on the petrographers' evaluation, which also included some informal heating tests, the state was convinced that surface temperatures on the bottom flange soffits exceeded 1500 °F during the fire.

Compression tests performed on core samples indicated that much of the undamaged concrete had a compressive strength exceeding 9000 psi. Significant portions of core samples from the hottest zone, however, were fractured and untestable.

Eight concrete cores were taken from the two columns at Pier 9. These confirmed the existence of delaminations in the interior core of the column. The maximum depth of fracture was found to be 5 in. from the original surface and more than 1 in. inside the vertical column reinforcement. Aside from the delaminations, the concrete remaining in the column appeared to have very good strength.

A core sample from the crossbeam at Pier 9 did not show any abnormalities and indicated that the crossbeam sustained only superficial damage from the fire.

Summary

The railroad tanker fire subjected all 15 girders in Span 8 to intense heat in a short period of time. Flame temperatures were estimated to be approximately 3000 °F and surface temperatures on the soffit of the prestressed concrete girders may have reached 1700 °F. Internal temperatures in the bottom flange and webs were estimated to range from 500 to 1100 °F. The prestressing steel survived the fire without noticeable loss of prestress.

Rapid identification of concrete damage zones can be made by observing the variation in concrete color immediately following a fire. The visual color mapping correlated very well with variations in concrete hardness. The rebound hammer test validated the visual observations and provided an objective description of the damaged areas. With this information, rational discussions could be made about repair or replacement.

All 15 lines of girders in Span 8 were damaged by the fire but the bridge was opened on the next morning.

Reference

Design for Fire Resistance of Precast, Prestressed Concrete, Second Edition, MNL-124-89, Precast/Prestressed Concrete Institute, Chicago, IL, 1989, 96 pp.

Acknowledgement

This article is based on a full-length paper titled "Inspections and Repair of a Fire Damaged Prestressed Girder Bridge," presented at the International Bridge Conference, Pittsburgh, June 2004, Paper No. IBC-04-17 which is available at www.aspirebridge.org/resources.

Richard B. Stoddard is Bridge Design Engineer with the Bridges and Structures Office of the Washington State Department of Transportation.

Some surface damage occurred in the top flanges.

Damage concrete surrounding the straight prestressing strands was easy to remove.

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

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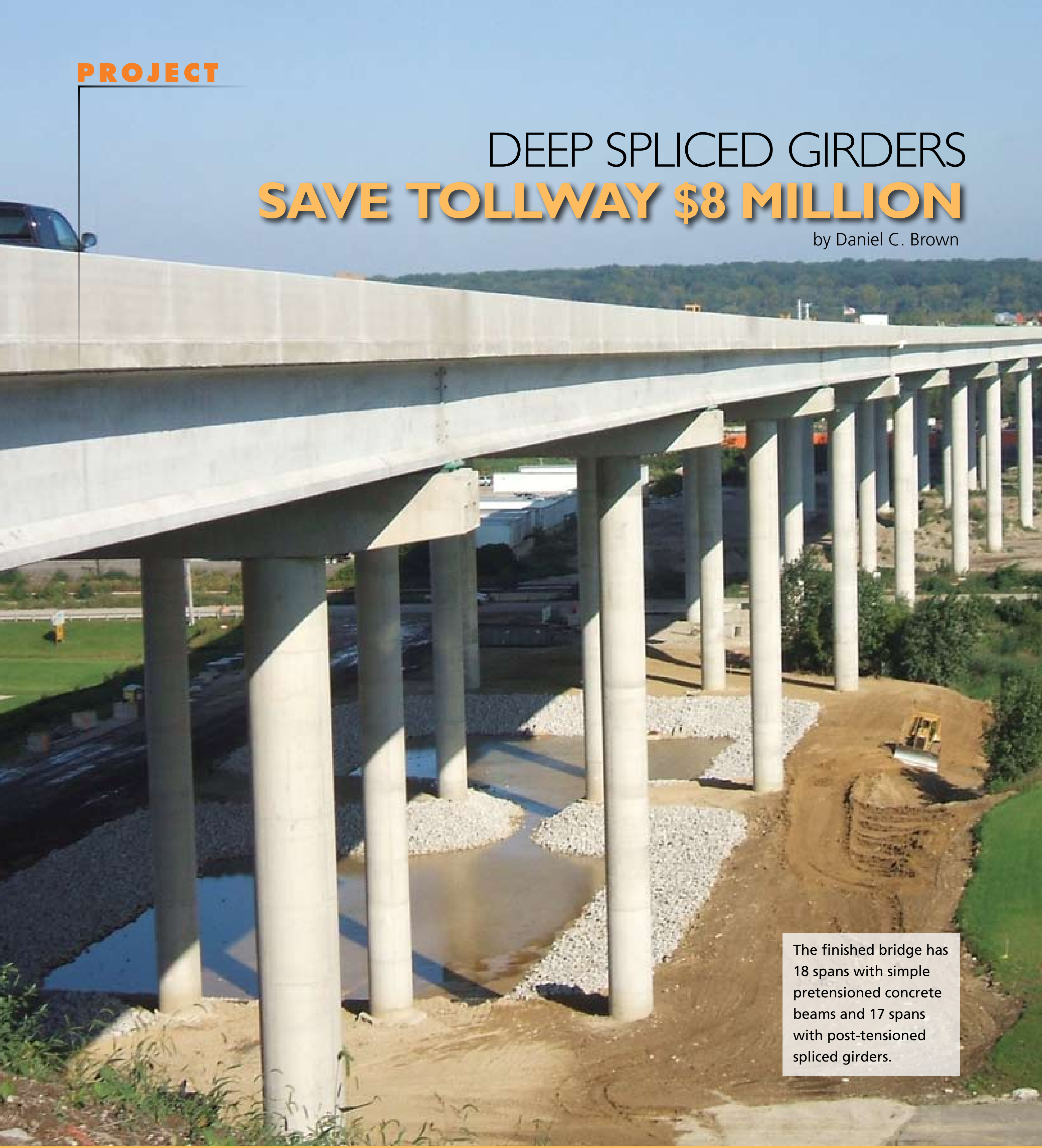
PROJECT

DEEP SPLICED GIRDERS SAVE TOLLWAY $8 MILLION

by Daniel C. Brown



The finished bridge has 18 spans with simple pretensioned concrete beams and 17 spans with post-tensioned spliced girders.

profile

DES PLAINES RIVER VALLEY BRIDGE ON I-355 / LEMONT, ILLINOIS

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

DESIGN QUALITY ENGINEER: Bowman, Barrett & Associates, Chicago, Ill.

PRIME CONTRACTOR: Walsh Construction Group, Chicago, Ill.

PRECASTER: Prestress Engineering Corp., Prairie Grove, Ill., a PCI-Certified Producer

SECONDARY GIRDER PRECASTER: Prestress Services, Decatur, Ind., a PCI-Certified Producer

The 1.3-mile-long Des Plaines River Valley Bridge has 34 piers and 35 spans, which range up to 270 ft long. All photos: Illinoise State Toll Highway Authority.

Offering a performance specification created benefits to entire construction team

Bridges like this one don't come along very often. The 1.3-mile-long Des Plaines River Valley (DPRV) Bridge on I-355 near the Chicago suburb of Lemont, Illinois, is the state's first to use post-tensioned, precast, prestressed concrete spliced bulb-tee girders. Its success means that it also won't be the last.

Opened last November, the DPRV Bridge combines the use of post-tensioned spliced bulb-tee concrete girders and pretensioned concrete bulb-tee girders. The post-tensioned spliced girder span lengths range from 216 to 270 ft, while the pretensioned concrete girders have span lengths ranging from 114 to 170 ft.

Officials at the Illinois State Toll Highway Authority (Tollway) had originally designed the bridge in two other configurations: a steel plate-girder bridge and a segmental concrete box-girder structure. "Shortly before the project was advertised for bids, there was a lot of fluctuation in material prices, especially steel," says Paul Kovacs, Chief Engineer for the Tollway. "To address the fluctuations, the Tollway decided to include a performance-based bid specification that would allow contractors to propose their own design."

Chicago-based Walsh Construction joined forces with Janssen & Spaans Engineering Inc. of Indianapolis, Indiana, to submit a $125-million, design-build proposal for the post-tensioned, spliced-girder design. The design represented the highest-priced bridge in Tollway history—but it still was the low bidder.

The winning proposal and the segmental concrete box-girder bridge alternate were both lower than the $175 million bid for a steel plate-girder structure.

Creating a performance specification cut costs, created flexibility, and saved 6 to 8 months.

"Not only did the performance specification allow us to mitigate the price fluctuations and save money, it gave the contractor the flexibility to build what he was comfortable with, and saved us 6 to 8 months in design," says Colin Makin, the Tollway's Deputy Program Manager for Bridges.

Indeed, the Walsh-Janssen team was awarded the contract in December 2005, before design was complete. By

MULTI-SPAN PRECAST, PRESTRESSED CONCRETE I-BEAMS AND POST-TENSIONED SPLICED GIRDERS / ILLINOIS STATE TOLL HIGHWAY AUTHORITY, OWNER

POST-TENSIONING CONTRACTOR: Dywidag Systems International (DSI), Bolingbrook, Ill.

BRIDGE DESCRIPTION: A 1.3-mile-long bridge with 252 girders 90 in. deep; 300 girders 102 in. deep; 60 girders 120 in. deep

BRIDGE CONSTRUCTION COST: $125 million

Each side of the bridge has six beam lines.

Two cranes prepare to place a drop-in segment. A strong-back is located at the right-hand end of the beam being lifted.

the following March, the contractor had begun drilling foundation caissons. Meanwhile, Janssen & Spaans finished superstructure design. The DPRV Bridge spans over two canals, several railroad lines, two local roads, the Des Plaines River, and forest preserve land.

The spliced girder design minimized the impact on the wetlands.

The bridge has a total of 34 piers and 35 spans. The bridge features 18 pretensioned concrete spans and 17 post-tensioned spans. The tallest pier cap is 82 ft above grade, with the bridge deck rising to 90 ft at the highest point.

The simple spans at the DPRV Bridge are made continuous with closure pours over their pier caps. "Over the piers, there's about a 1-ft-wide gap between the ends of the bulb-tee girders," says Brian Slagle, Vice President at Janssen & Spaans. "Reinforcing steel protrudes from the ends of the beams into the gap. And when you cast the deck and make the closure you lock the beams in at that point, establishing continuity. There are no joints at the piers."

A typical simple-span prestressed concrete girder is a 90-in.-deep bulb tee, with a top flange width of 4 ft 11 in., a web width of 6 in., and a bottom flange width of 24 in. The typical post-tensioned bulb-tee girder is 102 in. deep with a top flange width of 5 ft 1 in. and a bottom flange width of 26 in.

"We haunched the girders on the 270-ft-long spans," Slagle explains. "We

Formwork for pier columns shown during concrete placement.

made the typical girder 102 in. deep, but it's haunched to 120 in. over the piers, where you get maximum negative moment." Typically, each haunched girder was made in 120-ft lengths, but one was 138 ft long.

Falsework Supports Beams

For the post-tensioned spans, Walsh used falsework to support one end of the beams during erection, so that the beam rested on both a pier and the falsework. Two beams would extend toward each other, leaving space between for a drop-in segment with a length varying between 124 and 150 ft. The drop-in segment was lifted with a crane at each end. A temporary strong-back was clamped to each end of the drop-in segment to provide an overhang that rested on the adjoining beam end. "The strong-backs supported the beam in place, after which we could release the cranes," said Slagle.

Once the girder was released from the crane, the contractor connected the post-tensioning ducts between the beam ends. Formwork then was placed, and the closure pour was made. "There's a nominal 1-ft gap at the splice," said Slagle. "We coupled the ductwork, set all the reinforcement and formwork, and then made the closure placements across all six beam lines at once. That way, the closure acted as a monolithic diaphragm."

Once the concrete in the closure reached 5000 psi compressive strength, the post-tensioning contractor installed the strand and tensioned it with hydraulic jacks. Each girder had four ducts for

The $6.3-billion Plan

The DPRV Bridge is the largest of 18 construction contracts let by the Tollway for the I-355 South Extension. The 12.5-mile South Extension connects I-55 on the north end with I-80 on the south. Together, the South Extension and the rest of the I-355 Tollway have been named Veterans Memorial Tollway.

The I-355 South Extension is part of the Tollway's long-term $6.3-billion congestion-relief plan called Open Roads for a Faster Future. In late 2004, the Tollway's Board of Directors approved the plan, which is scheduled to last through 2016. One of its programs is Open-Road Tolling, by which 20 mainline toll plazas are being converted to barrier-free design. In addition, most of the tollway system will be rebuilt or modernized, and nearly half of the system's 117 miles of existing roads will be widened or have lanes added.

"Most of the tollway system was constructed nearly 50 years ago and has reached its design life," explains Lis Henderson. The growth of the northern Illinois region also has brought on the need for improvements.

The Tollway already has committed $3.6 billion worth of improvements to contract, including $2.8 billion in construction work. "We're trying to deliver as many of the benefits to the public as soon as we can."

Ongoing construction of the piers.

the post-tensioning strand, explains Slagle. "Generally speaking, the ducts are arranged to be high over the piers and low at mid-span—points where the beam is in tension."

Deck placement of unit 4 southbound bridge. Deck was cast in a specific sequence to avoid deck cracking over the piers.

New Forms Created

The $24-million contract for the precast, prestressed concrete girders produced the largest-ever contract for Prestress Engineering Corp. (PEC), which is Illinois' largest precast concrete bridge supplier. To handle the order, the precaster built two in-ground casting beds in 5 months, bought three beam forms, doubled its workforce to 200 people, and purchased eight 10-axle trailers.

"We had to purchase seven additional acres," says Terry Muntz, Vice President of Operations at PEC's Blackstone, Illinois, plant. "Half of the land went for storage of product and the other half was used to build the two casting beds." Each casting bed is 400 ft long by 20 ft wide by 10 ft deep.

The prairie winds blow strongly in Blackstone, so PEC built the beds in-ground to help keep the concrete warm during casting. The in-ground casting beds also permitted PEC to use shorter travel lifts. "This way we only had to lift the product the height of the beams before we could carry them," says Muntz. "If we had a 10-ft-high form and a 10-ft-deep beam, we'd need to lift the beams to a point 20 ft above ground."

Training the new employees was the biggest challenge, he adds. They also had to create a new safety plan to deal with the larger beams. The largest beams the company had previously cast were 72 in. deep, and the deepest beams at the DPRV Bridge were 120 in. deep.

Tollway officials take justifiable pride in their new bridge. "This bridge provides a great benefit to the driving public," said Lis Henderson, a spokesperson for the Tollway.

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

Minimal Environmental Impact

The spliced girder design allowed the Tollway to use spans long enough to minimize the bridge's impact on the wetlands through which it passes. The bridge and its construction had to meet environmental requirements set by the U.S. Army Corps of Engineers, the Illinois Department of Natural Resources, the Illinois EPA, and the U.S. Fish & Wildlife Service.

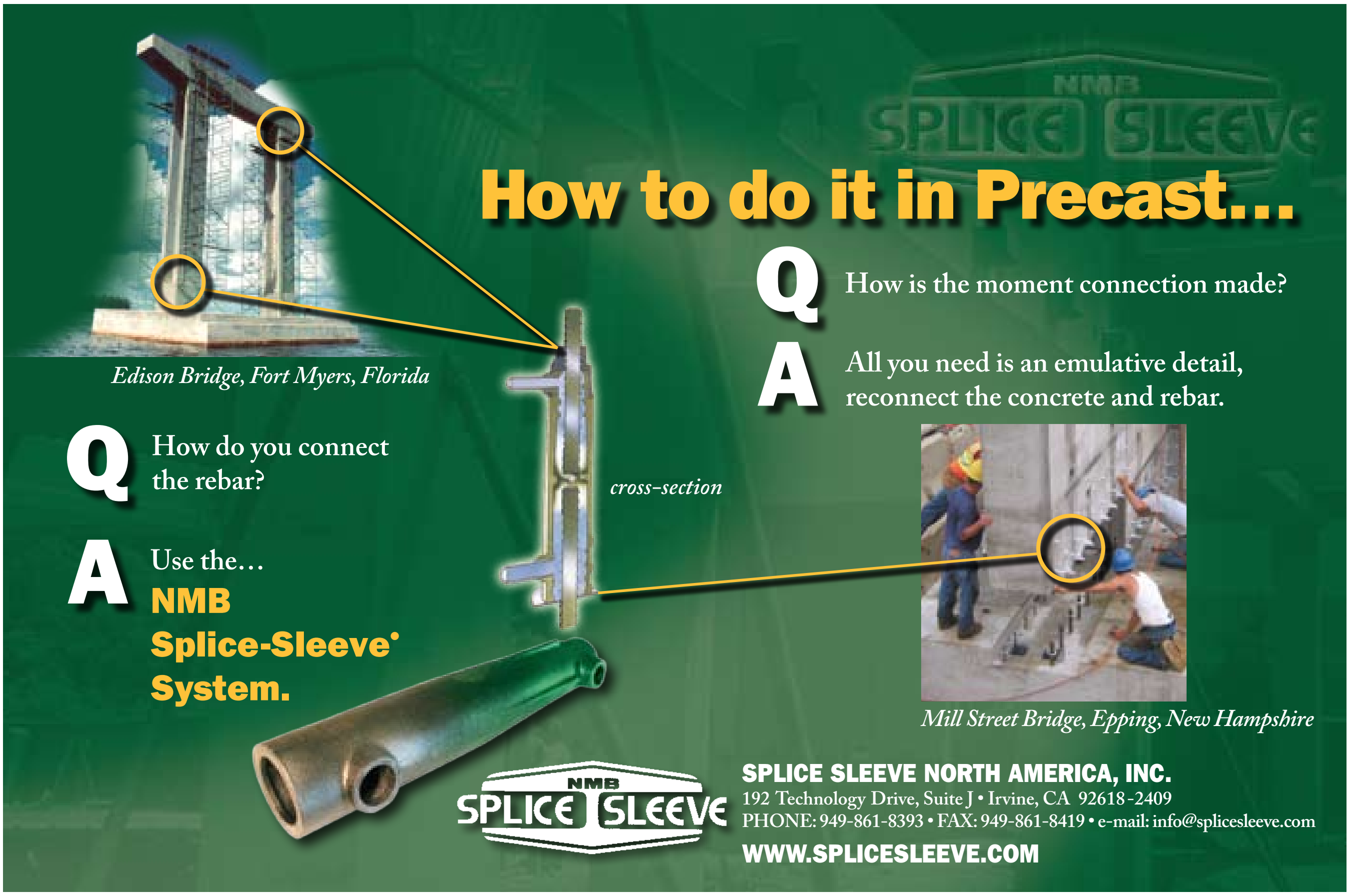
"This design allowed us to come in under the wetland acreages that we could impact on both a temporary and permanent basis," says Paul Kovacs, Chief Engineer for the Tollway. "We were able to affect only 8.77 acres during construction and only 3.87 acres permanently. We built 34 piers, and 16 of those are in wetland areas."

Protected Species

Believe it or not, a rare dragonfly helped influence the design of the DPRV Bridge. The area around the bridge serves as habitat for the Hine's Emerald Dragonfly, which was listed as an endangered species in 1995.

"The Hine's Emerald Dragonfly is one of the reasons the bridge was built as high as it is," says Kovacs. "We identified the dragonfly and studied its habitat. So we built the bridge 10 ft higher to keep cars out of the path of the dragonfly." At its highest point, the bridge is 90 ft above grade.

The area is also inhabited by the Blanding's Turtle, which needs to be protected. Colin Makin, the Tollway's Deputy Program Manager for Bridges, said the turtles have been found and fitted with electronic locators. If a Blanding's turtle roamed too close to the construction area, a group of environmentalists would pick up the turtle and relocate it.


How to do it in Precast…
Q How is the moment connection made?
A All you need is an emulative detail, reconnect the concrete and rebar.
Edison Bridge, Fort Myers, Florida
Q How do you connect the rebar?
A Use the… NMB Splice-Sleeve® System.
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Mill Street Bridge, Epping, New Hampshire
NMB SPLICE SLEEVE
SPLICE SLEEVE NORTH AMERICA, INC.
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AMERICAN SEGMENTAL BRIDGE INSTITUTE

ASBI's FIRST 20 YEARS AND THE FUTURE

By Linda Figg, FIGG and Ray McCabe, HNTB

In 2008, the American Segmental Bridge Institute (ASBI) will celebrate its 20th anniversary by hosting an international symposium on "Future Technology for Concrete Segmental Bridges" in San Francisco, California, on November 17-19, 2008. The expanded 3-day program will culminate the 20th anniversary celebration of ASBI and will feature keynote presentations by widely recognized United States and international bridge engineers, along with a tour to view the construction of the San Francisco-Oakland Bay Bridge. ASBI has come a long way over the years, growing to 51 organizational member companies and a total of 264 engineers, contractors, and suppliers—all focused on the segmental bridge industry. The 2007 convention, held in Las Vegas, Nevada, attracted 415 bridge industry professionals, the largest ASBI convention to date. ASBI has achieved many goals and is well poised to support the segmental bridge industry in the future.

ASBI's founding members — A moment in history
Standing (from left to right): W. Burr Bennett Jr., consultant; Robert P. McCrossen, material supplier; Clifford L. Freyermuth; Eugene C. Figg Jr., consultant; Raymond Schmahl, contractor; Juergen L. Plaehn, material supplier; Seated (from left to right): David T. Swanson, material supplier; W. Jack Wilkes, consultant; and Gary L. Peters, contractor.

ASBI was founded in 1988 through the vision and leadership of Eugene C. Figg Jr. In remembering those early days, Linda Figg reflects, "My father brought me into his office one day to share his ideas for what would become the American Segmental Bridge Institute. He believed that a focused organization with people from various industry interests would bring the greatest success to advancing segmental bridge technology. He thought Cliff Freyermuth would be excellent to manage the organization with his strong background with the Precast/Prestressed Concrete Institute and Post-Tensioning Institute. And now, 20 years later, ASBI has made significant achievements and Cliff Freyermuth has been a strong and dedicated day-to-day leader."

Background photo courtesy of Kiewit Pacific Company.

Cliff Freyermuth
Manager, ASBI

The original group gathered in Wichita, Kansas, to discuss how the segmental bridge industry could come together in one organization to provide a resource to advance the benefits of concrete segmental bridges in the United States. Each of the individuals in the founding group saw the benefits of segmental bridges and the increasing level of interest in segmental bridges nationwide. The vision was to create a unique organization that would bring together all areas of interest—owners, engineers, designers, contractors, and material suppliers. ASBI's founding members were a cross-section of interested leaders, who set the framework for how the organization and industry could grow and succeed.

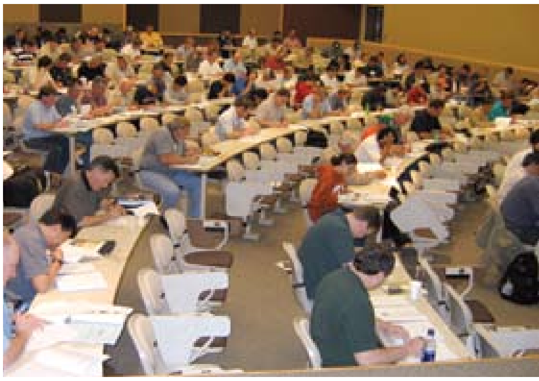
In ASBI's 20-year history, the industry has evolved and advanced in many positive ways. Many successful and beautiful segmental bridges have been completed and more are being designed and built by ASBI member firms. Segmental bridges are increasingly becoming a preferred bridge technology by many owners. Segmental bridges have been completed throughout the United States and continue to set new records for span lengths, to introduce new technologies, to be cost efficient, and to capture pleasing aesthetic qualities.

Grouting Certification

In order to continue to strengthen the industry and provide quality measures consistent with our goals, ASBI organized and began offering grouting certification training in 2001. The purpose of the training is to provide supervisors and inspectors of grouting operations with the training necessary to understand and successfully implement grouting specifications for post-tensioned structures. Over 1100 professionals have completed this training, which is offered annually, bringing improved construction to segmental bridges. In 2008, the grouting training and certification will be offered on April 14 and 15 at the J.J. Pickle Research Campus in Austin, Texas.

Cliff Freyermuth

ASBI has achieved many goals set out 20 years ago. Since the organization was founded, the day-to-day operations of ASBI have been managed by Cliff Freyermuth. In this anniversary year, it is with pleasure that we pay tribute to him for his dedicated service to ASBI. While Cliff is concluding his tenure at ASBI this year, he will continue to be an important voice in the industry and work in consulting. He came to ASBI after 12 years as Manager of the Post-Tensioning Institute, 5 years as Director of the Post-Tensioning Division of the Prestressed Concrete Institute, 6 years



ASBI Training Session Exam on Grouting Certification at the University of Texas.

Photo: T.Y. Lin International.

BRIDGE TOURS AND CONVENTION HOST CITIES

Over the years, ASBI has held annual conventions in 19 distinctive destinations. Bridge tours of nearby significant segmental bridges have been included. The bridges are typically under construction or recently completed, and serve as a 'classroom in the field' illustrating various aspects of segmental bridge design and construction.

2007 Hoover Dam Bypass Bridge
Las Vegas, *Nevada*

2006 Otay River Bridge
La Jolla, *California*

2005 Woodrow Wilson Bridge
Washington, *D.C.*

2004 Lee Roy Selmon Expressway
Tampa, *Florida*

2003 High Five Interchange
Dallas, *Texas*

2002 San Francisco-Oakland Bay Bridge & Benicia-Martinez Bridge
San Francisco, *California*

2001 Creve Coeur Lake Memorial Park Bridge
St. Louis, *Missouri*

2000 AirTrain JFK Light Rail
Brooklyn, *New York*

1999 Sidney Lanier Bridge
Amelia Island, *Florida*

1998 Central Artery
Boston, *Massachusetts*

1997 U.S. 183 Viaduct
Austin, *Texas*

1996 Seabreeze Bridge
Orlando, *Florida*

1995 Puyallup River Bridge
Seattle, *Washington*

1994 Chesapeake & Delaware Canal Bridge
Philadelphia, *Pennsylvania*

1993 Acosta & Dame Point
Ponte Vedra, *Florida*

1992 Natchez Trace Arches
Nashville, *Tennessee*

1991 San Antonio "Y"
San Antonio, *Texas*

1990 Keys Bridges & Dodge Island Bridge
Miami, *Florida*

1989 Pine Valley Creek Bridge
San Diego, *California*

2006 ASBI Leadership Awards: Cliff Freyermuth for Outstanding Career Contributions to the Segmental Concrete Industry as ASBI Executive Vice President. Also recognized are (bottom left to right) Guido Schwager, segmental/cable-stayed bridges; John Armeni, Chair, ASBI Committees on Membership and Construction Practices; Hala Elgaaly, Chair, ASBI Bridge Award of Excellence, Board of Directors; Paul Liles, ASBI President 2005-2006; (top left to right) Steven Stroh, concrete segmental/extradosed bridges; W. Denney Pate, concrete segmental/cable-stayed bridges; Alan Moreton, design/construction segmental concrete bridges.

with the Portland Cement Association, and 6 years in bridge engineering with the Arizona Highway Department in Phoenix, Arizona.

Cliff has been responsible for or had significant involvement in over 34 major publications in the industry. He led the development of the *Precast Segmental Box Girder Bridge Manual* published by PCI and PTI in 1978. He was Principal Investigator for the NCHRP Project for development of the 1989 *AASHTO Guide Specifications for Design and Construction of Segmental Concrete Bridges,* and served as the Chairman of the committee that developed three editions of the PTI *Recommendations for Stay-Cable Design, Testing and Installation*. His commitment and knowledge of the industry have been significant contributing factors in ASBI's success. Cliff's career accomplishments have been recognized by many organizations, including ASBI itself in 2006 with an ASBI Leadership Award for Outstanding Career Contributions to the Segmental Concrete Bridge Industry; PCI's Charles C. Zollman Award in 1999; American Concrete Institute's (ACI) Henry C. Turner Medal in 1991; and ACI's Arthur R. Anderson Award in 2004 for "his many contributions to the development and implementation of post-tensioned concrete building and segmental bridge design techniques and construction specifications." As the current ASBI President Ray McCabe reflects on Cliff's years of service, "We appreciate all the contributions and leadership that Cliff has provided over the past 20 years to ASBI. ASBI continues to grow and Cliff has been instrumental in the development of this forward thinking bridge institute."

Cliff Freyermuth receiving 1999 PCI Charles C. Zollman Award from John Dick, PCI Structures Director.

In 2003, in order to recognize and celebrate segmental bridge owners who have achieved outstanding projects, ASBI created the Bridge Award of Excellence program. Every 2 years, award-winning bridges are honored during the ASBI convention and are featured in *Concrete Products* magazine.

2003 WINNERS

I-25/I-40 Interchange, *Albuquerque*
New Mexico Department of Transportation

Vietnam Veterans Memorial Bridge, *near Richmond*
Virginia Department of Transportation

I-90/I-93 Interchange, *Boston*
Massachusetts Turnpike Authority

Broadway Bridge, *Daytona Beach*
Florida Department of Transportation

Foothills Parkway Bridges (#9 & #10), *Blount County, Tennessee*
Eastern Federal Lands, Highway Division, FHWA

Smart Road Bridge, *near Blacksburg*
Virginia Department of Transportation

ASBI's Future Vision

The Board of Directors has identified strategic steps to continue to look to the future for continued growth and advancement of segmental bridges. Concrete segmental bridges will continue to advance and lead the industry in new technologies for longer lasting bridges. The International Symposium to be held November 17-19, 2008, will feature some 64 topics and speakers highlighting extraordinary achievements in the bridge industry.

The American Segmental Bridge Institute will continue providing a forum where owners, designers, constructors, and suppliers can meet to further refine current design, construction, and construction management procedures, and evolve new techniques that will advance the quality and use of concrete segmental bridges. ASBI is a unique organization in that all components of the bridge construction industry are included as members.

This fall, ASBI will bring on a new manager to begin the next 20 years and work with future ASBI presidents. A committee, led by Ralph Salamie of Kiewit, is developing details on the manager's position and identifying interested candidates. For more information, contact Ralph at (360) 693-1478 or ralph.salamie@kiewit.com.

LEADERSHIP

ASBI has been led by some of the strongest supporters of the segmental bridge industry in the United States, each focusing on unique issues and opportunities and bringing their own signature to the organization while under their leadership. Leaders included representatives from owners, consulting firms, contractors and material suppliers, each contributing to ASBI and advancing the industry in their own way.

Term of Office	President
1989 – 1990	W. Jack Wilkes, Consultant
1991 – 1992	Gary L. Peters, Contractor
1993 – 1994	David Swanson, Material Supplier
1995 – 1996	Man-Chung Tang, Consultant
1997 – 1998	Eugene C. Figg Jr., Consultant
1999 – 2000	James E. Roberts, Transportation Official (owner)
2001 – 2002	Ronald J. Bonomo, Material Supplier
2003 – 2004	R. Craig Finley Jr., Consultant
2005 – 2006	Paul V. Liles Jr., Transportation Official (owner)
2007 – 2008	Raymond McCabe, Consultant

2005 WINNERS

Victory Bridge, *Sussex County*
New Jersey Department of Transportation

Four Bears Bridge, *New Town*
North Dakota Department of Transportation

AirTrain JFK, *Brooklyn, New York*
Port Authority of New York & New Jersey

Creve Coeur Lake Memorial Bridge
Missouri Department of Transportation

Sidney Lanier Bridge, *Brunswick*
Georgia Department of Transportation

I-95/Palm Beach Interchange
Florida Department of Transportation

Tarrango Bridge, *Mexico City*
Government of Mexico City

Panama Canal Second Crossing, *Paraiso*
Ministry of Public Works, Panama

2007 WINNERS

Lee Roy Selmon Crosstown Expressway Expansion, *Tampa*
Tampa Hillsborough Expressway Authority, Florida

Otay River Bridge, *San Diego County*
California Transportation Ventures

Penobscot Narrows Bridge & Observatory, *near Bucksport*
Maine Department of Transportation

I-76 Susquehanna River Bridge, *York and Dauphine Counties*
Pennsylvania Turnpike Commission

Second Vivekananda Bridge Tollway, *India*
Second Vivekananda Bridge Tollway Company Private Ltd.

Woodrow Wilson Memorial Bridge
FHWA, Departments of Transportation of Virginia, Maryland, and District of Columbia

Maroon Creek Bridge Replacement

by Thomas W. Stelmack, Parsons

A rendering of the completed project was prepared for approval by the CDOT and local agencies.

The residents and visitors at the world-class ski resort of Aspen, Colorado, have waited years for the 'Entrance to Aspen' project to be completed. This consists of the reconstruction of State Highway 82 as the primary access road and one of only two routes into the town from the west. The highway crosses the wide and deep Maroon Creek basin at the town limits on the oldest bridge in service on the Colorado state highway system. Due to its historical significance, the existing bridge is listed on the National Register of Historic Places.

Originally constructed as a railroad trestle bridge in 1888, the Colorado Midland Railroad Bridge became the property of what was then called the Colorado Department of Highways in 1927. The Maroon Creek Bridge was converted for highway use in 1929 and widened in 1963 to its current width of 30 ft by adding outrigger struts to the original A-frame trestles. Since then, the timber bridge deck with asphalt has been replaced once and repaired several times. To this day, the structure continues to require high maintenance

profile

MAROON CREEK BRIDGE REPLACEMENT / STATE HIGHWAY 82, ASPEN, COLORADO

ENGINEER: Parsons Transportation Group, Denver, Colo.

PRIME CONTRACTOR: BTE Concrete/Atkinson Construction JV, Glenwood Springs, Colo.

CONTRACTOR'S ENGINEER: McNary Bergeron & Associates, Denver, Colo.

CONSTRUCTION INSPECTION: Carter Burgess, Denver, Colo.

CONCRETE SUPPLIER: Lafarge North America, Carbondale, Colo.

A view of the nearly completed first cantilever shows the wide deck overhangs, deck ribs, and the adjacent existing historic bridge.

by the Colorado Department of Transportation (CDOT), which lowered the sufficiency rating to 24 because of substructure repairs to arrest scour and damaged pier foundations. This forced heavy trucks to be detoured around the bridge via the secondary route while repairs were made.

In 1990, the CDOT recognized the need to replace the existing bridge and completed the design of twin, three-span steel box girder bridges. The twin-bridge concept, however, was never built due to public concerns regarding the number of lanes, alignment, and impact the construction and resulting traffic would have on the environment.

Critical Issues and Project Goals

After extensive study, several requirements were identified and considered in the design of the replacement bridge. The primary issues were environmental impact, aesthetics, and impact on the traveling public using SH 82. These were added to CDOT's original project goals of cost,

CAST-IN-PLACE, CONCRETE, SEGMENTAL BOX GIRDER BRIDGE CROSSING MAROON CREEK / COLORADO DEPARTMENT OF TRANSPORTATION, REGION 3, OWNER

POST-TENSIONING SUPPLIER: VSL, Hanover, Md.

FORM TRAVELER SUPPLIER: Mexpressa, Xochimilco, D.F., Mexico

BRIDGE DESCRIPTION: Three-span, cast-in-place, balanced cantilever segmental box girder with a main span of 270 ft, end spans of 170 ft, and a width of 73 ft

BRIDGE CONSTRUCTION COST: $13.97 million

'It's also going to be a very durable and long-lasting bridge.'

maintenance, and durability in the evaluation of the alternative structures.

During preliminary design, several bridge types were identified that could achieve the aesthetic goals of the project, have estimated construction costs within an acceptable range, and meet the maintenance and durability requirements. Therefore, constructibility became the differentiating factor in selection of the bridge type.

Recommended Alternative—Cast-in-Place Segmental Concrete

After careful evaluation of several alternative bridge types and construction methods, a cast-in-place (CIP), segmental concrete box girder bridge to be built using a pair of form travelers and the balanced cantilever method of construction was selected.

Superstructure—The final span configuration is a 270-ft-long main span flanked by equal 170-ft-long side spans. The single cell box girder is 73 ft wide and is a constant 13 ft 6 in. deep, with 19-ft-long long deck overhangs, using ribbed elements for support of the long slab spans. The typical segments are 15 ft long, with one deck rib in each segment placed 5 ft from the leading edge of the segment. The segment layout consists of a 25-ft-long pier table with eight segments in the main span cantilever and 10 segments in the side span, the last connecting directly to the abutment segment. The two cantilevers are connected with a 5-ft-long closure segment at the center of the main span.

Piers and Foundation—The piers form an 'A' shape with a capital section at the top of the pier that is flared at the same angle as the outriggers on the existing bridge. The flared section provides the required connection to the wide box girder section, while reflecting the shape of the existing trestles. As the lines of the capital flow into the pier legs, the outside face of the pier

Form travelers were used to construct the superstructure segments from above to minimize impacts to the environmentally sensitive creek basin and wetlands below the bridge.

Balanced cantilever construction of second cantilever is nearly 50 percent complete.

An 'Environmentally Friendly' Bridge

The new Maroon Creek Bridge has been a successful project for many reasons, but none more important than its utilization of a 'from the top' construction method. The wetlands in the Maroon Creek basin have been subjected to serious environmental impacts since the area was first settled in the 1800s. Recently completed wetlands restoration projects include eradicating non-native plants, re-grading, re-planting, and improving drainage to create a thriving riparian complex. Therefore, one of the major goals of the project was to design an economical bridge that could be constructed with minimal impact to the basin. The Entrance to Aspen documents required that the new bridge be constructed with a maximum temporary disturbance to wetlands of 0.2 acres, and maximum permanent displacement for piers of 0.1 acres.

The balanced cantilever, cast-in-place concrete, segmental bridge construction technique using overhead form travelers minimized the need for heavy cranes and allowed the majority of the superstructure construction work to be done from above.

Detailed constructibility studies of all viable alternatives were done to determine the size and location of the cranes and other equipment for both substructure and superstructure construction, laydown areas for materials and girders, and access roads to both pier locations. While all the alternatives could be carried out within the allowable impact limits, the segmental alternative impacted less than half the area impacted by the girder alternatives. Also, the area impacted for the segmental structure is constrained to the area below the bridge and around the piers—the area previously disturbed during construction of a pedestrian bridge that was removed as part of this project. Based primarily on the results of this study, the segmental scheme was deemed to be preferable by all of the stakeholders, including CDOT, Pitkin County, the City of Aspen, and the public. The final plans included detailed limits for the disturbance areas and also included details for a temporary construction crossing of Maroon Creek, with a narrow footprint in order to minimize in-stream construction activities.

Another challenge to the project design team was to provide extensive water-quality protection and a protected staging area, while still allowing for movement of wildlife in the basin. A wildlife movement study was conducted with a three-fold purpose to:

- Evaluate current large mammal movement through the proposed project area;
- Predict how the staging and construction of the bridge replacement could impact those movements; and
- Make recommendations on how to mitigate those impacts.

The results of this study, which were included in the project plans and implemented during construction, included requirements for special fencing, monitoring during and after construction, and limitations on night work to minimize disruptions during nocturnal wildlife movements. A special wetland-restoration seed mix was also developed to restore disturbed areas.

Additional environmentally sensitive features of the bridge include low-energy LED lighting of the pedestrian path and the accommodation of an 8-in.-diameter pipe inside the box girder to carry reclaimed water from a new city development for irrigation of the adjacent Aspen City golf course.

The project has already been the recipient of CDOT's own Environmental Award in 2007 and Pete Mertes, CDOT Resident Engineer, states, "it was an excellent choice of structure type to minimize the environmental footprint, as well as virtually avoiding the impacts to traffic and the traveling public."

leg is recessed. This recess, together with a change in concrete color within the recess, combines to reduce the visual mass of the very tall pier. The conventionally reinforced concrete pier legs are tapered in the direction transverse to the roadway centerline from 10 ft at the base to 6 ft at the top and have a constant 10 ft thickness in the longitudinal direction. The pier is founded on a footing supported by twelve 4-ft-diameter drilled shafts socketed into rock approximately 20 ft below the footing.

Construction Details

Construction began on the piers in late fall 2005 and continued throughout the winter. Once the pier was completed, the 25-ft-long pier table section was cast on falsework supported directly from the top section of the pier. The first form traveler was then erected on top of the pier table and the first typical segment cast in early fall 2006. The segments were cast alternately on either end of the cantilever until reaching the eighth segment in the main span and ninth on the side span. Although the site is located at an elevation of 7900 ft, the contractor controlled temperature in the segments throughout the winter by insulating the forms and running heated glycol through pipes on the exterior surface of the forms. Concrete for the segments was pumped from the creek basin with a pumper truck located near the pier. The entire superstructure was constructed from the top, with impacts to the creek basin limited to the areas designated during design with one exception. The path connecting the two work pier areas was relocated from the centerline of the structure to just outside the edge of the bridge. This was done to allow better crane access for lifting segment materials, while keeping the overall area of impact the same.

The second cantilever was completed in late 2007 and the main span closure connecting the cantilevers was cast in December 2007. Bottom slab tendons were then stressed to complete the main span. The final closure to the second abutment was made in January 2008, which completed the segment casting a little over a year after the first segment was cast. Joe Elsen, CDOT Region 3 East Program Engineer expressed his satisfaction with the project, "The bridge is an extremely elegant structure and the aesthetics are very pleasing. It's also going

Only the final closure segment to the abutment remains as the form travelers are lowered to the ground near the pier.

to be a very durable and long-lasting bridge due to the prestressing and high strength concrete." Local agencies and the public have also been receptive to the new structure and are looking forward to the day later in 2008 when the bridge will be opened to traffic completing the first phase of the 'Entrance to Aspen.'

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Thomas W. Stelmack is Senior Project Manager with Parsons, Denver, Colo.

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

AESTHETICS COMMENTARY

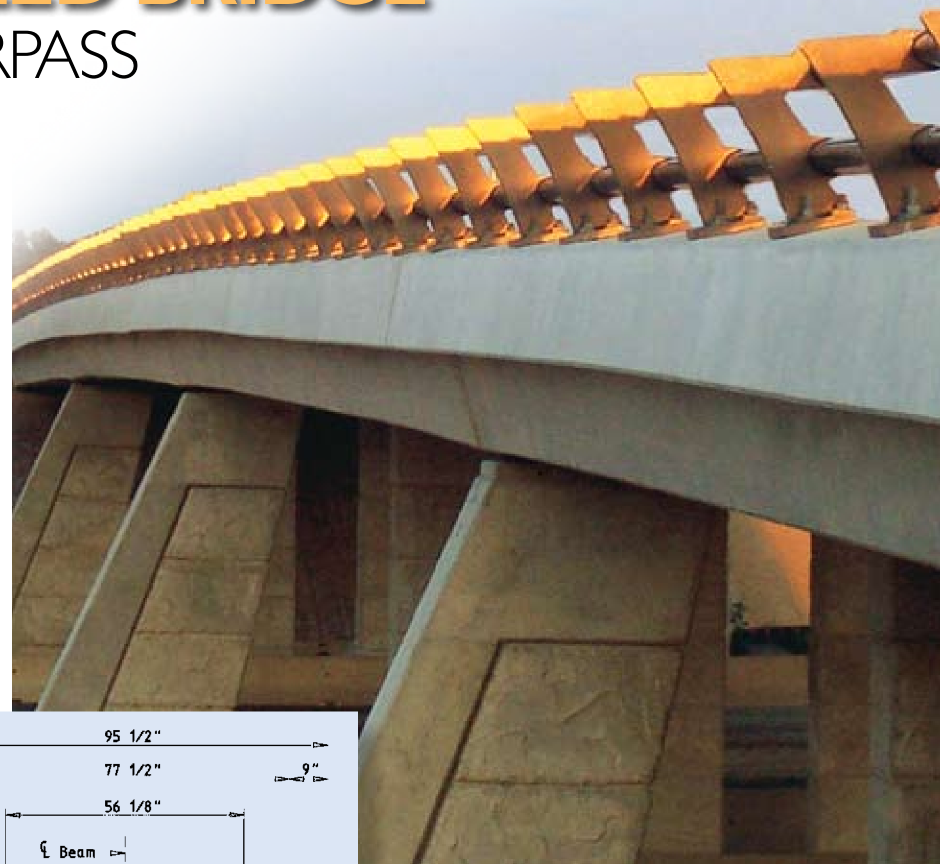
by Frederick Gottemoeller

The new Maroon Creek Bridge and the former railroad trestle that it replaces present a fascinating contrast in bridge design philosophies. Happily, both will remain in place to remind engineers that there is always more than one way to bridge a gap. The original railroad bridge crosses the valley with 19 spans supported by multiple thin steel piers. It achieves transparency because the members are so thin that you can see right through them. The new bridge crosses the valley with three spans on two massive piers. It achieves transparency because you can see between them. Even non-engineers will find the differences between these bridges interesting and worth thinking about.

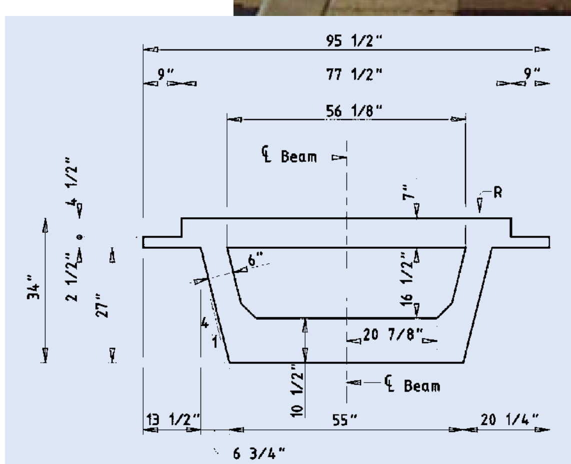
When the railroad bridge was converted to automobile use in 1929, diagonal struts were added at each pier line and gave the cross section a pinched-waist silhouette. The new bridge takes this silhouette as a point of departure for the design of the new piers. This very effectively provides a visual tie between the bridges in spite of the fact that they are otherwise quite different. The long deck overhangs are another successful feature of the new bridge. Their shadows on the girder webs reduce the apparent depth of the girder. At the same time, the deep setback of the girder webs from the edges of the deck reduces the shadow of the bridge on the ground. The piers themselves appear heavy, particularly when seen together with the thin steel members of the original bridge. They would have been improved with thinner proportions, especially at the "knuckle" just below the girder. However, overall this is a fine bridge. The crossing of the creek by State Highway 82 will continue to be a memorable feature of the Maroon Creek valley.

PREASSEMBLED BRIDGE
FACILITATES OVERPASS CONSTRUCTION

by Jamie Griffin, Lloyd Wolf, Gregg Freeby, Michael Hyzak, David Hohmann, and Randy Cox, Texas Department of Transportation



The bridges incorporated pretopped U-beams, precast concrete column shells, and preassembly.



Typical pretopped U-beam section.

The design challenge was to provide an aesthetically pleasing set of bridges that minimized traffic disruption.

The Texas Department of Transportation (TxDOT) employs innovative techniques to accelerate bridge construction while providing durable, economical, and aesthetically pleasing solutions on a wide variety of projects. From such bridges as the Jim Cowan Memorial Bridge at Lake Belton to the Cottonwood Creek and Battleground Creek Bridges, fully precast bridge systems have played an important role in reducing the impact of bridge construction to the traveling public in Texas' rural areas.

Reconstruction of I-35, the main north-south artery and a crucial commercial corridor in central Texas, necessitated the construction of several overpasses.

profile

LOOP 340 BRIDGES / WACO, TEXAS

ENGINEER: Texas Department of Transportation, Austin, Tex., and Structural Engineering Associates, San Antonio, Tex.

PRIME CONTRACTOR: Archer-Western Contractors, Arlington, Tex.

PRECASTER: Heldenfels Enterprises Inc., San Marcos, Tex., a PCI-Certified Producer

PRECAST SPECIALTY ENGINEER: Structural Engineering Associates, San Antonio, Tex.

PRECASTER'S ENGINEER: Unitech Consulting Engineers, San Antonio, Tex.

AWARD: Co-Winner of 2007 PCI Design Award for Best Bridge with Spans Between 75 and 150 ft

This construction provided TxDOT with a unique opportunity to utilize accelerated construction techniques in a dramatically different environment from the rural areas in which these techniques had previously been employed. Here, the design challenge was to provide an aesthetically pleasing set of bridges that minimized traffic disruption to the busy interstate by reducing construction time within the right-of-way of I-35. These bridges would then be used as prototypes for many such overpasses along the I-35 corridor.

TxDOT identified four candidate bridges on Route 340 Loop near Waco for which the prototype design would be formulated. Two 58-ft 3-in.-wide mainlane bridges and two 48-ft 3-in.-wide frontage road bridges, each comprised of four 115-ft-long spans crossing over I-35, were selected. The final design for the Loop 340 bridges incorporated pretopped U-beams, precast concrete column shells, and an innovative off-site preassembly method to reduce the impact to motorists caused by superstructure construction over the busy lanes of I-35.

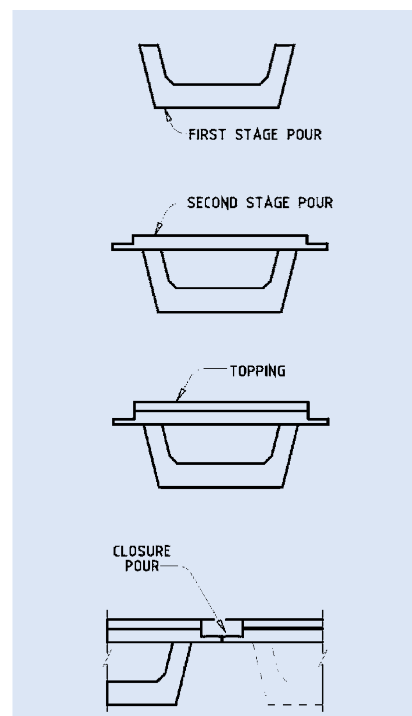
Pretopped U-Beam Design

The Texas chapter of the Precast Concrete Manufacturers Association (PCMA), together with TxDOT and partners in industry, developed a superstructure system to be used for the first time nationally in the construction of the Loop 340 bridges. New beams were developed from TxDOT standard precast, prestressed concrete U-beams that incorporated a 7-in.-thick top flange cast by the beam fabricator. Plans specified an additional 4 in. of concrete slab to be placed by the contractor at the off-site casting yard near the construction site. The top flange plus the 4-in.-thick pretopping provided a precast slab and reduced site-cast concrete to a narrow closure pour between pretopped beams. The exterior beam design included an overhang, also precast off-site, which eliminated the need for form removal over traffic, thereby reducing construction time and increasing worker safety.

The pretopped U-beam is comprised of a 34-in.-deep precast, prestressed concrete beam with a 4-in.-thick topping slab added at the off-site casting yard, for a total final section depth of 38 in. The beams are spaced at approximately 8 ft on center and utilize 0.6-in.-diameter strands on a 2-in. grid. With up to 77 prestressing strands and concrete strengths of 6500 psi at release and 7400 psi final, the beams can span up to 115 ft, for a span-to-depth ratio of 36.3.

The design required debonding up to 75 percent of the prestressing strands in the beam ends to satisfy allowable tensile stresses at release. While AASHTO limits debonding to no more than 25 percent of the total number of strands, previous experience had shown success with up to 75 percent of strands debonded in prestressed concrete beams. This experience was supported by research conducted at the University of Texas at Austin confirming the successful use of 75 percent debonding and by further calculations to ensure that the beams would have adequate shear resistance.

In order to facilitate inspection and reduce the chance of honeycombing in the bottom slab, the beam fabricator cast the bottom flange and webs as the first step of a two-stage placement. In the second stage, the fabricator placed the 7-in.-thick top flange. After the specified release strength was attained, the prestressing strands were released and the beams were transported to the contractor's staging yard near the construction site, where the final 4-in.-thick topping was placed.



Pretopped U-beam construction sequence.

PRECAST, PRESTRESSED, PRETOPPED, CONCRETE U-BEAMS / STATE OF TEXAS, AUSTIN, TEXAS., OWNER

BRIDGE DESCRIPTION: Two mainlane and two frontage road bridges comprised of newly developed precast, pretopped U-beams spanning 115 ft over I-35. Precast substructure features individual columns with no bent cap. Superstructure completely preassembled in off-site casting yard to obtain final elevations and grading prior to placement on-site.

STRUCTURAL COMPONENTS: Precast, pretopped U-beams incorporating a 4-in.-thick pretopped slab from the beam fabricator, with an additional 4-in.-thick slab cast by the contractor in an off-site precasting yard. Individual precast concrete columns with no bent caps.

BRIDGE CONSTRUCTION COST: $8.4 million

Formliners were used to simulate limestone blocks for the column shells. The column shells were precast for rapid erection.

Beams were preassembled for casting the deck.

A 4-in.-thick topping was cast on the beams before onsite erection.

Precast Column Shells

In keeping with the goals of reducing construction time within the right-of-way and reducing impact to the motoring public, column shells were precast at the contractor's off-site staging yard and then moved into position within the right-of-way. The columns were precast full height using a hollow rectangular section and featuring a unique formliner to produce the appearance of large limestone blocks. Outer columns were designed with a tapered width for added aesthetic value.

Once ready for placement, the column shells were moved into their final locations within the right-of-way and placed on top of a conventional drilled shaft with a top-cast footing and a projecting reinforcing steel cage. Elevations were adjusted with the aid of leveling pads. Infill concrete completed the precast column assembly. Due to the wide spacing of the pretopped U-beams, each line of beams was able to be directly supported on individual columns, eliminating the need for a bent cap. Bent cap construction constitutes a considerable amount of construction and curing time within the right-of-way, so elimination of the bent cap through the use of the individual columns further reduced construction time.

Prefabricated Bridge Construction System

Among the most unique developments featured in the construction of the Loop 340 bridges was the off-site preassembly of the bridge spans. In order to address grading issues when adding the final 4-in.-thick slab, the contractor erected the beams on temporary supports constructed to simulate the permanent supports on which the beams would ultimately rest. The supports were designed to provide the same cross-slope, longitudinal slope, and relative elevation between beams as specified for the finished structures.

The beams were first assembled side-by-side on temporary supports and bearing pads. The contractor then placed reinforcing steel for the remaining 4-in.-thick slab, and formed and placed the final topping slab and outside curbs, using blockouts to form the longitudinal and transverse closure strips that would be cast after the beams were moved to their final locations. The topping was graded using a screed to help achieve the correct elevation and to account for differential camber between beams.

Once the final 4-in.-thick topping cured and the bridge rail was attached, the beams were transported from the

TxDOT developed a prefabricated system appropriate for construction in high-traffic areas.

off-site staging yard to the bridge construction site where they were placed on the individual columns. The initial night-time placement rate was one span per night, but ultimately increased to two spans per night as the contractor became more familiar with the system. An exterior beam with final deck and curbs weighed approximately 148 tons.

Pretopped beam placement marked the only times during which the mainlanes of I-35 were closed to traffic. After all beams were in position forming the bridge superstructure, the contractor placed reinforcement in the longitudinal and transverse closure strips and placed concrete, tying the bridge together. Stay-in-place forms were used in the closure strips. Since the forms prevented concrete from leaking onto the lanes below, I-35 was opened to traffic during the placement of the closure strip concrete. Grinding was permitted to a maximum depth of 1/2 in. in order to achieve final required grades, but the pretopped U-beams aligned so well in their final positions that no grinding was necessary. After the closure strips cured, the bridge was ready for traffic.


Beams were erected at night.

Conclusion

The preassembled prefabricated bridge system proved to be a successful alternative to traditional construction over high-traffic roadways. Although the preassembly did incur additional costs, at $86.06 psf compared to $62.00 psf for conventional prestressed concrete beam bridge construction, the direct cost of the bridges still proved economical. Indirectly, the time saved by motorists and commercial operators in the form of reduced construction-related delays further validated the increase in cost.


Pretopped U-beams were joined in the field with longitudinal and transverse closure placements.

With the successful construction of the Loop 340 bridges, TxDOT has not only developed a prefabricated bridge system appropriate for construction in some high-traffic areas, but has also found this system effective in mitigating damage to the local environment. As more of these bridges are commissioned along interstates and in rural areas, we look forward to continuing to provide unique solutions designed to minimize the impact of bridge construction to the motoring public.

Jamie Griffin, Engineering Assistant; Lloyd Wolf, Bridge Design Group Leader; Gregg Freeby, Bridge Design Group Leader; Michael Hyzak, Senior Bridge Design Engineer; David Hohmann, Design Section Director; and Randy Cox, Bridge Division Director, are all with the Texas Department of Transportation.

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

Aesthetically Pleasing Solution with Minimal Impact

Accelerated construction techniques and enhanced bridge aesthetics have long been touted as a means of reducing construction-related delays and improving the appearance of our local roadways. The Loop 340 bridges gracefully combine rapid construction techniques and striking architectural features to produce a set of bridges remarkable in both form and function. The aesthetics concept, developed by TxDOT engineers, incorporates sloped exterior columns, slender beams, and a short sloped overhang reflecting the slope of the exterior columns. A new open steel railing, used for the first time nationally on these bridges, was also developed to complement the bridge aesthetics. Large formliners to simulate limestone blocks provided the surface texture that completed the unique appearance of the substructure. This careful attention to aesthetic detail produced the graceful and dynamic style of the Loop 340 bridges and served as further evidence that a focus on function and economy does not exclude the addition of aesthetic features.

The preassembled superstructure and precast columns reduced time spent within the right-of-way, improved worker safety, and allowed for greater environmental controls. Since most construction activity occurred at the off-site casting yard, little construction waste was introduced into the environment surrounding the construction site. The contractor was better able to contain construction waste at the casting location than would have been possible in conventional on-site construction at a high-speed interstate highway, thereby preventing excessive dust and other waste from affecting the local community and interstate traffic.

The Loop 340 bridges have thus incorporated the elements of sustainability—they not only significantly diminished construction-related delays and the related impacts to the community, but have provided a series of attractive and distinctive bridges that are the subject of pride for the surrounding areas.

Aircraft Bridges Take Off

by Ted Bush, Kent Bormann, and Rob Turton, HDR Inc.

profile

TAXIWAY SIERRA UNDERPASS / SKY HARBOR AIRPORT, PHOENIX, ARIZONA

ENGINEER: HDR Inc.

CIVIL ENGINEER: Dibble Engineering, Phoenix, Ariz.

PRIME CONTRACTOR: Kiewit Western Co., Phoenix, Ariz.

AWARDS: 2007 American Public Works Association Project of the Year (Arizona); 2007 Southwest Contractor Project of the Year; 2007 Associated General Contractors Project of the Year (Arizona)

A five-span, cast-in-place, post-tensioned box girder bridge carried the taxiway across Sky Harbor Boulevard at the Sky Harbor International Airport. Photos: Richard Strange.

Taxiway at Sky Harbor International Airport in Phoenix shows how concrete designs can meet the growing need

Airport administrators are commissioning more bridges than ever before to handle airplane traffic, and this trend will continue. Airport bridge design requirements differ from highway and railroad designs due to their applications, geometries, and rules set out by the Federal Aviation Administration. But they also must meet the same goals as any bridge in providing a safe, long-lasting, and low-maintenance structure.

Site constraints are forcing airports to build runways at greater distances from terminals, and to shuttle planes over runway and taxiway bridges to access them. These same constraints also create challenges for bridge designs. Their geometry must accommodate the largest airplane type envisioned to use the structure, as defined by wingspan and tail height. A "safety area" that increases the width requirement is also desirable.

These designs are also governed by function. For example, impact loads are significantly higher for runways and taxiways than highways, and aircraft braking exerts substantial forces, which typically control lateral load for substructure design. Other non-gravity loads include the usual wind, thermal, and seismic considerations that are applied in accordance with AASHTO specifications.

Structural components have unique design considerations. For example, the deck design is more apt to be controlled by punching shear than flexure due to the heavy wheel loads. Additional considerations include provisions for edge curbs, to prevent aircraft from sliding off the bridge during icy or windy conditions, and fencing to prevent vehicles or pedestrians from gaining access.

Sky Harbor Reconstruction

An example of how these considerations are addressed in the field can be seen in the $35-million Taxiway Sierra Underpass reconstruction at Sky Harbor International Airport in Phoenix, Arizona. Airport administrators wanted to reconstruct the existing taxiway, including replacing the pavement and two single-span, reinforced concrete, rigid-frame structures.

Working with the City of Phoenix Aviation Department, designers established three key goals:

1. **Minimize interruptions to operations during construction.** Shutting down the existing taxiway would increase congestion on the other airside routes, and drilling operations for foundation construction and the erection of falsework would complicate landside access to the terminals.
2. **Create a design that was aesthetically compatible, cost-effective, and low-maintenance.** The nearby Taxiway Tango Underpass served as a standard, having been constructed with cast-in-place, post-tensioned concrete box girders. The bridge had experienced minimal service issues during the past 15 years.
3. **Eliminate the potential for conflict with future facilities.** Parking was

CAST-IN-PLACE, POST-TENSIONED CONCRETE BOX GIRDER / CITY OF PHOENIX AVIATION DEPARTMENT, OWNER

POST-TENSIONING AND REBAR INSTALLER: Paradise Rebar, Phoenix, Ariz.

POST-TENSIONING AND REBAR SUPPLIER: Consolidated Rebar Inc., Phoenix, Ariz.

CONCRETE SUPPLIERS: AZ Portland Cement, Phoenix, Ariz.; Salt River Materials Group, Phoenix, Ariz.; and Rinker Materials, Phoenix, Ariz.

BRIDGE DESCRIPTION: Five-span, cast-in-place, post-tensioned concrete box girder

STRUCTURAL COMPONENTS: Cast-in-place, five-span superstructure, pier bents, columns, drilled shaft foundations, and cantilevered abutments

BRIDGE CONSTRUCTION COST: $13 million

The structure was designed to support a gross aircraft weight of 1.5 million lb, plus a 30 percent impact factor. Photo: HDR Inc.

available beneath the Taxiway Tango Underpass, and the owners wanted the same revenue-generating option available for the Sierra project.

Three superstructure types were considered: a cast-in-place, post-tensioned concrete box girder to replicate the Taxiway Tango Underpass design; precast, prestressed concrete I-girders; and precast, prestressed concrete box girders. Steel girders were not considered due to the relatively high cost of steel in the area and the incompatibility with nearby concrete bridges and buildings.

Each option provided advantages, and they were all factored into the evaluation including cost, closure times, under-deck potential, constructibility, aesthetics, and serviceability. Ultimately, replicating the Taxiway Tango Underpass design was selected for the structure, which spans Sky Harbor Boulevard and provides three interior spans for future under-deck use.

The 406-ft-long, design-build project features five continuous spans of post-tensioned concrete box girders. The bridge was designed to be 214 ft wide to meet the safety area requirement for Group V aircraft and to support a gross aircraft weight of 1.5 million lb using the wheel configurations for a Boeing 747-400. A vertical force equal to 30 percent of the design aircraft's weight was added to the live load to account for impact, while a longitudinal braking force equal to 75 percent of the design aircraft weight was applied.

Conventional design techniques were used to distribute live loading across the bridge deck, and the 15-in.-thick deck slab was sized for punching shear and flexural requirements. Transverse flexural reinforcement in the girder was determined using various possible aircraft landing gear configurations. Drop beams were added at taxiway-lighting locations to effectively transfer loads to the adjacent girders.

3-D Modeling Verifies Design

The girder design was accomplished using traditional techniques accounting for the number of girder webs within the footprint of the landing gear. This distribution factor was verified by three-dimensional, finite-element modeling. The design aircraft was positioned transversely across the full bridge width to determine the extreme live-loading effects. A girder web spacing of 5 ft 11 in. and a total post-tensioning jacking force of 87,800 kips was required to support the bridge weight and design aircraft.

The substructure features four piers and two abutments, supported on deep-foundation cast-in-place drilled shafts. The columns at the outside pier lines are much wider than the interior pier lines to accommodate braking forces.

Nonintegral abutments were chosen due to the bridge's length. A 5-ft-thick stemwall and two rows of drilled shafts were used to accommodate the live-load surcharge from the approaching aircraft. Fortunately, as Phoenix is in a low-seismic region, seismic loads were not a significant consideration.

The approach slab at each end of the bridge required a thickness of 20 in. to meet flexural demands from aircraft loads. Anchor slabs also were provided between the taxiway pavement and the approach slabs.

Longitudinal and transverse construction joints were an important consideration, due to the continuous nature of the structural system and the sheer expanse of the girder. Considerable time was spent detailing the location of construction joints in the construction of the continuous structure. All bridge expansion and contraction movements were accommodated at expansion joints at the abutments. Expansion joints, with a 3-in. width, were also provided between the anchor slabs and approach slabs, and doweled construction joints between the anchor slabs and taxiway pavement accommodate any taxiway pavement movement.

Several additional constructibility issues were addressed during design. Heavy reinforcement requirements at the pier caps to column connections and abutment anchorages required special detailing to avoid congestion and ensure adequate concrete consolidation. Other

Cast-in-place drilled shafts, columns, and abutments were used for the substructure. Photo: HDR Inc.

construction considerations included airside and landside staging/phasing requirements, foundation construction, and requirements for sequencing, falsework construction, and post-tensioning operations.

Sequencing Was Critical

Removal of the existing bridge also had to be addressed. The same detour that was created to facilitate demolition was also used during falsework construction. Construction sequencing of the new bridge was planned to minimize obstacles for users and reduce detour time. In the first phase of work, drilled shafts for the deep foundations were constructed, after which all substructure elements, including abutments, abutment walls, and pier columns, were built.

Falsework was erected for the construction of girder soffit and web stems, with transverse joints provided to aid sequencing of the work. Crews first erected falsework for the two end spans of the bridge, which required openings

Deck concrete placement was carefully sequenced longitudinally and transversely. Photo: HDR Inc.

for maintenance of traffic on Sky Harbor Boulevard. This was accomplished by diverting traffic with a temporary detour through the infield. Upon completion, traffic was reverted to allow erection of falsework for the interior spans.

Deck concrete was placed in a patchwork sequence both longitudinally and transversely to maximize construction efficiency and account for staged construction efforts with respect to stress and camber.

The design of the Taxiway Sierra Underpass shows some of the unique considerations required for aircraft bridges, compared to those designed for highways and railroads. Factors that must be addressed include unusual design specifications, requirements for airside and landside geometry, and designing structural components to transfer large aircraft loads. These projects are becoming more commonplace, creating more opportunities for designers who understand the unique conditions they represent.

Early discussions with the owner and local officials so that all considerations are understood can ensure the proper type, size, and location for the bridge. Working as a team with the owner, contractor, and key suppliers will save time and cost while leading to a successful project.

Ted Bush, Structural Engineer; Kent Bormann, Senior Bridge Engineer; and Rob Turton, Vice President and National Technical Director for Bridges are all with HDR Inc.

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

CONCRETE CONNECTIONS

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

IN THIS ISSUE

http://trb.org/news/blurb_detail.asp?id=1373
NCHRP Report 480, *A Guide to Best Practices for Achieving Context-Sensitive Solutions* focuses on how state departments of transportation and other transportation agencies can incorporate context-sensitive solutions into transportation project development. The guide is applicable to the variety of projects that transportation agencies routinely encounter.

www.tfhrc.gov/structur/pubs/07024/Index.htm
This site provides a pdf version of the report titled "Flexural Capacity of Fire-Damaged Prestressed Concrete Box Beams."

www.dot.state.co.us/marooncreek/
This Colorado Department of Transportation website contains additional information about the history, design, and environment of the Maroon Creek Bridge replacement.

www.fhwa.dot.gov/environment/ecosystems/
This website explains FHWA's Exemplary Ecosystem Initiatives. The ecosystem approach looks at the present and *beyond*. It envisions future conditions under which ecological, economic, and social factors are integrated. The website contains details of the 43 initiatives that were designated from 2002 through 2006.

http://azdot.gov/Highways/Privately_Funded_TI.asp
The Arizona Department of Transportation (ADOT) has established a handbook for the private development community as a uniform protocol for requesting new traffic interchanges (TI) or modifications to existing interchanges. Links are provided to the Requirements Handbook and other ADOT Sections included in the Privately Funded Traffic Interchange Process.

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

Bridge Research

http://ntlsearch.bts.gov/tris/index.do
The National Research Information System provides a bibliographic database of over 640,000 records of published research for all modes of disciplines and transportation.

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

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

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

http://trb.org/news/blurb_detail.asp?id=7443
NCHRP Report 579, *Application of LRFD Bridge Design Specifications to High-Strength Structural Concrete: Shear Provisions*, examines research performed to extend the applicability of shear design provisions for reinforced and prestressed concrete structures in the AASHTO LRFD Bridge Design Specifications to concrete compressive strengths greater than 10 ksi.

http://trb.org/news/blurb_detail.asp?id=8375
NCHRP Report 595, *Application of the LRFD Bridge Design Specifications to High-Strength Structural Concrete: Flexural and Compression Provisions*, explores recommended revisions to the AASHTO LRFD Bridge Design Specifications to extend the applicability of the flexural and compression provisions for reinforced and prestressed concrete to concrete compressive strengths greater than 10 ksi.

Stiffer Bridges Result in Slower Bridge Deck DETERIORATION

by James M. Barker

For many years, bridge design engineers have been discussing and debating the benefits of stiff bridge superstructures. The issue involves the use of stiffer longitudinal girders relative to the cracking of bridge decks. The presence of cracks leads to accelerated deterioration caused by reinforcement corrosion from water and corrosive salts entering the cracks. A number of studies and research reports have been completed since the early 1990s. This article provides an update on some of the more recent studies.

The majority of this discussion is related to transverse cracks in bridge decks mostly near pier locations on continuous bridges. These cracks do not surprise any design engineer because, after all, the design theories assume that the slab is cracked when computing the areas of reinforcement required to carry the design loads.

Transverse cracks are also possible in longitudinal positive moment areas near midspans of bridges. This can be particularly true for older bridges where short end spans may be continuous with longer second and third spans. These cracks can be caused by permit loads or overloads, which may exceed the slab compression caused by the dead loads and provide sufficient tension to transversely crack the slabs. There is not usually sufficient residual compression in the slab due to dead load to cause the cracks to close afterwards. Rational thinking indicates that a stiffer heavier superstructure would result in larger dead load stresses and thus reduce the creation of transverse slab cracks in positive moment areas of the bridge spans due to overloads. The Portland Cement Association (PCA) Report SN 2936 titled *"Effect of Superstructure Properties on Concrete Bridge Deck Deterioration"* by Sanya Mackela Johnson, includes a discussion of the relationship of girder stiffness and deck cracking in the longitudinal direction parallel to the support girders. There seems to be a similar correspondence in the transverse direction as in the longitudinal direction due to load differentials and deformations associated with the transverse distribution of wheel loads.

Transverse Cracks due to Longitudinal Loads

Investigations have delivered a substantial amount of evidence that stiffer bridges exhibit less transverse cracking of bridge decks even where we expect to find those cracks. The work by Johnson is one of the latest studies that confirms this thinking.

Several states have invested in the belief that stiff bridges are longer-lasting bridges by the establishment of policies making every bridge deck composite with the longitudinal support girders no matter what material is used to fabricate the girders. Some states have even adopted a policy that composite action with the use of shear studs or extended reinforcement stirrups should be carried across the supports of continuous structures as well as in positive moment midspan regions. While most designers still assume the top slab is cracked over the pier supports, they do include the reinforcement in the moment of inertia computations thus resulting in a stiffer bridge in the longitudinal direction.

Deck Slab Cracks and Vibrations

The New York State Department of Transportation (NYSDOT) study titled *"A Qualitative Study of Correlations between Bridge Vibration and Bridge Deck Cracking"* by Sreenivas Alampalli, et al. and published at the TRB Annual Meeting, Washington, D.C., 2002, was also summarized by Johnson in the PCA report.

In the NYSDOT work, the cracking of the bridge deck was found to be related to the dynamic deflection component exhibited as bridge superstructures vibrate during the passage of live loads. A person standing on a bridge during the passage of a loaded concrete truck or semi-trailer can certainly feel the difference in vibrations that occur on a stiff bridge versus those occurring on a flexible bridge. The resulting oscillations can also be felt after the passage of the loads. The New York authors make the following statement: "In time, such a phenomenon can cause cracking or make the existing cracks, especially any transverse cracks, deeper and wider."

The NYSDOT report includes the following in their conclusions:

Vibration severity is the most significant parameter influencing bridge deck cracking. Higher severity equates to higher deck cracking. Decks with noticeable vibration cracked most severely.

Longer spans exhibit more deck cracking than shorter spans.

Bridges with noticeable vibration combined with longer span lengths exhibited significant bridge deck cracking.

NCHRP Report 297 reported on tests in the United Kingdom that showed that the most influential factor on the risk of cracking caused by traffic-induced dynamic deflection reversals is the amplitude of the deflection, not the frequency. The maximum dynamic deflection generally increased as the maximum static deflection increased.

Thus it seems that vibrations can play a very important role in bridge deck cracking. Stiffer bridges vibrate to smaller deflection amplitudes and exhibit less deck cracking.

FHWA'S "GREEN" INITIATIVES

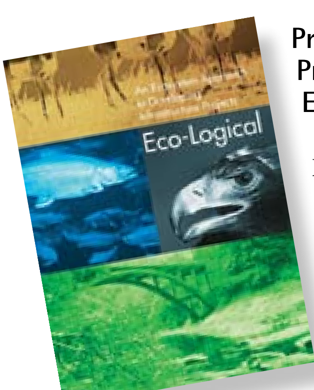
by M. Myint Lwin

SUSTAINABILITY IS...

In the Winter 2008 Edition of *ASPIRE*,™ we read many exciting articles about projects and the application of sustainability concepts in the planning, design, construction, operation, and preservation of highway bridges. The FHWA realizes the importance of developing and implementing sustainable solutions through working together at the federal, state, and local levels. Communities, industry, academia, and many others are in the chain of sustainable solutions for a sustainable future.

In this issue of *ASPIRE*, we continue to read about sustainability and learn about ideas and practices in applying the concepts of "Green Highways/Bridges" to enhance the natural and built environment.

Protecting and Preserving the Environment



In 2006, the FHWA published an environmental guide titled *"Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects"* to help improve the understanding of how infrastructure impacts habitat and ecosystems. This multi-agency initiative describes a vision for integrating infrastructure development and ecosystem conservation processes with economic, environmental, and social needs and objectives. An ecosystem approach is a method for sustaining or restoring ecological systems and their functions and values. It is goal driven and is based on a collaboratively developed vision of desired future conditions that integrate ecological, economic, and social factors.

The FHWA is committed to protecting and preserving the environment through stewardship and timely reviews. In recent years, the FHWA and its partners have made substantial contributions to the environment and to the communities, through planning and programs that support wetland banking, habitat restoration, historic preservation, air quality improvements, bicycle and pedestrian facilities, context-sensitive solutions, wildlife crossings, public and tribal government involvement, and others.

The FHWA is working closely with partners to take proactive measures in moving from simply mitigating environmental impacts to actively contributing to environmental enhancements.

Technology Deployment Programs

The FHWA's technology deployment programs promote initiatives with social, economical, and ecological benefits, including:

- Use of high performance materials in pavement and bridge construction to increase durability, minimize maintenance, and reduce cost;
- Use of prefabricated systems in pavement and bridge construction to accelerate construction, improve work-zone safety, and reduce disruption to the public. Fabrication of the systems is done in controlled environments on or off the jobsite, resulting in improved quality and less impact on the environment;
- Use of self-propelled modular transporters (SPMT) in accelerated bridge construction for removal and replacement of heavy bridge components in record time; and
- Use of span-by-span, balanced cantilever, and incremental launching techniques in bridge construction to protect the environment by minimizing the needs for construction equipment or work on the ground or wetlands below the bridges.

Recycled Materials in Highway Construction

The FHWA promotes and supports the use of recycled materials in highway construction. Through the Recycled Materials Resource Center at the University of New Hampshire, the FHWA is making changes in the extent of use of several industrial by-product materials in highway construction. The FHWA also has an active Recycling Team that works with the states, the Environmental Protection Agency, and industry to implement recycling technology.

SAFETEA-LU directs the reuse of debris from bridge demolitions in shore erosion control or stabilization, ecosystem restoration, and marine habitat creation.

FHWA Exemplary Ecosystem Initiatives

In 2002, the FHWA identified ecosystem conservation as one of three performance objectives under the Agency's "Vital Few" goal of Environmental Streamlining and Stewardship. To demonstrate its commitment to this goal, the FHWA agreed to identify a minimum of 30 exemplary ecosystem initiatives in at least 20 states or Federal Lands Highway Divisions by September 2007.

FHWA developed the following specific criteria for selecting the exemplary ecosystem initiatives:

1. An exemplary ecosystem initiative helps sustain or restore natural systems and their functions and values.
2. An exemplary ecosystem initiative is developed within a landscape context.
3. An exemplary ecosystem initiative uses partnering and collaborative approaches to advance common goals.
4. An exemplary ecosystem initiative uses the best available science in ecosystem and habitat conservation.

Il 29 – Oak and hickory woodland on right. Floodplain forest wetland on left. Photo: IDOT.

5. An exemplary ecosystem initiative provides clear examples of innovative environmental solutions by transportation agencies and achieves high standards in the environmental process.
6. An exemplary ecosystem initiative achieves high-quality results.
7. An exemplary ecosystem initiative is recognized by environmental interests as being particularly valuable or noteworthy.

As of 2006, the FHWA had identified more than 40 exemplary ecosystem initiatives in over 30 states. More exemplary ecosystem initiatives are expected to be designated in 2007 and beyond. Examples of these initiatives are described below. See Concrete Connections on page 52 for the website with the locations and details of these initiatives.

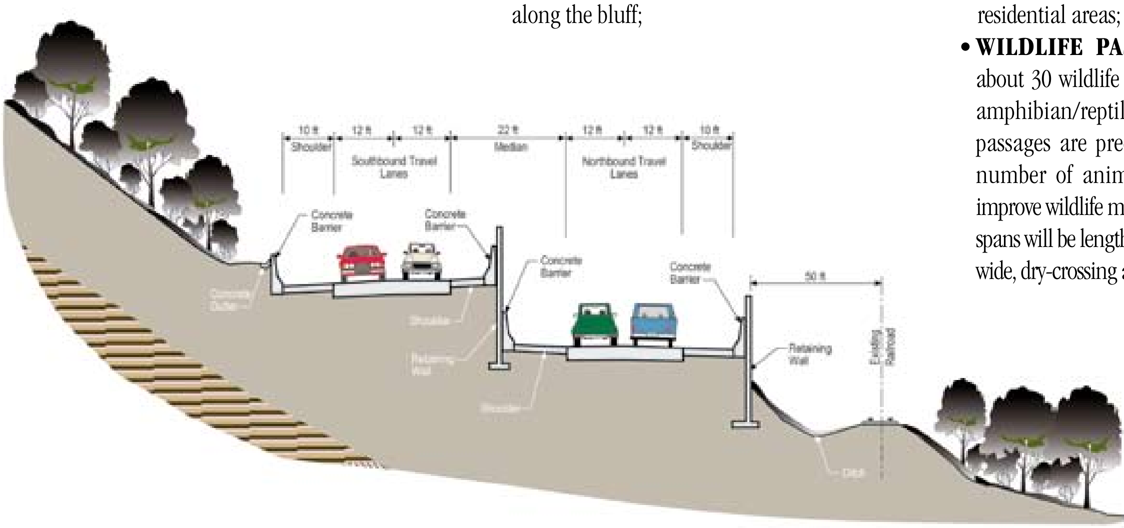
California—South Bay Expressway Mitigation Program

The South Bay Expressway, State Route 125 South in San Diego County, is a 10.8-mile-long alignment that crosses through sensitive habitat for threatened and endangered species, known historic and cultural sites, community park areas, and established residential communities. The $20-million mitigation program includes everything from restoring habitat, mitigating noise and air pollution, protecting water quality, and recovering cultural resource data.

Illinois—Route 29 Improvements to Protect Ecosystems

This is a 35-mile-long corridor that runs from State Route 6 near Mossville in Peoria County to I-180 in Bureau County. The highway lies between bluffs and blufftop farmlands to the west and the Illinois River to the east. Two-lane Route 29 is being studied for expansion to four lanes. The Illinois Department of Transportation (IDOT) partnered with the Illinois Department of National Resources (IDNR), U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Department of the Interior, and the FHWA to develop minimization and mitigation strategies, such as:

- **SPLIT PROFILE ROADWAY.** Three miles of Route 29 have been designed as a "split profile" roadway, meaning that the southbound lanes will be 3 to 17 ft higher than the northbound lanes, avoiding impacts to upland forests and natural areas along the bluff;
- **SPLIT INTERCHANGE DESIGN.** IDOT uses a "split interchange" design for a new Route 27-Route 29 interchange within the village of Sparland. A "split interchange" design divides an interchange in half. Half of the interchange will be located at the southern end of Sparland, and the other half at the northern end. Separating the ramps by nearly a mile is expected to reduce impacts to Sparland, nearby wetlands, an IDNR property, flood-buyout properties, and residential areas; and
- **WILDLIFE PASSAGES.** IDOT proposes about 30 wildlife passages for mammal and amphibian/reptiles roadkill hot spots. The passages are predicted to reduce the high number of animal-vehicle collisions and improve wildlife movement. Additionally, bridge spans will be lengthened to provide a sufficiently wide, dry-crossing area for large animals.



Rendering depicts a "split Profile" roadway. Rendering: CH2M Hill.

The New Hampshire Department of Transportation created a 320-acre Pine Road Wetlands Mitigation Site. Photos: Normandeau Associates Inc.

New Hampshire—Route 101 Ecological Protection and Enhancement Feature

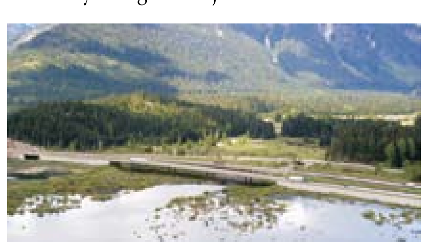
This initiative showcases a multi-faceted mitigation plan to improve 17.6 miles of Route 101 from Epping to Hampton. The governor of New Hampshire appointed a Task Force to address the concerns of local residents on the potential impact on their homes, businesses, and historic properties, and the desire of the environmentalists to avoid impacts on local wetlands and other wildlife habitat. The Task Force guided the project development to a mitigation strategy that focused on a broad "landscape approach" to fit the local ecosystem and resource management needs. Some of the ecosystem solutions are:

- **OUTDOOR LABORATORY.** The New Hampshire Department of Transportation created a 320-acre Pine Road Wetlands Mitigation Site. Students from high schools and colleges use this wetland site to study water quality and other wetland functions;
- **REPLACING CULVERTS WITH BRIDGES.** Existing culverts on the Piscassic River were replaced by a twin-span bridge to provide improved hydraulic performance and a better corridor for wildlife movements across the highway; and
- **LENGTHENING A BRIDGE.** A bridge over the Squamscott River was lengthened by 560 ft to restore 4 acres of salt marsh.

Washington—I-90 Snoqualmie Pass East Project

Interstate 90 is the main east-west route across the Cascades into Seattle. The Snoqualmie Pass—a 15-mile-long section of the highway—is infamous for its avalanche hazards, its dangerous curves, its deteriorating pavement, and increasing traffic. The project crosses a critical north-south corridor for elk, lynx, gray wolf, grizzly bear, and wolverine. The project also cuts through areas of habitat connecting much larger habitat areas along the mountain range. The Washington State Department of Transportation (WSDOT) partnered with the U.S. Forest Service, state, and federal resource agencies in working together with the Cascades Conservation Partnership, the Alpine Lakes Protection Society, the Mountains-to-Sound Greenway, and the Kongsberger Ski Club to provide ecological solutions to the I-90 improvements. Some of the solutions are

- **WILDLIFE DISTRIBUTION.** U.S. Forest Service researchers used geographic information systems technology, snow-tracking, and other techniques to learn the movements of animals to understand wildlife distribution along and near the highway;
- **CONNECTIVITY BRIDGES.** A working group of biologists and hydrologists identified where and how connectivity bridges should be built along I-90. The connectivity bridges should provide wide and open space for large mammals to cross; and
- **STREAM CROSSINGS.** The working group recommended that bridges be built primarily at stream crossings, since they represent locations where multiple project and ecosystem needs converge and therefore offer an opportunity for synergistic solutions. The stream-crossing bridges should be designed to accommodate aquatic, riparian, and terrestrial habitat features. The crossings should be expansive enough for large mammals to utilize and built at key linkages of major creeks and wetlands.



Washington—I-90 Snoqualmie Pass East Project, stream crossing. Photo: WSDOT.

The common threads in the exemplary ecosystem initiatives are reducing habitat fragmentation, removing barriers to animal movement, encouraging the development of more sustainable mitigation sites, stimulating early ecosystem planning, and fostering ecosystem-based studies and solutions in working closely with partners, stakeholders, and the communities.

Closing Remarks

SAFETEA-LU, Section 6002 Efficient Environmental Reviews for Project Decisionmaking, has integrated environmental planning factors into statewide and metropolitan planning processes by requiring that transportation agencies coordinate with resource agencies and public stakeholders as early as possible in the environmental review process. These efforts are expected to lead to more informed decision-making in transportation planning; proactive integration of natural resource considerations with transportation needs; and identification and prioritization of opportunities with the greatest potential to mitigate the possibly harmful environmental impacts of proposed transportation projects.

The FHWA has been and continues to be a leading partner in the Green Highways Partnership (GHP), which is a voluntary, public/private initiative dedicated to the innovative concepts and approaches to "Green Transportation Infrastructure" through community partnering, environmental stewardship, and transportation network improvements in safety and functionality. The FHWA has contributed significant resources towards the partnership, including staff time, monetary commitments, and technological expertise. The environment is everybody's concern, and at FHWA, it assumes a particular importance—one that touches virtually every aspect of highway planning, design, construction, and preservation.

In the next two issues of *ASPIRE*, we will continue to explore the social, economic, and ecological benefits of sustainability in planning, design, construction, preservation, and renewal of the highway infrastructure. I invite readers to share ideas and suggestions, facts and figures, case studies, and photographs on these topics by writing to me at myint.lwin@dot.gov.

U.S. Department of Transportation
Federal Highway Administration

Silica Fume Association

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

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

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

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

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

STATE

Concrete Bridges in

Arizona

by Jean A. Nehme and Tina Sisley, Arizona Department of Transportation

Loop 202 over Indian Bend Wash, Tempe. (Seven-span prestressed concrete I-girders). All photos: Arizona Department of Transportation.

Historically, concrete has been the material of choice for bridge construction in Arizona. Raw materials needed to produce concrete are readily available within the state. Prestressed I-girder and post-tensioned box girder bridges have been the most commonly constructed bridge types on Arizona's highways for the past several decades, especially in urban settings. Examples of early precast I-girder bridges dating to the 1950s can still be found throughout the state. Over time, Arizona bridge construction has followed the industry trends to use larger precast, prestressed I-girder shapes that can span longer distances, thus eliminating costly substructure units and providing plausible solutions to complex bridge sites.

Historical Overview

The use of precast concrete girders began in Arizona in the late 1950s. Precast girders of various types can be found on all of Arizona's interstate and state highway routes. The earlier types of precast girders consisted of small I-girder shapes, voided slabs, and box beams. The AASHTO Type II girder appears to be the primary precast girder used in many bridges in the original construction of I-10 and I-17 in the Phoenix and Tucson areas. For economical reasons, similar span and girder arrangements were used as frequently as possible. Voided

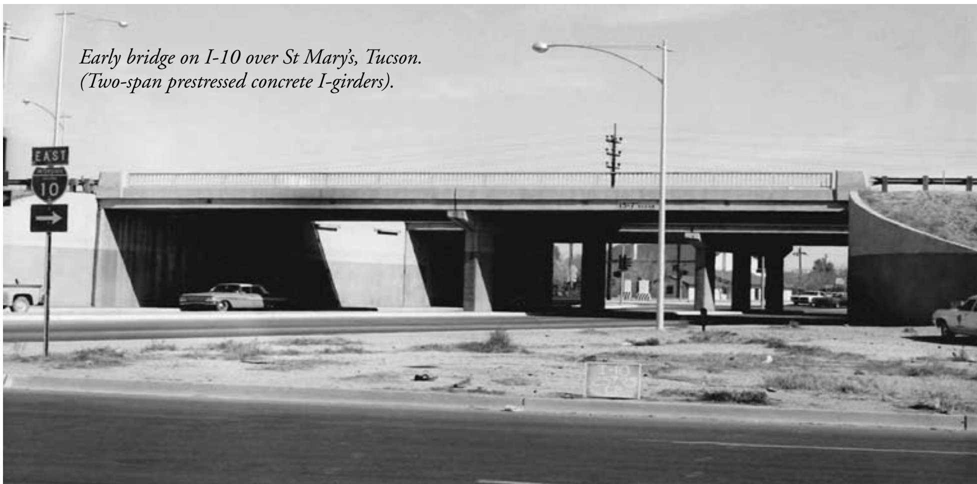
Early bridge over I-17, Central Phoenix. (Two-span prestressed concrete I-girders).

slabs and box beams with asphaltic concrete overlays were used on the I-40 and various state highways. Construction plans for these girders often allowed the contractor a choice between prestressing methods: either pretensioned or post-tensioned. In most instances, as-built drawings did not document which method was used. High profile vehicle collisions with such girders, exposing ducts or strands, offered some clues to the mystery.

Current Practice

Today, the more commonly used precast girders are those that can span 90 to 135 ft, such as the AASHTO Type IV, V, and VI girders.

Loop 202 and Interstate 10 Interchange, Chandler. (Post-tensioned box girders).



Early bridge on I-10 over St Mary's, Tucson. (Two-span prestressed concrete I-girders).

Arizona uses modified versions of the Type V and VI for most bridges. The modified girder type has flange and web widths that are 2 in. narrower than the regular type to reduce the amount of dead load transferred to the substructure. Type II and III girders are no longer being used on new bridge construction due to their span limitations. Their use has declined so much that Arizona fabricators no longer have the formwork to make them. Recently, a contractor replacing a Type II girder damaged by a high vehicle collision had to use an Idaho supplier.

Damage assessment at Tangerine over I-10, Tucson. (Two-span prestressed concrete I-girders).

Another modified girder type used in the past and in several recent projects is what we term a Super Type VI girder. The depth of the AASHTO Type VI girder is increased by 6 in. The Super Type VI girder was first used on the mile long Salt River Bridge carrying the Loop 202 freeway within the city of Tempe. The eastbound and westbound bridges consist of 34 spans with one span of Type V girders, eight spans of standard Type VI girders and 23 spans of the Super Type VI girders.

Loop 202 over Alma School, Mesa. (Two-span prestressed concrete I-girders).

Collision Damage

The strength and resilience of precast concrete girders have been tested on many occasions when girders have been damaged by over-height vehicles. In most cases, the damaged girders have been easily repaired with epoxy injection and high strength grout patching. Only in few instances were the whole girders replaced.

Phoenix metropolitan area. (Relief on exterior girder).

Expansion of the Urban Freeway System

During the last two decades, the Arizona Department of Transportation (ADOT) has been faced with the challenge of expanding the freeway system to accommodate the increased volume of traffic generated by the growing urban metropolises of Phoenix and Tucson. This expansion is being accomplished by widening existing freeways and the construction of additional freeways.

In the heart of Phoenix on I-17, ADOT has replaced many of the first generation AASHTO Type II girder bridges, which carry local streets over the interstate, with shallower precast, prestressed adjacent box beam bridges to accommodate longer spans and to improve vertical clearances over the interstate.

In the Tucson area, I-10 is currently being widened. Many of the bridges use AASHTO Type II girders and are being widened in kind with Type II girders shipped from out of state.

Future Outlook and Challenges

Aesthetics considerations are becoming increasingly important in the construction of transportation facilities. Bridges constitute some of the most visible elements of the transportation infrastructure. Precast, prestressed concrete bridge elements can be constructed with reliefs on the exterior girder or box elevations to enhance the visual appearance of the structure. ADOT has implemented these methods on many urban projects.

We also realize that new shapes and some innovative bridge design ideas will have to be implemented in order to meet some of the future challenges that we are facing. We are experiencing increased demand for longer spans, shorter construction durations, and reduction in construction-caused traffic delays. Use of precast member elements for bridge construction in other than the superstructure such as in column cap beams and abutments could solve some of these issues. Precast, prestressed concrete is versatile, durable, and enables shorter construction durations.

Due to a recent increase in development throughout Arizona, bridges are being proposed and funded by private developers. In order to streamline this process, ADOT has developed an on-line manual. (See *Concrete Connections* on page 52 for website address.) This includes a typical footprint for urban traffic interchange bridges that incorporates future widening criteria for both the highway and the cross street. This footprint consists of a two-span bridge with span lengths of 135 ft, which could be achieved through the use of AASHTO Type VI girders. Longer spans would be required in case of a skew to the bridge.

In the Phoenix metro area, many of the freeways that were built within the last two decades are already being widened. In many cases, these freeways were originally constructed prior to the land being developed around them. This afforded us the luxury of building on new alignments without being concerned about traffic control. Common bridge types were cast-in-place post-tensioned box girders. However, widening of these existing roadways is presenting many challenges. We are faced with a wide range of issues, which include minimizing traffic impacts during construction, constructing over traffic, maintaining minimum vertical clearances, site restrictions due to tight right-of-way, various environmental issues, and multiple requests

Wild Horse Pass over I-10, south of Phoenix. (Two-span prestressed concrete I-girders).

from the public and the affected municipalities.

Nowadays, Arizona bridge designers are looking at new solutions to conquer these challenges. A current project involving the widening of 10 miles of urban freeway, including 20 post-tensioned box girder bridges and three precast AASHTO girder bridges, is under development. Four of the box girder bridges span over single point interchanges, one with a single span of 250 ft. A combination of precast, prestressed girders; precast, post-tensioned spliced girders; and several new precast shapes such as tub girders and trapezoidal box beams are being considered. While the tub and trapezoidal box beam girder shapes have been used in other states, they have not been developed in Arizona partly due to the startup cost involved with their development.

Jean A. Nehme is State Bridge Engineer and Tina Sisley is Bridge Design Leader with the Arizona Department of Transportation.

For more information on Arizona's bridges, visit www.azdot.gov/highways/bridge/index.asp.

Camelback over I-17, central Phoenix. (Two-span prestressed concrete I-girders).

Environmental Constraints

Arizona highways traverse a variety of terrains including flat desert, rolling hills, and deep canyons. Environmental concerns such as minimizing the impact to unique or impaired waterways, minimizing disturbances of sensitive sites, and avoiding archeological features create many construction challenges. Precast concrete elements can minimize the footprint of the bridge. For waterway crossings, precast members eliminate the need for falsework during construction. This reduces the environmental impacts and minimizes the risk posed by flash floods.

A recent project to construct a 7.5-mile-long segment of the new Route 188 connecting the city of Globe with the Roosevelt Lake recreational area northeast of Phoenix contained six precast concrete girder bridges. Some bridges were needed to provide wide open areas beneath the roadway for wildlife crossings within the Tonto National Forest and others were built to span waterways. Precast girder types ranging from AASHTO Type IV to Type VI provided the means to span the varying terrain of the new roadway alignment. The use of precast, prestressed concrete girders minimized site disturbance, eliminated the need for falsework construction in washes prone to unpredictable flooding, and reduced the construction time. This project won the ARTBA 2006 Globe Award for Environmental Excellence.

State Route 188 over Apprentice Wash, Gila County. (Three-span prestressed concrete I-girders).

Expanded Shale, Clay, and Slate Institute

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

Lightweight aggregate concrete has been used successfully in the rehabilitation of many bridges, including such well known bridges as the Brooklyn Bridge (N.Y.), the San Francisco-Oakland Bay Bridge (Calif.), the Woodrow Wilson Bridge (D.C.), the Louis and Clark Bridge (Wash. and Ore.), the Whitehurst Freeway (D.C.), the Chesapeake Bay Bridges (Md.), the Cape Cod Canal Bridges (Mass.), and the Coleman Bridge (Va.).

Using lightweight concrete for bridge rehabilitation can provide the following benefits:

- Wider decks with little or no modification of the existing structure;
- Reduced deck weight to improve the load rating on an existing structure;
- Reduced weight of precast elements for hauling and installation; and
- Enhanced durability.

For more information on lightweight concrete, including a listing of ESCSI members and available publications, please visit www.escsi.org. The members of ESCSI look forward to assisting owners, designers, and concrete producers in using lightweight concrete for bridges.

Annual bridge projects are fairly standard, except for occasional standouts

Thinking BIG in Boone County, Iowa

by Robert Kieffer, Boone County, Iowa

Boone County typically constructs one bridge per year based on needs developed from our master map, which breaks down structures by posted weights, number of lanes, traffic flow, and other factors. Our key challenge is that, as a rural county, we have a variety of roads that aren't paved, which are used by farmers with heavy equipment. We also have the Des Moines River running through the county, which requires more complex bridge designs compared to a structure over a creek or stream.

Most of the projects that we build consist of reinforced concrete slabs or precast, prestressed concrete beams with a cast-in-place concrete deck. We're in a pretty good area for doing those types of designs, with a number of bridge contractors and high-quality precasters within a 100-mile distance of our county. Concrete is an excellent material to work with, because it requires virtually no maintenance over the years.

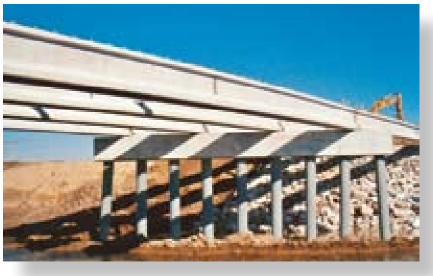
We typically use standard Iowa Department of Transportation bridge designs. We are pleased that the designs are being updated to provide more flexibility and reflect concrete's versatility. For instance, concrete slab beams previously could be extended up to span lengths of 125 ft, but that has been now lengthened to 150 ft. Designs used to be divided into 12.5-ft-span length increments, but now they are provided in 10-ft increments. The changes provide more options and help us create greater span lengths.

The changes are particularly significant for bridges over water, because the slab bridges require less clearance than concrete beam bridges. Raising a slab bridge so it is above the design high-water elevation requires less earth work and material costs, which creates savings—and savings are critical when funding is restricted.

Occasionally we have special projects such as a 700-ft-long, five-span precast, prestressed concrete beam bridge across the Des Moines River. This structure was constructed with beams ranging in span length from 130 to 140 ft that were specially designed for the project.

These unusual projects teach us a great deal about using materials to their fullest. That, in turn, helps us to design the more standard bridges that we deal with every year.

Robert Kieffer is County Engineer, Boone County, Iowa.



The Mackey Bridge in Boone, Iowa, was designed with precast concrete components as a feasibility project to determine how construction could be accelerated. Photos: Iowa DOT.

Accelerated Bridge Construction

Not all of the county's bridges utilize standard designs. In 2006, the county worked with the Bridge Engineering Center at Iowa State University in nearby Ames and the Iowa Department of Transportation to determine the feasibility of using precast concrete components to accelerate bridge construction. Through the Federal Highway Administration Innovative Bridge Research and Construction Program, 120th Street Bridge over Squaw Creek was constructed using several different precast, high-performance concrete elements. The result was a 152-ft-long, three-span bridge featuring precast concrete abutment footings, precast pier caps, and precast full-depth transversely pretensioned and longitudinally post-tensioned, 8-in.-thick deck panels. Standard 32-in.-deep precast, prestressed concrete I-beams were used, with four (rather than the standard five) beams per span. The Mackey Bridge won the award as Best Owner-Designed Bridge in the Precast/Prestressed Concrete Institute's Design Awards Competition for 2007.

Information learned from the project about designing completely with precast concrete elements will benefit future projects especially in the areas of scheduling and staging. We believe that another such design would move even faster due to the steep learning curve we experienced.

EDITOR'S NOTE

If your county has a high percentage of concrete bridges or some interesting and innovative concrete bridges and would like to be featured in ASPIRE,™ please let us know at info@aspirebridge.org.

NRMCA

National Ready Mixed Concrete Association

The National Ready Mixed Concrete Association is sponsoring the Third Annual *Concrete Technology Forum: Focus on Sustainable Development*. The symposium will bring researchers and practitioners together to discuss the latest advances, technical knowledge, continuing research, tools, and solutions for concrete and sustainable development.

Over 50 technical sessions on state-of-the-art developments, new construction techniques, and product formulations that optimize environmental performance of concrete construction will be presented including:

- Pervious Concrete Systems;
- Concrete's Impact on Urban Heat Islands;
- The Carbon Footprint of Concrete;
- Sustainable Development Initiatives; and
- Optimizing Recycled Content.

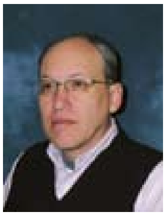
A product expo featuring companies that offer products and services for sustainable development will be open during the conference. Attendees will earn valuable professional development hours (PDHs) and will receive a copy of the conference proceedings.

NRMCA, based in Silver Spring, Md., represents the producers of ready mixed concrete and the companies that provide materials, equipment, and support to the industry. It conducts education, training, promotion, research, engineering, safety, environmental, technological, lobbying, and regulatory programs.

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

Safety and the LRFD Specifications

by Dr. Dennis R. Mertz



With the collapse of the I-35W Bridge in Minneapolis, bridge safety is a timely subject of discussion. A review of the level of safety inherent in our patrimony of highway bridges is in order.

For over 50 years, beginning with the AASHTO *Standard Specifications for Highway Bridges*, Allowable Stress Design (ASD) was the design methodology employed. The ASD methodology uses a factor of safety (FS) as a multiplier on load to set the required resistance as shown in Equation 1:

$$R \geq (FS) \times Q \qquad (1)$$

where R is the resistance and Q is the load or force effect. The factor of safety varies for different loads and materials. The factors of safety were chosen subjectively by the code writers, but history proved that highway bridges designed to ASD are inherently safe. The question is, how safe?

With the introduction of Load Factor Design (LFD) in the 1960s, the varying uncertainties of different load components were acknowledged. The design equation is similar to the LRFD equation but with load and resistance factors chosen through comparison with bridges designed using ASD. Again, the level of safety is unknown, but bridges apparently are safe enough as failures are very few.

During the late 1970s, the theory of structural reliability evolved into a useable highway bridge design methodology with the development of the Ontario Highway Bridge Design Code. AASHTO followed in the late 1980s with the development of the *LRFD Bridge Design Specifications*, eventually published in 1994. For the first time, a rational quantification of safety was available. The questions now become: Do we have all of the data required to determine safety, and if so, how safe is safe?

To develop an LRFD-format specification, exemplified by Equation 2, where a deterministic approach is made probabilistic through the application of carefully chosen load and resistance factors, a target level of safety is necessary to define the values in the LRFD equation:

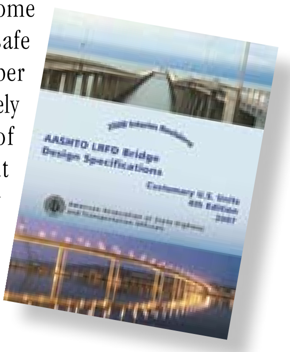
$$\sum_i \gamma_i Q_i \leq \phi R_n \qquad (2)$$

where γ and ϕ represent carefully selected load and resistance factors to achieve a target level of safety. Structural reliability provides the tools to select the factors' required values to reach a target level of safety. But, what level of safety? Safety against failure of a member, such as can easily be produced in a laboratory, or safety against failure of the entire bridge system?

Much data exist for the resistance of individual members at failure (in the terminology of LRFD; the nominal resistance); little data exist for failures of whole bridges. The calibration of the *LRFD Specifications* is based upon member resistance, but individual members do not fail in a true system. Consider a multi-girder bridge: as one girder softens due to approaching ductile failure, and a sufficient load path to the adjacent girders exists (and the concrete deck can be such a load path), the load redistributes to the other girders from the softening girder. Before, the complete ductile failure of the one girder, the other girders begin to help carry the load shed from it. Thus, the target level of safety inherent in the *LRFD Specifications* with a probability of failure of 2 in 10,000 (where the reliability index $\beta = 3.5$) for member failure (introduced in this column in the Winter 2007 issue) is much lower for whole system behavior for typical ductile designs. So depending upon the degree of system behavior, the inherent probability of failure of LRFD designs is lower than 2 in 10,000.

The final question with regard to safety and the *LRFD Specifications* is, why 2 in 10,000 as a target failure rate? This question was answered during the development of the first edition of the *LRFD Specifications*. A sample of bridges designed using the LFD methodology of the *Standard Specifications* was analyzed probabilistically to ascertain their inherent probability of member failure. The approximate average failure rate associated with bridges designed using LFD was about 2 in 10,000. Thus, this member failure rate was chosen as the target for the calibration of the load and resistance factors of the *LRFD Specifications*. Some existing bridges (short span bridges) appear to have inherent member failure rates as high as 6 in 100 ($\beta = 1.5$), yet these bridges are not considered unsafe. For load rating, bridges are rated at the operating level in the Load and Resistance Factor Rating (LRFR) methodology at a failure rate of 6 in 1,000 ($\beta = 2.5$).

All of the member failure rates used to calibrate our current design and rating specifications are based upon comparisons with past practice—a practice based upon subjectively chosen factors of safety. Our bridges have proven safe over the last 75 years of the AASHTO specifications, but the question remains, how safe is safe enough? With the *LRFD Specifications*, our nation's new bridges have become more uniformly safe in terms of member failure and extremely safe in terms of system failure, but the level of safety is still relatively subjective.



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In our industry, the right mix of people, products and service is essential. This philosophy is the blueprint we used to build our business nearly 100 years ago, and it's how we continue to help our precast/prestressed customers produce the best concrete in the market. Our top-notch experts are armed with the most innovative admixture technology, technical proficiency, and knowledge of construction challenges to help you navigate your way to success.
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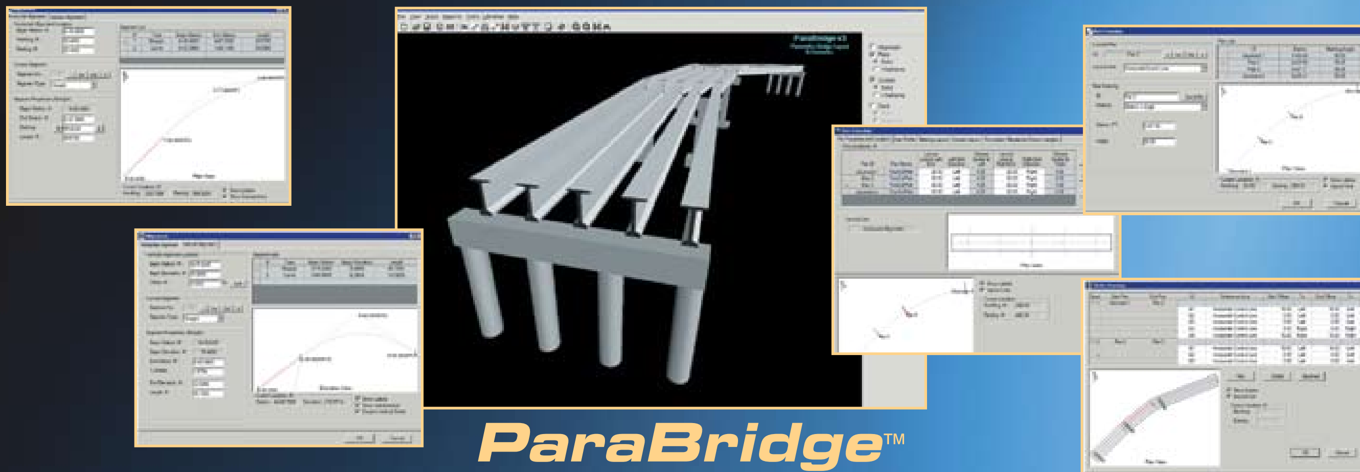


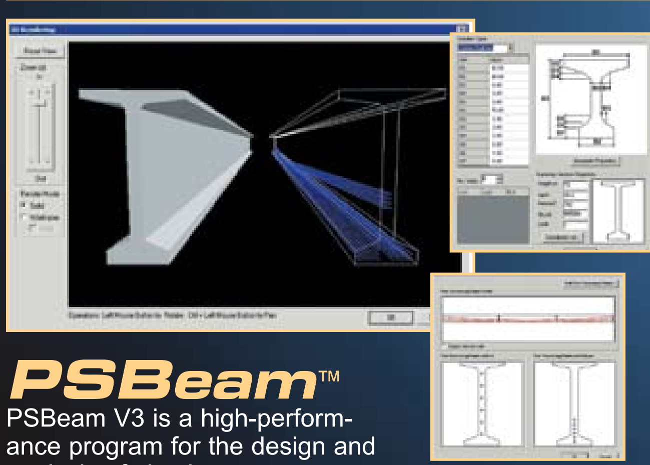
ParaBridge™

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

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

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

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

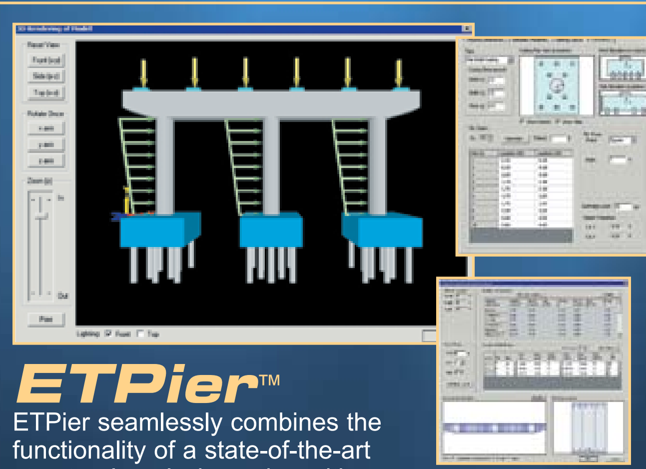


PSBeam™

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

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

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



ETPier™

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

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

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Photos: Oklahoma, DOT

Photos: Oklahoma, DOT


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DES PLAINES RIVER VALLEY BRIDGE ON I-355 / LEMONT, ILLINOIS

Photos: Illinois State Toll Highway Authority.

Photo: Illinois State Toll Highway Authority.

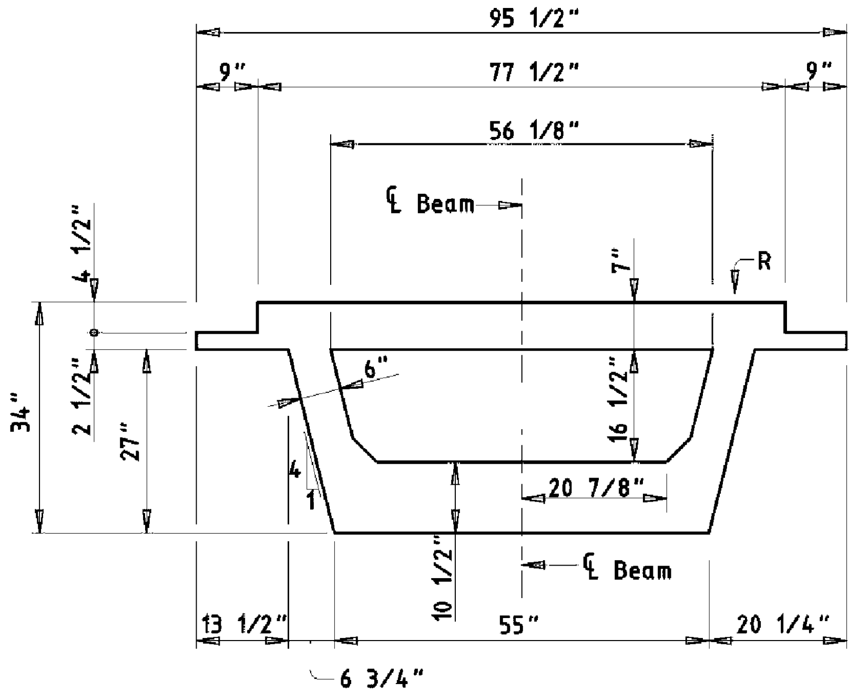
Photos: Illinois State Toll Highway Authority.

Construction of the second cantilever continues over the Maroon Creek Basin as work begins on the closure segment between the end of the first cantilever and the abutment.

Overhead construction using form travelers continues on the second cantilever.

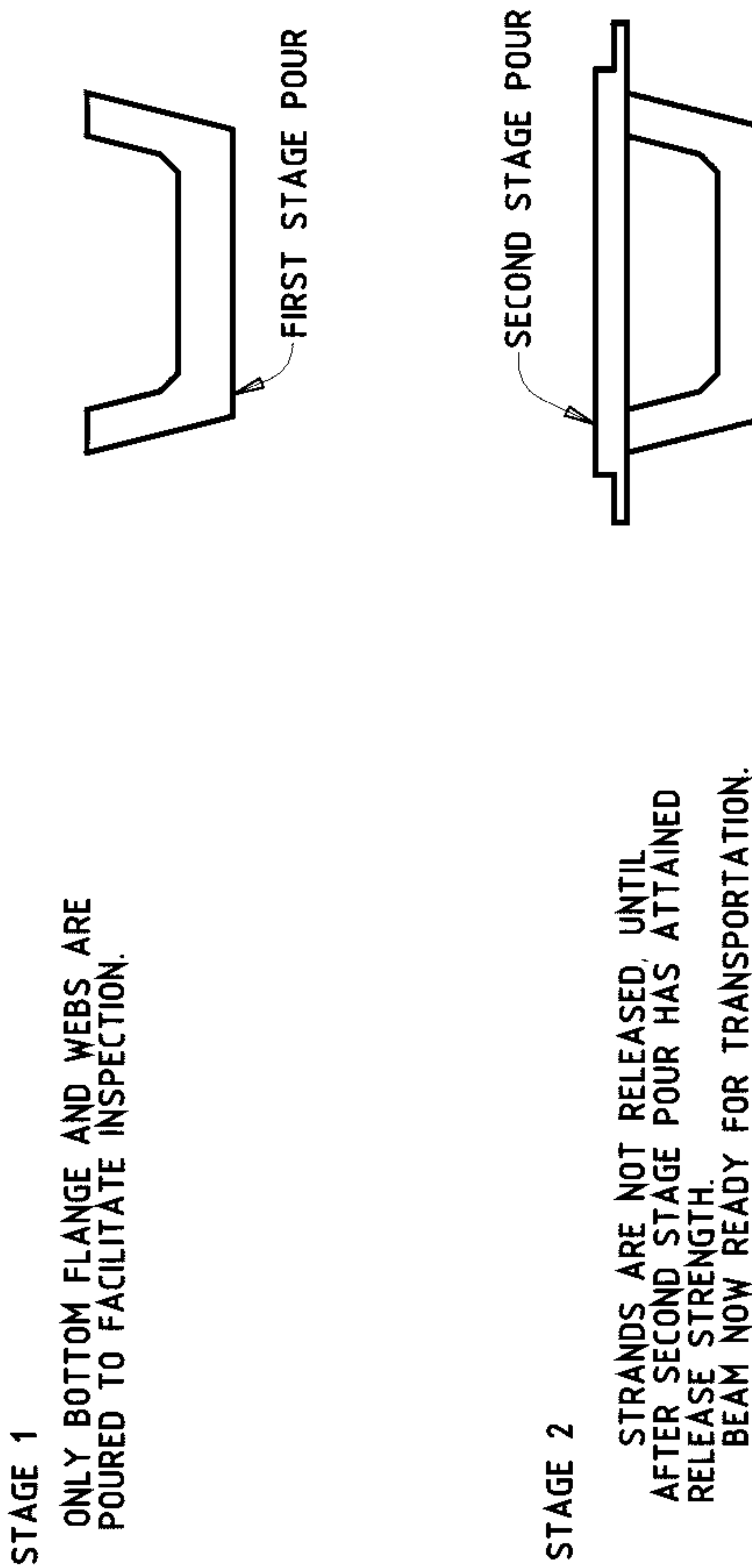
After casting segments throughout the winter, the first cantilever is almost complete and grows closer to the abutment.

LOOP 340 BRIDGES / WACO, TEXAS



Typical pretopped U-beam section.

The bridges incorporated pretopped U-beams, precast concrete column shells, and preassembly.



Pretopped U-beam construction sequence.

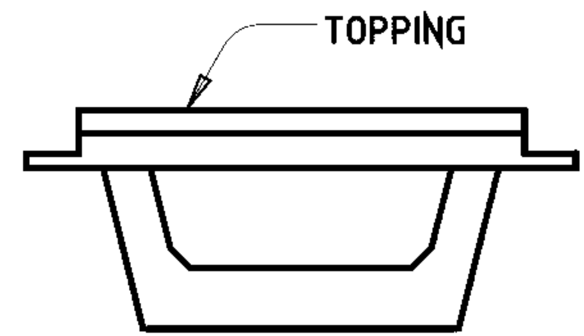
STAGE 3

AT CONTRACTOR'S YARD (NEAR JOB SITE), TOPPING & CURB SHALL BE POURED AND RAIL SHALL BE INSTALLED PRIOR TO ERECTION.

TOPPING SHALL BE GRADED TO ACCOUNT FOR DIFFERENTIAL CAMBER OF BEAMS IN THE SAME SPAN.

THE RESULTING TOPPING SURFACE SHALL CONFORM TO THAT REQUIRED BY PLANS.

BEAM NOW READY FOR ERECTION.



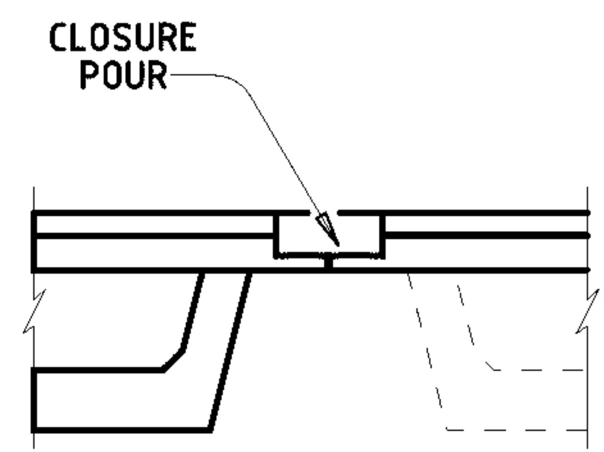
STAGE 4

AFTER ERECTION, CLOSURE POURS SHALL BE MADE BETWEEN BEAMS TO TIE SUPERSTRUCTURE TOGETHER.

STAY-IN-PLACE FORMS SHALL BE USED FOR CLOSURE POURS.

AFTER CLOSURE POURS HAVE REACHED SUFFICIENT STRENGTH, GRINDING OF THE ROADWAY SURFACE MAY BE NECESSARY TO ACHIEVE REQUIRED GRADES.

NO MORE THAN ½" OF GRINDING WILL BE PERMITTED AT ANY ONE LOCATION.



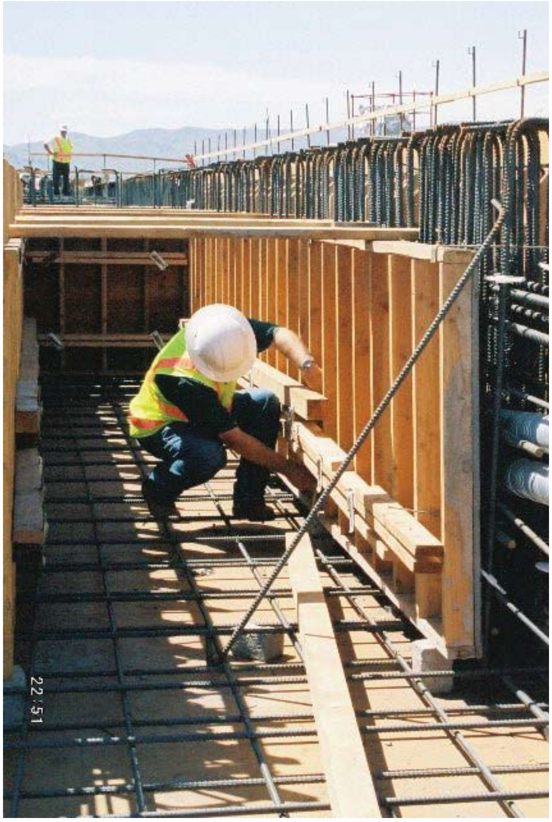
Pretopped U-beam construction sequence.

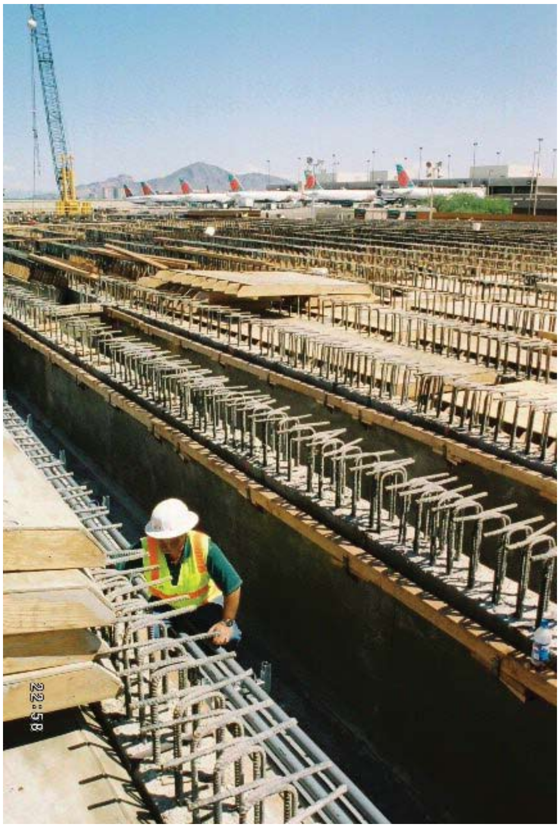
Beams were preassembled for casting the deck.

Northeast view of rebar cage set in cassion pier.

Photos: HDR Inc.

Worker with deck reebar.





Inspector checking rebar placement for abutment 1.

Photos: HDR Inc.

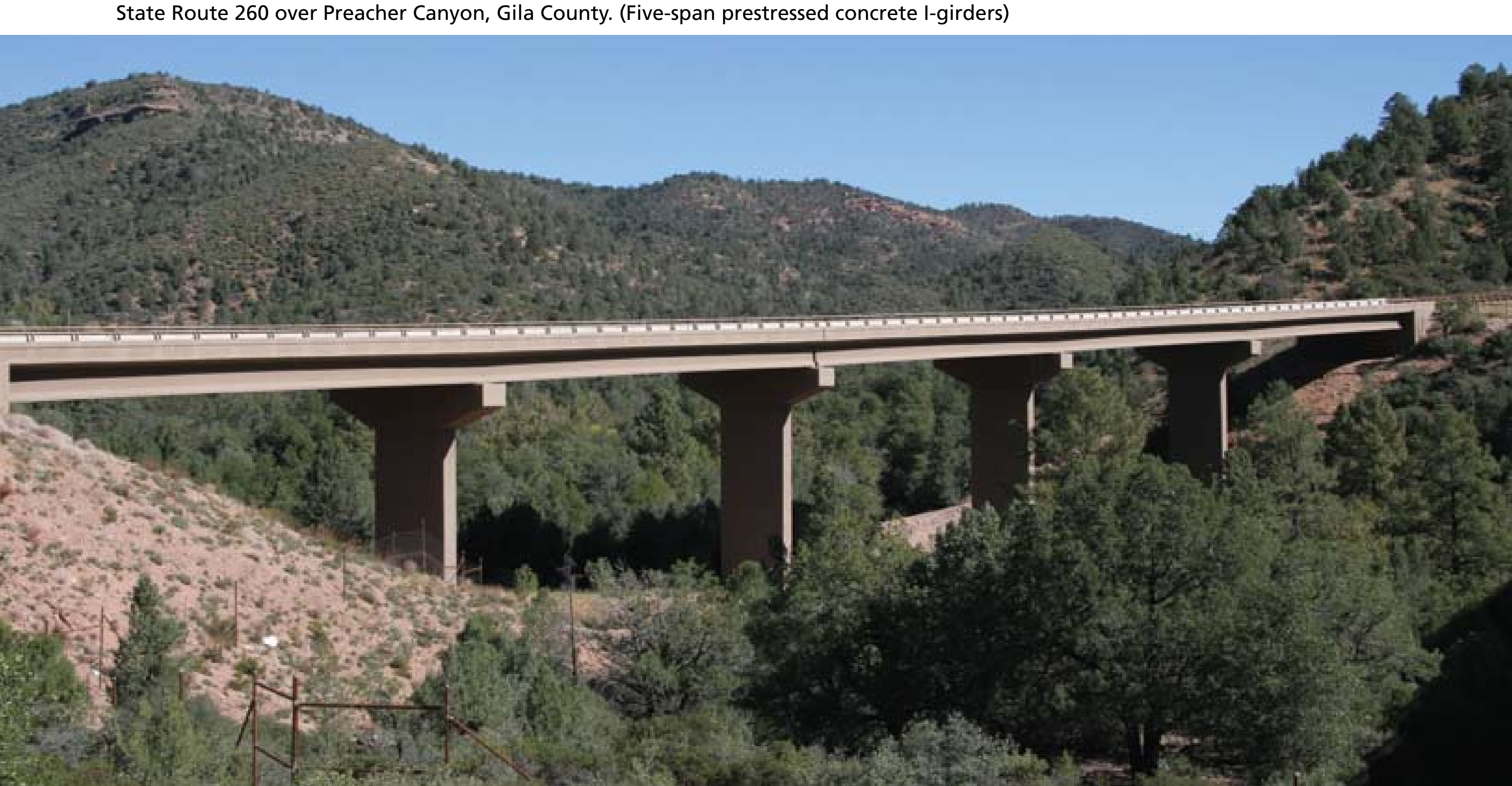
Eastern view of completed pier 2 and 3 colums. Photo: HDR Inc.

All Photos: Arizona Department of Transportation

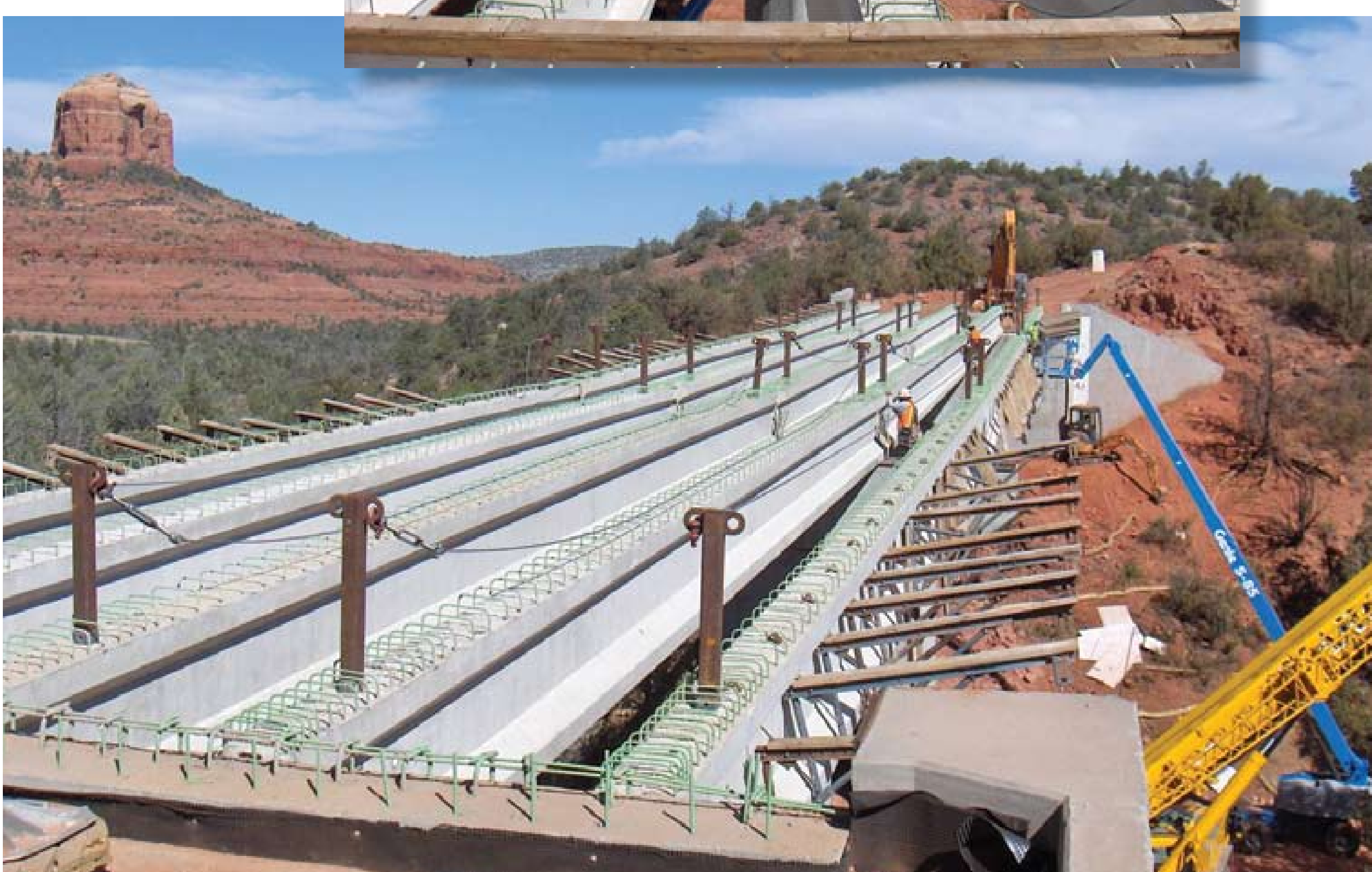
Raintree over Loop 101, Scottsdale.
(Two-span prestressed concrete I-girders)

Loop 202 over Salt River, Tempe. (39-span prestressed concrete I-girders)

State Route 260 over Preacher Canyon, Gila County. (Five-span prestressed concrete I-girders)



All Photos: Arizona Department of Transportation



State Route 179 Under Construction, south of Sedona. (Three-span prestressed concrete I-girders)

Inset Photo:
Jefferson over I-17, Phoenix.
(Damaged two-span
prestressed concrete I-girders)

Jefferson over I-17, Phoenix. (Repaired two-span prestressed concrete I-girders)

All Photos: Arizona Department of Transportation

I-10 HOV, Central Phoenix.

State Route 87 over Sycamore Creek, Maricopa County. (Six-span prestressed concrete I-girders)

All Photos: Arizona Department of Transportation

67th Avenue over U.S. 60, Glendale. (Six-span prestressed concrete I-girders)

Loop 101 over Chandler Blvd, Chandler. (Two-span prestressed concrete I-girders)

All Photos: Arizona Department of Transportation

Loop 202 and Interstate 10 Interchange, Chandler. (Post-tensioned box girders)

State Route 51 HOV, North Phoenix. (Under Construction)

All Photos: Arizona Department of Transportation

Superstition Springs over U.S. 60, Mesa. (Damaged two-span prestressed concrete I-girders)

Superstition Springs over U.S. 60, Mesa. (Repaired two-span prestressed concrete I-girders)