

# ASPIRE

THE CONCRETE BRIDGE MAGAZINE

SPRING 2012

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Photo: PCI Civil Constructors and Archer Western Construction, joint venture.

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Photo: Ted Lacey Photography.

## Evolution in Project Delivery Underway

John S. Dick, *Executive Editor*

**W**ith the increasing demand for transportation infrastructure improvements, and the growing inability to fund them, interest in alternative delivery systems continues to grow. Public-private partnerships, or P3s, are becoming more attractive to help solve these needs. This issue includes two perspectives on the subject that will interest bridge designers nationwide.

P3s take several forms including design-build, design-build-operate (and often maintain), and design-build-finance-operate (and maintain). All result in greater private sector participation in the delivery and, where applicable, financing of transportation projects. All enable owners to transfer risk associated with design and construction and, in the latter two methods, with life-cycle performance, operations, and maintenance.

Presently, 23 states have enacted statutes that enable various P3 approaches for the development of transportation infrastructure. Numerous projects have been completed or are presently underway. The typical projects range in cost from about \$50 million to more than \$2.6 billion. Much information can be obtained on the Federal Highway Administration's Innovative Program Delivery website, <http://www.fhwa.dot.gov/ipd/index.htm>.

The two perspectives in this issue on P3s come from a builder and a state agency who have both engaged in large P3 projects. The first, "Public-Private Partnerships: A Guide for Infrastructure Designers and Contractors" by the Flatiron Construction Corp. begins on page 12 and the second, "Virginia's Public-Private Partnership Program is Open for Business" is on page 14.

In the Summer issue of *ASPIRE*,™ a follow-up article will delve into some of the financial and legal issues that appear to be standing in the way of these new systems.

You might wonder why *ASPIRE* is venturing into these waters. New delivery methods will continue to play an increasingly critical role in delivering the nation's complex

infrastructure. Only a limited number of agencies and a small segment of the concrete industry have had exposure to this changing business climate to date, but many more will become familiar with it in the future.

In these systems, alliances and teams form early. Equity positions on these teams will often control the selection of materials for the bridge. We intend to help inform all stakeholders in the concrete bridge industry—from the owner agencies to the builders, subcontractors, and fabricators—about the options and the projects that take advantage of these new approaches.

To ensure concrete remains the bridge industry's material of choice, it will be necessary to remain dedicated, vigilant, and proactive to the changes occurring in the industry.

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- Adaptability to unique and demanding geographical challenges
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To continue to realize beautiful, long-lasting concrete bridges, all stakeholders in the concrete supply chain need to be cognizant of these new relationships. We are confident that concrete's inherent values will ensure it remains the preferred structural material for bridges.

Two projects featured in this issue also were constructed using the design-build method which continues to grow in preference among many bridge stakeholders: the Benson Road Bridge over I-405 beginning on page 24 and the I-15 Beck Street Bridges starting on page 36. The former is another example of the use of concrete components to accelerate bridge construction.

## On a Personal Note...

This is the 22nd issue of *ASPIRE* since we began publishing with the Winter issue in 2007. Having been involved with conceptualizing the magazine and producing each of those issues has been an educational and enriching experience for me. Now, I am about to take on a new challenge called retirement. The production team and Editorial Advisory Board shown in the column to the right have been a delight to work with. They have taught me a great deal, and I embrace their friendship. The team is poised to carry on with some new blood at the top of the masthead. The tremendous success I've experienced with the *ASPIRE* team during our first 5 years has been due to you, our readers and advertisers. Please continue to support *ASPIRE* as I will. Thanks to all of you for your input, contributions, and support!

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I-4/Lee Roy Selmon Expressway Interchange

Tampa, Florida

Photo: PCL Civil Constructors and Archer Western

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## The PCI State-of-the-Practice Report of Precast/Prestressed Adjacent Box Beam Bridges



The *State-of-the-Practice of Precast/Prestressed Adjacent Box Beam Bridges* (SOP-01-2012) presents the state of the practice on adjacent precast pretensioned box beam bridges. A discussion on current practice, historical issues, lessons learned, and improved performance of box girder bridges is provided in the report. Much of the information presented is based on responses to a survey of U.S. states and Canadian provinces, as well as a review of current practices and publications. The report is relevant for Accelerated Bridge Construction, new bridge construction, or superstructure replacement projects.

## The PCI State-of-the-Art Report on Full-Depth Precast Concrete Bridge Deck Panels



The *State-of-the-Art Report on Full-Depth Precast Concrete Bridge Deck Panels* (SOA-01-1911) is a guide for selecting, designing, detailing and constructing precast full-depth deck panels for bridge construction. This report is relevant for new bridge construction or bridge deck replacement. It includes an introduction to relatively new technology of full-depth bridge deck systems and information on typical practices including transverse and longitudinal design, as well as design examples. Additionally, there are examples of successful detailing including transverse joints, horizontal shear connection, leveling and temporary support and haunch details between beam and deck. The report also includes information on the production, handling, and construction of full-depth precast deck panels.



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**Matt Girard** is executive vice president of business development at Flatiron Construction. He is engaged in the emerging North American P3 market, leading business development efforts on more than \$5 billion of design-build work for P3 projects.



**Christie DeLuca** is communications manager at Flatiron Construction. She has led the company's internal and external communications for nearly 10 years and writes frequently about the construction industry.



**Dusty Holcombe** serves as deputy director of the Commonwealth of Virginia's Office of Transportation Public-Private Partnerships where he administers the daily operations of the Public-Private Partnership program.



**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.



**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.

## CONCRETE CALENDAR 2012/2013

For links to websites, email addresses, or telephone numbers for these events, go to [www.aspirebridge.org](http://www.aspirebridge.org) and select "EVENTS."

**April 16-17, 2012**  
**ASBI 2012 Grouting Certification Training**  
J.J. Pickle Research Campus  
The Commons Center  
Austin, Tex.

**May 6-8, 2012**  
**Post-Tensioning Institute Annual Convention**  
Loews Vanderbilt Hotel  
Nashville, Tenn.

**May 7-10, 2012**  
**International Concrete Sustainability Conference**  
Renaissance Hotel  
Seattle, Wash.

**May 20-25, 2012**  
**14th International Conference on Alkali-Aggregate Reactions in Concrete**  
Hyatt Regency Austin  
Austin, Tex.

**June 10-13, 2012**  
**International Bridge Conference**  
David L. Lawrence Convention Center  
Pittsburgh, Pa.

**July 7-12, 2012**  
**2012 AASHTO Subcommittee on Bridges and Structures Meeting**  
Hyatt Regency  
Austin, Tex.

**July 23-27 (Tentative)**  
**2012 PCA Professors' Workshop**  
PCA Headquarters  
Skokie, Ill.

**September 29-October 2, 2012**  
**PCI Annual Convention and Exhibition and National Bridge Conference**  
Gaylord Opryland Resort & Convention Center  
Nashville, Tenn.

**October 3-5, 2012**  
**PTI Committee Days**  
The Inn at St. John's  
Plymouth, Mich.

**October 21-25, 2012**  
**ACI Fall Convention**  
Sheraton Centre  
Toronto, Ontario, Canada

**October 29-30, 2012**  
**ASBI Annual Convention**  
Turnberry Isle Hotel & Resort  
Miami, Fla.

**January 13-17, 2013**  
**92nd Annual Meeting Transportation Research Board**  
Marriott Wardman Park, Omni  
Shoreham, and Hilton Washington  
Washington, D.C.

**February 4-8, 2013**  
**World of Concrete 2013**  
Las Vegas Convention Center  
Las Vegas, Nev.

**April 14-18, 2013**  
**ACI Spring Convention**  
Hilton & Minneapolis Convention Center  
Minneapolis, Minn.

**September 21-24, 2013**  
**PCI Annual Convention and Exhibition and National Bridge Conference**  
Gaylord Texan Resort and Convention Center  
Grapevine, Tex.

**October 20-24, 2013**  
**ACI Fall Convention**  
Hyatt and Phoenix Convention Center  
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This up-to-date reference complies with the fifth edition of the *AASHTO LRFD Bridge Design Specifications* through the 2011 interim revisions and is a must-have for everyone who contributes to the transportation industry.

The third edition includes a new chapter on sustainability and a completely rewritten chapter on bearings that explains the new method B simplified approach. Eleven LRFD up-to-date examples illustrate the various new alternative code provisions, including prestress losses, shear design, and transformed sections.

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"This is an excellent resource for designing precast, prestressed concrete bridges. The amount of time and effort invested by PCI and by the many highly experienced, accomplished, and well-respected professionals in the bridge industry in producing this publication is truly remarkable!"

-Shri Bhude, Bentley Systems



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## READER RESPONSE

Editor,

I'm a regular reader of ASPIRE™ magazine and the AASHTO LRFD feature. I'm fascinated by Dr. Mertz' thorough knowledge and explanations of subjects pertaining to the code. I would like to ask a question in regard to applicability of creep and shrinkage forces to be used in the design of integral columns in multi-span, continuous concrete bridge structures. What is the best methodology to calculate the effects of creep and shrinkage for substructure design? The AASHTO LRFD Bridge Design Specifications includes CR and SH as part of all service and strength limit states (Table 3.4.1-1), but no guideline is provided on how to quantify these forces for design of columns and other substructure elements. The concrete columns that are integrally connected to the superstructure will deform due to the creep and shrinkage of the superstructure. The LRFD Specifications does not address how to determine the column moments and shears resulting from creep and shrinkage. Can you please answer this question in your AASHTO LRFD page? Please feel free to email me if you have any questions.

Name and company withheld  
San Francisco, Calif.

[Editor's Note]

We completely agree that Dr. Mertz' knowledge of and ability to explain provisions of the LRFD Specifications is invigorating. We continue to receive similar compliments about his articles and we appreciate his time and skills in contributing to ASPIRE. He carefully considered this reader's question and has responded in his column on page 56.

Editor,

Love the magazine! One suggestion: In some of the articles (e.g., "Texas' Longest Beams," page 29, Winter 2012), it's not clear exactly where the project is located because no mention is made of nearby cities. How about a small map for such articles?

Kathleen Bergeron  
Federal Highway Administration  
Washington, D.C.

[Editor's Note]

We like this suggestion and apologize to readers who may have been left wondering about the location of this or other such projects. In the future, we will more carefully describe locations or provide a locator map!

Editor,

Our company was the general contractor for the Mayor Mike Peters Bridge featured in your Winter 2012 issue (pages 18-20). Would it be possible to have some additional copies of the magazine sent to us? We'd like a few copies for us and will send some to a few of our subcontractors.

Brendan Parker  
Loureiro Contractors Inc.  
Plainville, Conn.

[Editor's Note]

Happy to send them, Brendan. Nice project in a tough location. The results speak for themselves.

Editor,

On behalf of myself and my co-authors, we would like to thank you and the dedicated team at ASPIRE for your very nice job with the Presidio Viaduct article (pages 30-33). The article really looks good with the combination of photos, rendering, and diagrams. Great job.

Ahmed M. M. Ibrahim  
California Department of Transportation  
Sacramento, Calif.

Editor,

I must compliment you on your productions. I read almost every article and find them to be well written and informative. I am happy that you were able to put together this very useful magazine for the industry.

A. Joseph Siccardi  
FIGG Bridge Engineers  
Denver, Colo.

Editor,

I am a long time reader of the ASPIRE magazine and find it contains a lot of interesting and practical information.

Hong Guan  
CH2M HILL  
Bellevue, Wash.

Editor,

I receive and enjoy ASPIRE. It is the highlight of my "work" magazines.

Andrew Howe  
OBEC Consulting Engineers  
Salem, Ore.

Editor,

ASPIRE is a high quality publication...

Kent Barnes  
Montana Department of Transportation  
Helena, Mont.



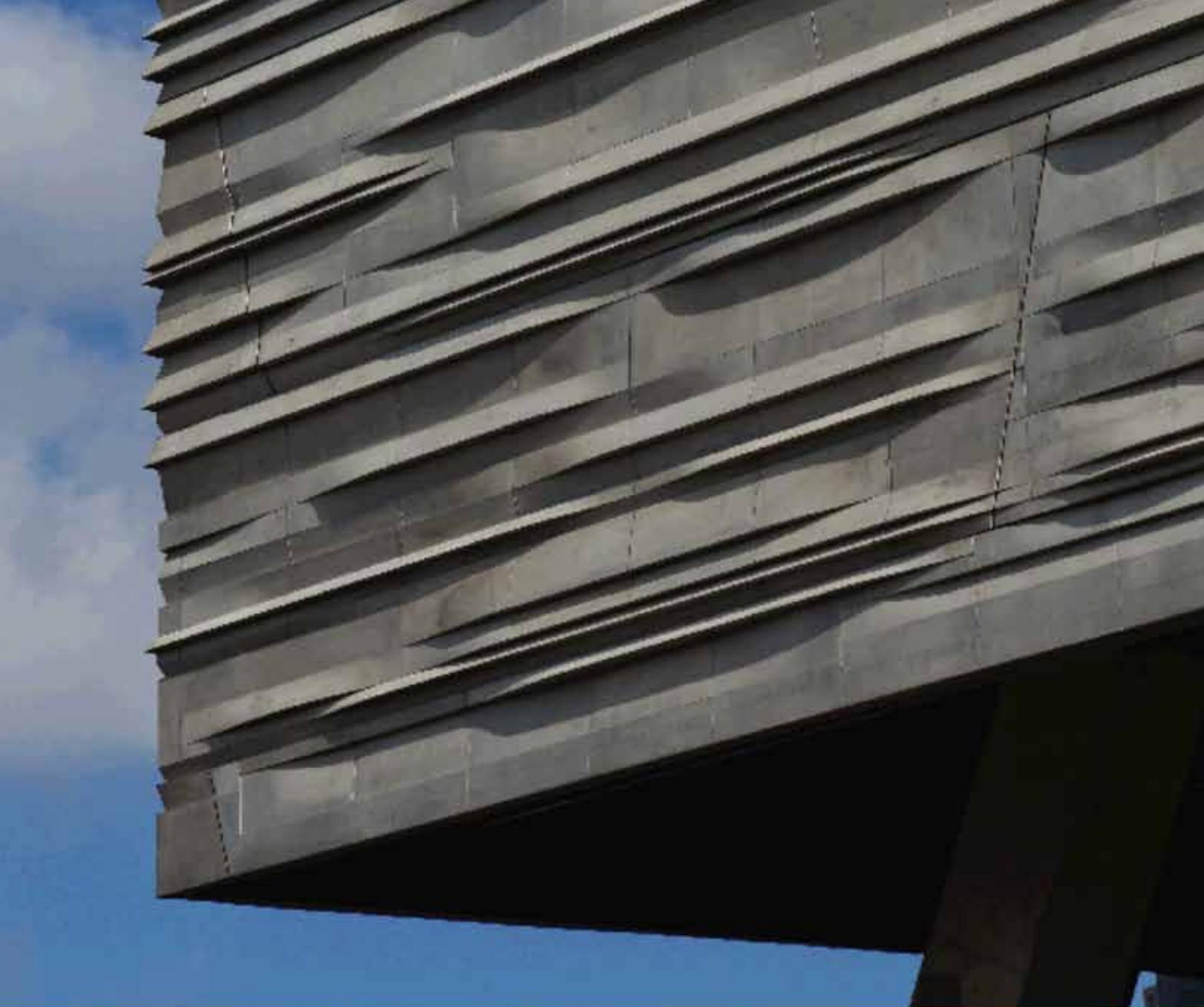
Editor,

I read with interest the ASPIRE article on the Route 22 Bridge over the Kentucky River near Gratz, Kentucky (Winter 2011 issue, pages 24-27). The measures taken to design and build the structure were interesting. I was even more intrigued when I was asked about the design and construction requirements for a precast, spliced post-tensioned girder for a 500 ft. span. I returned to the article on the Route 22 Bridge and read it again considering the possibilities. I was hoping that you may have provided some of the design parameters or dimensions of the girder. I looked at your website to see if other girder dimensions or description of construction equipment might be contained there somewhere, but found no further information. While I am skeptical, I will at least look into the Route 22 Bridge and consider if the 500 ft. span is possible or if it is simply impractical. If you have any of that information or can point me in the right direction I would be grateful. That was a very interesting article. Keep up the good work!

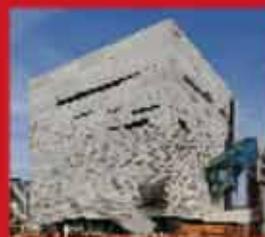
Bruce Kates  
Jacobs Engineering Group Inc.  
St. Louis, Mo.

[Editor's Note]

We try to include as much technical information in the articles as we can while staying within the space available and telling the story about the bridge. You may be able to obtain more information about the Route 22 Bridge by contacting the author. NCHRP Report 517—Extending Span Ranges of Precast Prestressed Concrete Girders is available to download at [www.trb.org/NCHRP/NCHRP.aspx](http://www.trb.org/NCHRP/NCHRP.aspx) and click on Project Reports under PUBLICATIONS on the left side.



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# Corven Engineering stays true to its roots while leveraging its expertise to maximize potential

Corven Engineering has its mind set primarily on one goal: providing clients with the best possible, post-tensioned concrete bridge engineering. "We do this by staying focused and maximizing potential within our niche," says founder John Corven, president and chief bridge engineer of the Tallahassee, Fla.-based company.

The firm's expertise in concrete segmental and cable-stayed bridges serves as its foundation. The company leverages that expertise in four areas of work: new designs, construction engineering, inspection and rehabilitation, and developing and sharing technology. "Work in these areas mutually supports the others, solidifies the niche, and keeps us current and relevant," he says.

This approach also provides many entry points for providing engineering services throughout the life of a bridge. "We love to design new bridges and support contractors during construction," Corven adds, "but it is just as important to work with owners to extend bridge life and increase operational capacity."

Corven Engineering's approach to work has diversified its customer base. The firm opened its doors in 2000 working primarily for state departments of transportation. "The biggest change in our company has been the transition to gaining more work with other types of clients," he explains. "The major part of our business now comes from teaming with contractors or larger engineering firms to provide our expertise on large projects."

An example is the company's work on Phase 1 of the Dulles Corridor Metrorail Project in Tysons Corner, Va. Corven is working for Dulles Transit Partners, a



joint venture of Bechtel and Washington Group, on this \$1.8-billion project. Their work focuses on the design and construction support for more than 5 miles of aerial guideways to carry the extension of the Washington Metropolitan Area Transportation Authority (WMATA) system. It includes four types of precast concrete segmental bridge construction. (For more on the project, see the Fall 2011 issue of *ASPIRE*.™)

"Mega-firms were needed for that kind of project," Corven says. "But we are able to help provide cost-effective solutions for specific bridge challenges. That help can involve a specific design feature or the entire bridge design."

### Post-Tensioned Designs

Post-tensioned concrete bridges, and segmental bridges specifically, continue to offer great potential for new bridge designs, he notes. "The basic principles of segmental construction are sound. It permits construction where access is extremely difficult, especially

above traffic. It can help protect the environment, keep traffic moving, and provide complex geometry where necessary. It makes a very good choice in those circumstances."

Corven Engineering has worked with clients in a variety of delivery methods, although the designers favor the design-build approach, says Phil Hartsfield, vice president and head of construction engineering. "It allows us to be involved from the beginning and follow the project through to construction." In many cases, he explains, the company's entry point comes on the construction engineering aspects, which brings them to the project after many decisions have been made that could have been made more cost effective if made earlier.

"If we are involved earlier, we can often spot problems that can be resolved before they reach a critical point," he says. "Design-build gives us that early input and lets us work through challenges that arise all the way through the process."

# Staying Focused

by Craig A. Shutt



Segmental construction has proven to be an excellent solution for the Dulles Corridor Metrorail Project, located in the congested Washington, D.C., metroplex. Corven worked with Dulles Transit Partners to design and construct the aerial guideway, featuring more than 2700 precast concrete segments. Photo: Dulles Transit Partners.

One such project is the Foothills Parkway Bridge No. 2 now under construction in Blount County, Tenn. This balanced cantilever, precast segmental bridge is being built around

girder bridge in the United States. The three-span, 480-ft-long bridge is anchored by two precast, prestressed concrete adjacent box-beam spans crossing a local road and a railroad.

a steep, rugged mountainside that is environmentally very sensitive. Bell and Associates Construction (prime contractor), VSL (segment erection and post-tensioning), and Corven (engineer of record and construction engineer) collaborated to develop a unique erection trestle and segment walker for segment erection. By working together early, Corven was able to design the bridge with VSL's erection equipment in mind.

Another such project was the Cross Street Bridge in Middlebury, Vt., on which Corven served as the spliced-girder, main-span engineer of record. The structure was the first project in the state to use a design-build format. That delivery method produced a 240-ft-long center span, the longest simple-span, post-tensioned, spliced-

Environmental concerns led to the design, which eliminated a pier in Otter Creek. (For more on this project, see the Winter 2011 issue of *ASPIRE*.)

"Owners are aware of the capabilities of these approaches and are using them more often," says Hartsfield. "Owners are very intelligent and are embracing different delivery methods. Sometimes there are misconceptions that design-build approaches will eliminate every issue early on, but there's still a lot of work to be done. But it does allow you to get the project into construction quicker."

Owners are focusing on speed of construction as a priority, notes Corven. "There is a growing demand for faster delivery, as citizens want projects completed, and they don't get cheaper down the road. Precast concrete, including segmental construction, lends itself well to accelerating bridge construction. We strongly support the federal government's 'Every Day Counts' initiative."

## Construction Engineering

The company also provides construction engineering services to a growing number of contractors, adds Hartsfield. "We are finding a lot of success by supporting contractors during construction and ensuring that designs are constructable."

An example can be seen in the work performed on the I-95/I-295 North Interchange in Jacksonville, Fla. The interchange serves as a main access route and is the first major feature seen by tourists and visitors arriving from the north. The precast concrete segmental alternative, built with the balanced-cantilever method, created a third-level



The three-span Cross Street Bridge in Middlebury, Vt., was the first bridge built in the state using the design-build delivery method. Corven provided engineering for the spliced precast concrete girders. Photo: Vanasse Hangen Brustlin Inc.



The 790-ft-long Foothills Parkway Bridge No. 2 near Wears Valley, Tenn., is a precast segmental concrete bridge with span lengths up to 180 ft. Corven supplied design and construction engineering services to Bell & Associates Construction. Photo: Corven Engineering Inc.



The balanced-cantilever method was used to construct the I-95/I-295 North Interchange Ramp in Jacksonville, Fla., for which Corven provided construction engineering services. The bridge features precast concrete segmental box girders in a 10-span continuous configuration with a total length of 2256 ft. Photo: Superior Construction Company.

ramp with a horizontal curvature of more than 90 degrees and a radius of 1250 ft. The thin, curving profile provides a striking entry to the city. (For more on this project, see the Winter 2011 issue of *ASPIRE*.)

Another example currently underway is the \$350-million I-4/Lee Roy Selmon Expressway Interchange in Tampa, Fla. The 12 elevated ramps provide a vital transportation link in downtown Tampa. There are more than 2500 precast segments, consisting of more than 1 million ft<sup>2</sup> of precast concrete, being used. They are being built with both the balanced-cantilever method, using deck-mounted mobile segment erectors, and the span-by-span method using an overhead gantry.

Corven worked with PCL/Archer Western to improve the constructability, including introducing the deck-mounted erectors. Of the 149 segmental spans, lengths range from 105 to 260 ft with radii as small as 590 ft and cross-slopes up to 10%.

### Rehabilitation is Growing

Post-tensioning rehabilitation offers a rapidly growing area of opportunity. "We are working more and more on bridges in service, for which we perform post-tensioning inspections, evaluate problems, and create a rehabilitation plan," Corven says. "It's very interesting work. In addition to the work plan, we have had the opportunity to assist in the needed repair work. We're not afraid to get our hands dirty."

On the Florida Keys Segmental Bridges in Monroe County, Fla., Corven provided in-depth inspections and evaluations of the post-tensioning system, and then performed the needed rehabilitation work. Photo: Corven Engineering Inc.



## Corven's 12-Year History

Corven Engineering was formed in 2000 after John Corven left DMJM to take on a project for the FDOT where several post-tensioned tendons had failed. That project began a 12-year history of focusing on post-tensioned and cable-stayed bridges.

Corven began his career in 1979 at Figg & Muller Engineers, where he worked with Philip Hartsfield on a variety of projects. Both men also worked for different periods with Jean Muller in his Paris office. Hartsfield joined Corven in 2006 from Parsons Corp., where he'd been working since his previous firm, Finley McNary Engineers, had been purchased.

Among the projects undertaken by the company, in addition to those mentioned here, are widening the Ramp A Bridge at the I-75/SR 826 Interchange in Miami, the first such widening of a segmental bridge in the United States, and the rehabilitation of more than 70 miles of external post-tensioning tendons in segmental bridges in the Florida Keys.

An example is the work done on four bridges in the Florida Keys: the Channel 5, Long Key, Niles Channel, and Seven Mile Bridges in Monroe County, Fla., for the Florida Department of Transportation (FDOT). The series of concrete segmental bridges, more than 11 miles in length, required an in-depth post-tensioning inspection that led to Corven directing the repair operation. The \$11-million project included inspection of external tendons,

vibration testing, pour-back removals, and non-destructive inspections using endoscopes.

"It was a special project, in which we were permitted to supplement our staff with a contractor to do work together in an 'Inspect/Maintain format' Corven says. "There was no reason for us to inspect the bridges and prepare a set of plans, have FDOT take bids, and then have a third entity inspect the contractor's work. We saved time and money."

With such work, the company's goal is to help achieve or extend a bridge's service life. That will be the result next summer when work is completed on the 943-ft-long Plymouth Avenue Bridge, a segmental concrete design that spans the Mississippi River near Minneapolis. The 29-year-old bridge was the first segmental design built in the state and, due to a drainage system failure, now needs its post-tensioning system repaired. The work will include the phased replacement of concrete while installing new post-tensioning tendons. "When complete, the bridge will return to its original load-carrying capability," he says.

Such rehabilitations often are more challenging than building from scratch, he notes. "It takes time to discover the unique characteristics of the bridge and the means and methods of how it was built, and then engineer a rehabilitation scheme within that framework. It's very rewarding work but very difficult work."

Rehabilitation work offers great potential for the company, he says. "There's not enough money to fix all of our deficient bridges. We're just scratching the surface now. Our goal is to work with owners to develop more innovative repair approaches that will last longer and be more cost efficient." That will involve such techniques as using supplemental post-tensioning and resupporting anchorage locations to provide longer life.

## Developing and Sharing Technology

Durability also has become a key focus, as owners look to cut maintenance costs and extend service life. Corven's expertise with evaluations of existing



On the I-4/Lee Roy Selmon Expressway Interchange in Tampa, Fla., Corven is providing construction engineering services to a joint venture of PCL Civil Constructors and Archer Western Construction. The project includes more than 2500 precast segments that vary in width from 30 to 60 ft. Photo: PCL Civil Constructors and Archer Western Construction, joint venture.

bridges has led to a new facet of its niche: production of manuals for federal and state departments, especially related to durability. The procedural guides detail how to install, inspect, grout, and protect tendons to ensure long life.

The company developed the 10-volume "New Directions for Post-tensioned Bridges in Florida" for the FDOT, as well as the "Post-tensioning Tendon Installation and Grouting Manual" for the Federal Highway Administration (FHWA) and LRFD concrete superstructure design courses for the National Highway Institute. The manuals are written by Corven and long-time associate Alan Moreton. The firm is now writing a manual for the design of cast-in-place, post-tensioned concrete bridges for the FHWA.

Creating design manuals along with its other services keeps the firm busy. "We produce a fair amount of work with a small group of professionals," Corven says of the company's 20 employees. "We pride ourselves on being able

to produce a large amount of quality engineering product quickly, whether it's designs, inspection reports, or manuals."

Most satisfying for Corven are repeat clients, "We feel really blessed when a client trusts us to work for them again. We don't take it for granted. It raises the bar for us to do even better this time."

Repeat clients, coupled with the firm's versatility in growing niches, have it poised for more prosperity. "Infrastructure remains a big need, and even in tough economic times, we're still moving forward on building bridges," Corven says. "There are many great opportunities for us to keep doing what we do. The outlook is very positive."

**For additional photographs or information on this or other projects, visit [www.aspirebridge.org](http://www.aspirebridge.org) and open Current Issue.**

# A Contractor's Point of View

## Public-Private Partnerships: A Guide for Infrastructure Designers and Contractors

by Matt Girard and Christie DeLuca, Flatiron Construction Corp.



Project delivery methods have been in a state of flux for many years in the United States. Legislation for public-private partnerships (P3s), and for other alternative delivery systems, varies greatly from state to state. However, the demand for P3s is growing.

### P3s—A Natural Progression

The recent push for more P3s, and for alternative delivery models in general, is due to the nation's dire need to repair and upgrade existing infrastructure, and to do so quickly, with limited public resources. The public sector has also begun to notice potential benefits of P3s, namely, the ability to transfer cost escalation risks, as well as those associated with operations and maintenance, to the private sector.

The Canadian Council for Public Private Partnerships states that, "... under the P3 approach, the public sector contracts with a single entity ... Under the traditional procurement approach, the public sector must contract separately with each discipline. The efficiencies created through the P3 approach can yield significant savings for the public sector, both through a

simplified management structure and by mitigating the risk of interface between disciplines."

The private sector demand for P3s is also growing. Infrastructure provides diversification benefits for investors and is a solid investment over the long haul—transportation is a service that the public will always use.

P3s are not necessarily a new model, but rather the next level of risk transfer to the private sector. Departments of transportation used to construct their own facilities. They soon figured out that private contractors did a better job at managing risk for things like equipment, labor productivity, unions, or even weather.

About 25 years ago, a trend to shift design to the private sector began. At that point, the private sector was handling design and construction under separate contracts. A few years later, the notion of combining design and construction emerged as design-build, further reducing the public sector's risk of managing separate designers and constructors. Then, over the last

10 years in places like the United Kingdom, Australia, and Canada, came the P3 contract, under which design, construction, and financing—and in most cases operations and maintenance as well—are handled by the private sector.

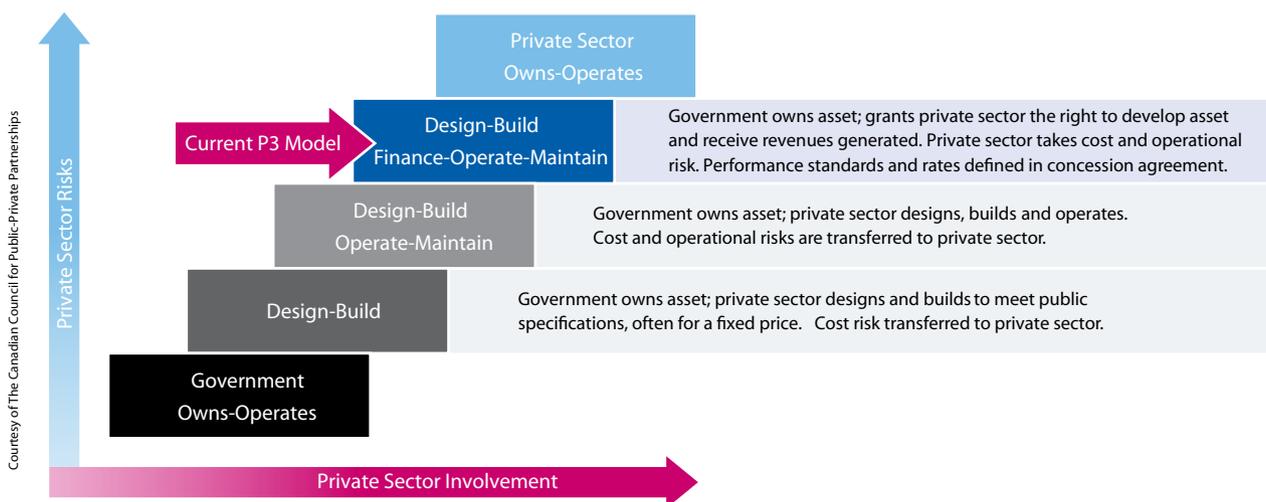
### P3s Provide Risk Transfer Benefits to the Public Sector

One of the main benefits of P3s for the public sector, in addition to reduced construction, operations, and maintenance costs, is the ability to transfer the risks that come with managing multiple contracts to the private sector. P3s also enable owners to transfer the risks associated with long-term, life-cycle performance, operations, and maintenance.

### Tips for Designers and Contractors

According to a recent P3 report by FMI, the industry's largest consulting, investment banking, and research firm, contractors should be very strategic about selecting projects, build expertise through strategic ventures, understand that concessionaires on these projects

Degree of private sector risk & involvement.





As part of a larger P3 consortium, Flatiron led the design-build team on the Northeast Anthony Henday project, a new 13-mile (21-km) portion of a ring road around Edmonton, Alberta, Canada. The owner, Alberta Transportation was able to complete this more than \$1 billion project significantly faster and arguably less expensively by letting it as a single P3 project, rather than multiple low-bid contracts.

usually require large financial backing, and start building relationships very early on.

Because P3s are large and complex projects, designers and contractors need to be very careful to select the right projects. Flatiron bases decisions about which P3 projects to pursue on a few key factors. First, owners should shortlist three or fewer teams. Second, owners should offer a stipend, typically around 0.5 to 1% of the capital costs for the project, and the contract terms must be reasonable.

Flatiron also wants to make sure the project will actually get built. We don't want to pursue projects that get cancelled during procurement, or worse, after the procurement is over and before award. Needless to say, Flatiron is extremely selective.

Flatiron also prefers to work with owners who have a past history with P3s (or who have good advisors if they

have no history). We also prefer to work with owners who have already resolved third-party issues, like right-of-way, permitting, and agreements with other stakeholders like municipalities or utility companies.

When forming partnerships, Flatiron asks questions like: Who is an expert in this type of work? Who has worked with this owner before? Who is in the area? Who has the resources available? Partners with the lowest price are not necessarily the best choice for a P3.

### What a Good Design-Build Team Brings to a P3

With so many factors and players involved in a P3, one of our jobs as the design-build contractor during a P3 pursuit is to help the financial and technical advisors feel confident about lending and investing money in the project.

Lenders feel most comfortable with people who have designed and built

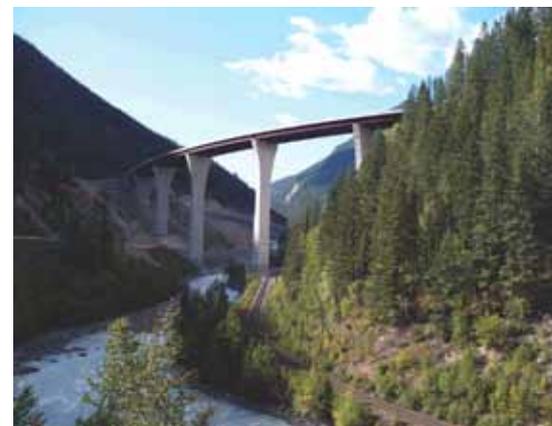
P3 projects before and who understand the risks. As a contractor, we help communicate how this is a solid financial opportunity for them. If they feel confident we have covered all our bases, in terms of risks, and have priced the project accordingly, the lenders' technical advisors can write a good report.

This report affects the credit rating that financial advisors place on the project. A better credit rating means lower interest rates on borrowed money, which in turn means lower repayment costs—and the lowest payment typically wins the job. It's like a mortgage. If a homebuyer has a better credit rating, the bank's mortgage rate will be lower and the payments from the home buyer, in this case the public sector, will be lower.

The need for reliable infrastructure will continue well into the future. P3s, with inherent advantages and risks, can at the very least provide a viable alternative for public owners to finance, build, and maintain infrastructure projects. It is our job to help educate owners in the United States and bring our P3 experience from places like Canada in hopes that together we can meet the growing demand for safe and reliable infrastructure.

**For additional information on P3s, visit The Canadian Council for Public-Private Partnerships website at [www.pppcouncil.ca](http://www.pppcouncil.ca).**

Flatiron constructed approximately 3 miles of four-lane highway through Kicking Horse Canyon on the border between British Columbia and Alberta, Canada. It included a 1328-ft-long bridge nearly 300 ft above the river.



# Perspective—An Owner’s Viewpoint

## Virginia’s Public-Private Partnership Program is Open for Business



by Dusty Holcombe, Virginia’s Office of Transportation Public-Private Partnerships

The Commonwealth of Virginia was founded in the seventeenth century as a risky, but ultimately highly successful business venture. Today, Virginia continues to focus on creating an inviting business environment that promotes competition, encourages private investment, and invites the private sector to identify and develop innovative solutions to enhance its infrastructure.

As with any successful business venture, Virginia must remain focused and diligent about creating an attractive business environment. Virginia must continue searching for solutions to attract private investment. A significant aspect of that effort is maintaining a transportation network that allows for efficient freight movement, access to its ports, and interstate movement of goods and services.

Since Virginia’s enabling legislation for public-private partnerships (P3) was enacted by its General Assembly in 1995, Virginia has advanced nearly \$5.0 billion worth of P3 for transportation infrastructure either constructed, under construction, or under agreement.

### Reinventing the P3 Program

In 2010, the governor initiated a full assessment of Virginia’s P3 program in an effort to reinvigorate the development and completion of P3 projects. The results of the assessment were as follows:

- The program was limited in focus to development of highways.
- Ownership rested with multiple staff.
- The program was reactive and was constrained by a lack of funding for project development.

In response to the assessment, the Secretary of Transportation, in December 2010, introduced a manual titled, *Public-Private Transportation Act Implementation Manual and Guidelines*. The manual provides a project delivery framework for the development and implementation of both solicited and unsolicited P3 projects that proactively identifies, develops, and delivers the Commonwealth’s priority transportation projects in a consistent, transparent, timely, and cost-effective manner. The result of this action means Virginia’s approach to its P3 program is now a program-based perspective rather than a project-by-project response. Key to the program-based approach is development of a multimodal pipeline of candidate P3 projects.

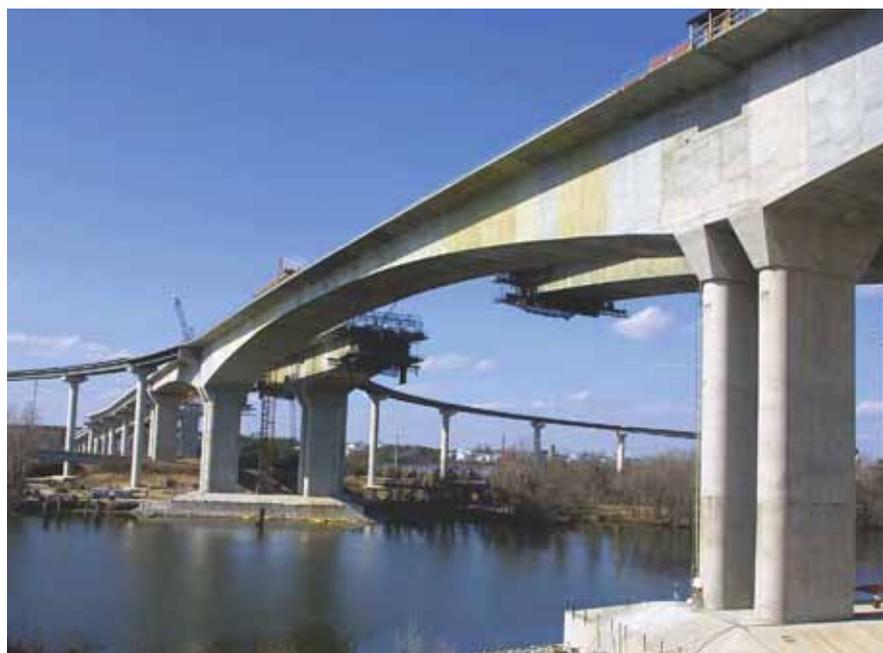
In addition to the process reviews and improvements in the manual, an Office of Transportation Public Private Partnerships (OTP3) was created to focus specific financial and human resources on the identification, development, and delivery of P3s across all modes of transportation, including

rail, transit, marine, aviation, and roadway projects. In 2011, the director of OTP3 was charged with creating an environment that encourages private investment and proactively identifies, assesses, and delivers the Commonwealth’s priority transportation projects. Furthermore, the internal structure of the OTP3 utilizes resources with diverse backgrounds in finance, law, project development, engineering, and operations along with legal, financial, risk, and business consultants that augment the internal staffing resources.

### Learning from the Past

Virginia’s leaders have taken tangible steps forward to implement a P3 program that has learned from its past experiences. In addition to the creation of the OTP3 and the restructuring of the manual, Virginia has learned from its experience in the areas of risk assessment and project development.

Risk analysis and management is an essential part of the development of any project, whether it is procured following



Construction of Pocahontas Parkway.

All photos: Virginia Department of Transportation.



I-495 Capital Beltway Express Lanes connection to I-395.

a more traditional delivery method, design-bid-build or design-build, or as a P3. The assessment of risk, especially on a complex transportation project, must be conducted throughout the life of a project to assist in determining if the continued development of the project brings a value to the owner or the private sector investor. For Virginia's transportation agencies, the OTP3 has developed a guidance document that can be utilized to increase the effectiveness of risk analysis and management. It is available at [www.vappta.org/publications.asp](http://www.vappta.org/publications.asp). The document includes processes that facilitate the agency's:

- identification and understanding of a project's risks,
- identification strategies to mitigate the likelihood of and impact of risk elements,
- allocation of risk to the party best able to manage the impact, and
- preparation of an adequate contingency to cover both known and unknown risks.

Lessons in project development have also been implemented including completion of value for money analysis guidance and increasing the transparency of the program. When the OTP3 opened in December 2010, its first objective was the creation of a website ([www.vappta.org/](http://www.vappta.org/)) that provides accurate and updated information on each of the stages of project development and on documents created to assess, develop, and execute comprehensive agreements for P3 projects. The website provided

background in the structure of the office, information about projects at all levels of development, documentation developed for use by the OTP3 and Virginia's transportation agencies, and the latest news about existing and potential P3 projects. Additionally, the OTP3 codified a *Value for Money* guidance document. This will be used by the OTP3, in coordination with the transportation agency, several times throughout the project development process to assess whether the current structure of the project and the bid that has been presented by the private sector bring value to Virginia. It will also allow the OTP3 to assess and recommend a development structure, such as a tolled concession, availability payment, or a more traditional structure, which delivers the optimal structure of net life-cycle cost, quality development, and value for the investment provided by the Commonwealth.

### Looking to the Future

The development and sustainability of an adequate infrastructure network has become increasingly more expensive, making innovative financing and delivery methods a critical tool to maintaining the health of Virginia's economy. In 2011, the governor introduced legislation that provided the largest investment in transportation in Virginia in more than a generation—over \$4 billion additional funding for infrastructure improvement projects. Moreover, a Virginia Transportation Infrastructure Bank (VTIB) was created to provide another innovative financing tool for construction

and capital maintenance for Virginia's transportation infrastructure needs. Funding capitalized within the VTIB will provide low interest loans with maturity dates of 20 to 30 years. These funds will be made available to government entities, railroads, transit companies, and private sector companies for the initiation and development of critical transportation projects.

In this era of fiscal responsibility, the P3 delivery method offers an important tool for development, construction, and operations of transportation infrastructure by leveraging investments and partnering with the private sector. In other words, Virginia and its P3 Program are open for business.



Metrorail construction at Tysons Corner, Va.



I-495 Capital Beltway Express Lanes construction.

## PROJECT

# Zumbrota Veterans Memorial Bridge

by Todd R. Stevens, Minnesota Department of Transportation



View of Veterans Memorial Bridge showing bench provided for a future trail. Photo: MnDOT.

## Ample new access provided for pedestrians, snowmobiles, cars, and the Zumbro River

Zumbrota, Minn., is the quintessential quiet little town, tucked into the southeastern corner of the state between Minneapolis/St. Paul and Rochester. While it may be small, the town relies on its transportation infrastructure as much as any large metropolitan area. And a major component of Zumbrota's transportation system is the bridge that carries Minnesota Trunk Highway 58 (T.H. 58) over the North Fork of the Zumbro River. With a 23-mile detour to the nearest alternative trunk highway river crossing, a closure of the

T.H. 58 bridge would affect a variety of transportation users including residents going about their daily business, school buses, farm-to-market truckers, and commuters to the town's larger neighbors. Along with its functional importance, the crossing also has historical and social significance to the local community.

The T.H. 58 crossing was closed, however, in 2010 while the Minnesota Department of Transportation (MnDOT) had a replacement bridge built. The new bridge, Bridge 25025, was necessary for the usual reasons. Its predecessor, Bridge 5188, was both functionally obsolete and structurally deficient. The steel beams and concrete deck had suffered significant deterioration, its sufficiency rating had dropped to 18.4 (on a 100-point scale), and its inventory rating was only HS-11 (for comparison, new bridges in Minnesota are designed for approximately HS-25). This was not a routine bridge replacement project, however. Several challenges had to be

overcome, and a variety of design and community issues had to be addressed by the project team.

### Local Meaning of Bridge

The existing bridge, Bridge 5188, did not have an official historic designation. However, the bridge site had major historic significance because of the predecessor to Bridge 5188. When it was built in 1932, Bridge 5188 replaced a covered bridge that had been built in 1869. Instead of being demolished, the covered bridge was removed intact and stored for many years. It was refurbished in the 1990s, and in 1997 it was once again erected over the Zumbro River at a trail crossing approximately 300 ft upstream. The Zumbrota Covered Bridge is the only historic covered bridge in Minnesota and is a source of great pride for the Zumbrota community.

The Covered Bridge's replacement also had special meaning for the community, especially the area's military veterans. Bridge 5188 had a plaque on its

## profile

### VETERANS MEMORIAL BRIDGE (BRIDGE NO. 25025) / ZUMBROTA, MINNESOTA

**BRIDGE DESIGN ENGINEER:** Minnesota Department of Transportation, Oakdale, Minn.

**ROADWAY AND PRELIMINARY BRIDGE DESIGN ENGINEER:** Yaggy-Colby Associates, Rochester, Minn.

**PRIME CONTRACTOR:** Minnowa Construction, Harmony, Minn.

**PRECASTER:** Cretex Concrete Products, Maple Grove, Minn., a PCI-certified producer

**AWARDS:** 2011 PCI Bridge Design Awards, Best Bridge with Main Spans up to 75 ft

southwest corner post dedicated to the area's fallen military veterans. The bridge served as an unofficial veteran's memorial, a distinction made more special by the local VFW Post located just off the bridge's southeast corner. Project plans and special provisions called for the plaque to be salvaged during bridge removal, and reset into the southwest corner post of the new bridge. The new bridge was fittingly renamed the Veterans Memorial Bridge by proclamation of the mayor at the project's ribbon cutting. Other features from Bridge 5188 were also replicated in the new bridge, including the ornamental metal railing and concrete rail posts, which were stylistic representations of the Covered Bridge.

While not officially historic, Bridge 5188 turned out to have more historical significance than people realized. During demolition, a time capsule was discovered within the concrete behind the veterans plaque. The time capsule contained many fascinating artifacts from the time of the 1932 construction, including a page from the local newspaper, an American Legion roster, and a listing of local soldiers who had fought in conflicts dating back as far as the Civil War. All items were given to the Zumbrota Area Historical Society. A new time capsule, containing similar items, was placed in the same location in Bridge 25025. Much of the time capsule information was in current



The original Zumbrota Covered Bridge was built in 1869, removed in 1932, refurbished, and returned to service as a trail bridge in 1997. Photo: MnDOT.

electronic formats, along with written instructions to guide a future generation on how to access the information.

### Hydraulics and New Structure

Because of funding realities, MnDOT's hydraulic design guidelines, and the limitations inherent to the site, it was determined that hydraulic improvements were not possible. Consequently, the hydraulic focus shifted to alternatives that would avoid negative upstream impacts, particularly to the Covered Bridge. The final recommendation was a two-span bridge utilizing the Minnesota 27M beam, a 27-in.-deep precast, prestressed concrete bulb tee. It was the most practical combination of beam spacing and span length. The resulting 144-ft-long bridge is 34 ft longer than the bridge it replaced and provides nearly 25% more waterway opening for the 100-year flow. It moves the pier from the middle of the stream to the edge of the low-flow channel.

The pier columns are 4 by 8 ft with 1-in. chamfers on the corners. The pier cap is 4 ft 4 in. wide and 5 ft deep over the columns tapering to 4 ft deep between each column. The bridge's two equal, simple-span lengths are 72 ft. The concrete deck is continuous over the joint but there is no continuity diaphragm around the beams. This is standard practice with precast, prestressed concrete beams in Minnesota. The beams are spaced at 6 ft 5 in. for a total width of 68 ft 6 in. The bridge provides two 12-ft-wide travel lanes, two 14-ft-wide shoulders, and 6-ft- and 8-ft-wide sidewalks.

The specified compressive strength of the beam concrete was 8000 psi. Additional durability features include epoxy-coated reinforcement and the addition of a low-slump concrete wearing course over the 7-in.-thick cast-in-place structural deck.

The erection of beams in one span was accomplished by a single crane positioned on the earthen bench near midspan that will become a future trail. A launching beam was used for the erection of the beams in the span over the river, allowing the contractor to use two smaller cranes. With the launching beam, one end of the beam was lifted



The Zumbro River shown at flood stage on September 23, 2010, toward the conclusion of construction. Photo: City of Zumbrota.

**TWO-SPAN, PRECAST, PRESTRESSED CONCRETE BEAM BRIDGE WITH SEMI-INTEGRAL ABUTMENTS, CAST-IN-PLACE CONCRETE COMPOSITE DECK, AND CAST-IN-PLACE CONCRETE ABUTMENTS AND PIERS / MINNESOTA DEPARTMENT OF TRANSPORTATION, OWNER**

**BRIDGE DESCRIPTION:** 144-ft-long, 68.5-ft-wide, two-span precast, prestressed concrete beam bridge providing sidewalk and trail over a river

**STRUCTURAL COMPONENTS:** 27-in.-deep precast, prestressed concrete bulb tees, cast-in-place composite concrete deck, drilled shaft piers, cast-in-place concrete piers, and semi-integral abutments

**BRIDGE CONSTRUCTION COST:** \$111/ft<sup>2</sup>



Looking upstream at the river pier. Photo: MnDOT.

from the transport truck and placed on a roller support on the near end of the launching beam. That end of the beam is pushed across the span, with the other end supported by a crane. Once across, the girder was set into its final position with cranes at both ends. This operation was simplified on this bridge by the presence of the earthen bench under the north span. The use of launching beams is fairly common in Minnesota.

## Foundations

Like the existing bridge, the south abutment is founded on a spread footing on rock at an elevation approximately 3 ft below streambed. The abutment is tall, with the southeast wingwall carved into the existing rock face. The north abutment, located within the roadway embankment, is approximately 60 ft from the low-flow channel, where the top of bedrock had dropped to roughly 30 ft below streambed. Consequently, the recommendation for the north abutment was a short stub abutment

on steel H-piles. Both abutments utilized MnDOT's semi-integral details, eliminating the need for expansion joints in the superstructure.

At the pier, hydraulic modeling indicated 23 ft of potential scour and drilled shafts were used for the foundations, with a 48-in.-diameter rock socket approximately 15 ft into the dolostone bedrock and a 54-in.-diameter shaft from the top of the rock socket up to streambed. Since three shafts could provide the necessary support, a single shaft was positioned beneath each of the three pier columns.

## Schedule

The contract limited roadway closure to a 14-week period beginning the second week of June and ending before the Labor Day weekend in September. In the end, the contractor was not able to meet the Labor Day completion date, and completion was further delayed by unusually wet weather and historic flooding during September. The center travel lanes of the bridge were opened

The first beam has been placed in the Veterans Memorial Bridge in Zumbrota, Minn. The launching beam is seen in the background and is used to slide the concrete beams across the river where they could be lifted by a crane located there. Photo: MnDOT.



Northwest corner showing aesthetics, including railing post and insets replicating the covered bridge. Photo: MnDOT.

to traffic at a ribbon cutting ceremony on September 17, minimizing the inconvenience to local travelers. Minor work continued on the sidewalks and railings with all work completed by the end of September 2010.

## The Final Product

The construction of Bridge 25025 was a success in many ways. It replaced a severely deteriorated bridge with a cost-effective and durable concrete structure. The 27-in.-deep Minnesota 27M bulb tee allowed for the hydraulic opening to be optimized. Additional width provided by the new bridge cross section will accommodate all modes of transportation, including snowmobiles in the winter. The lengthened bridge provides space on the river bank under the north span for a trail underpass, which will be connected to the regional trail system in the future. And, the new bridge was designed and built in a manner that emphasized the local community's focus on the site's bridge history, as well as the sacrifices made by the area's military veterans.

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*Todd R. Stevens is principal engineer at the Minnesota Department of Transportation in Oakdale, Minn.*

**For additional photographs or information on this or other projects, visit [www.aspirebridge.org](http://www.aspirebridge.org) and open Current Issue.**



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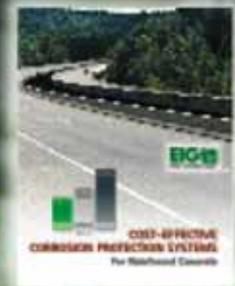


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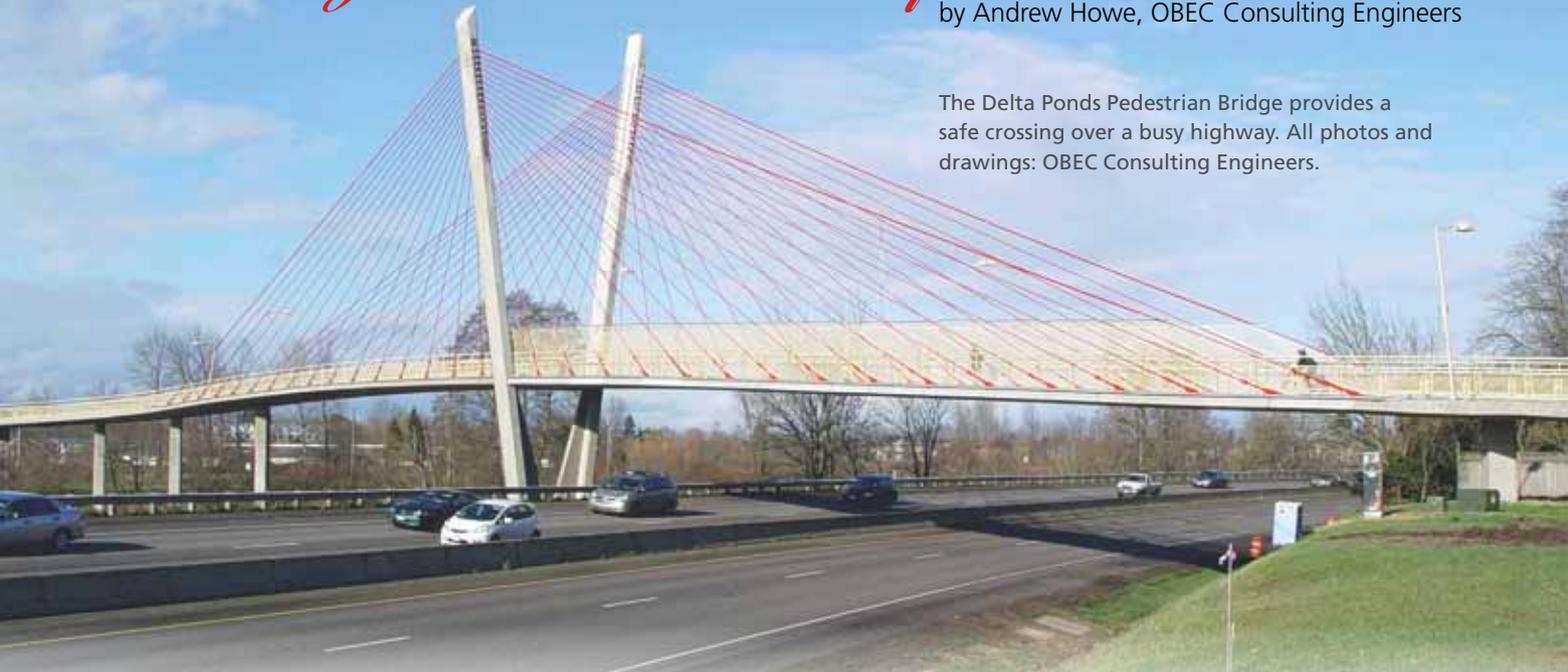
© Photo courtesy of EIG, photo by Tara Davis

# Delta Ponds Pedestrian Bridge

## *Extending a Sustainable Transportation Network*

by Andrew Howe, OBEC Consulting Engineers

The Delta Ponds Pedestrian Bridge provides a safe crossing over a busy highway. All photos and drawings: OBEC Consulting Engineers.



Eugene, Ore., is one of the leading regional areas for non-motorized commuting. A bicycle- and pedestrian-friendly transportation system is a way of life in this medium-sized university town located at the south end of the Willamette Valley. Not surprisingly, the residents of Eugene consider natural space very important and seek environmentally friendly solutions to problems.

As a result, the city of Eugene boasts an extensive path network. The city, bisected by the Willamette River and a four-lane highway, has promoted bicycle and pedestrian commuting by building paths near the river, connected by a series of bridges at strategic points. In north Eugene, Delta Highway runs roughly parallel to the east bank of the river. Historically, bicycle and

pedestrian traffic for this 2-mile-long stretch was restricted to crossing the highway at two busy interchanges.

The Delta Ponds Pedestrian Bridge, constructed in 2010, provides a key connection between the neighborhoods east of Delta Highway and the popular riverbank path system to the west of the highway. The bridge skirts the south edge of the Delta Ponds city park and natural area, a backwater pond system hydraulically connected to the Willamette River. The sweeping structure not only provides a much-needed safe crossing of the highway for bicycle and pedestrian traffic that is compliant with the Americans with Disabilities Act (ADA), it also offers a very popular and pleasant vantage point for viewing the surrounding ponds.

### Structural Form

The primary feature crossed by the Delta Ponds Pedestrian Bridge is Delta Highway. The bridge also crosses a slough immediately west of the highway and skirts one of the larger ponds in the Delta Ponds system. Keeping a light footprint on the ground dictated a bridge with a total length of 760 ft and out-to-out width of 18 ft 11 in. The width inside handrails is 14 ft.

Because it crosses the highway, the bridge occupies a visually prominent position in the landscape. Trees in the area are seldom taller than 50 ft, and buildings are no taller than two stories, so a properly proportioned structure would blend into this surrounding rather than overpower it. Spans had to be short, allowing slim columns and a shallow deck.

## profile

### DELTA PONDS PEDESTRIAN BRIDGE / EUGENE, OREGON

**BRIDGE DESIGN ENGINEER:** OBEC Consulting Engineers, Eugene, Ore.

**CONSULTING ENGINEER:** Jiri Strasky, Greenbrae, Calif.

**PRIME CONTRACTOR:** Mowat Construction, Clackamas, Ore.

**PRECASTER:** Knife River Prestress, Harrisburg, Ore., a PCI-certified producer

**CONCRETE SUPPLIER:** Eugene Sand and Gravel, Eugene, Ore.

**POST-TENSIONING CONTRACTOR:** DYWIDAG-Systems International USA, Long Beach, Calif.

Traffic clearances over Delta Highway dictated the bridge soffit elevation, and the short distance between Delta Highway and the required eastern path terminus became a significant issue during design. Because 1 ft of structure depth would add 20 ft of path length (using a 5% maximum grade), minimizing depth from soffit to finished path elevation was an absolute must if the bridge was to fit within the constrained site.

Keeping bridge foundations outside of sensitive natural areas meant that crossing the slough was a significant constraint to address. While the span over Delta Highway was 170 ft, the span over the slough was only slightly shorter at 120 ft. The required span lengths contradicted the use of a shallow, slender structure—unless a somewhat unconventional design was used.

The design team proposed a single-tower cable-stayed bridge, and the city selected it as the preferred structure type. The main cable-supported span was 170 ft with back spans of 120 ft (over the slough) and 50 ft. A series of thirteen 30-ft-long cast-in-place concrete slab spans at the west approach and a single 30-ft-long approach span at the east approach comprise the balance of the bridge's length.

### Small Footprint

The alignment of the bridge along the south side of the ponds had been used before. A 78-in.-diameter sanitary sewer line was previously constructed between the ponds and the adjacent developed property. This required the bridge to have a small footprint, meaning the use of spread footings or a pile group was not feasible. The solution was to use small-diameter drilled shaft foundations. Bedrock in the area is relatively shallow

## The bridge occupies a visually prominent position in the landscape.



Because the site is surrounding by short buildings and trees, the design team sought to blend the 760-ft-long Delta Ponds Pedestrian Bridge into its surroundings as much as possible.



The Delta Ponds Pedestrian Bridge looking over Delta Ponds. Red LED lighting along the deck edge and the top stay create a stunning effect at night.

and light loads meant that drilled shafts wouldn't normally be longer than 30 ft.

Four-ft-diameter drilled shafts were selected and installed within 10 ft of the sanitary sewer. A cast-in-place concrete column sits on each drilled shaft. There are 15 columns with a 2-ft 7-in.-square cross section and 4-in. chamfers at each corner. The tallest column is 33.5 ft long.

### Precast "V" Pylon Tower

One of the immediately noticeable elements of the Delta Ponds Pedestrian Bridge is its innovative twin-leg, "V"-shaped pylon, evoking an upside-down delta shape—the mathematical symbol typically used to denote change. The "V" shape was dictated by underground constraints because the 78-in.-diameter sanitary sewer turns to run parallel to Delta Highway,

## ASYMMETRIC, THREE-SPAN, CABLE-STAYED CONCRETE BRIDGE WITH 14 APPROACH SPANS OF CAST-IN-PLACE CONCRETE SLAB / CITY OF EUGENE, OREGON, OWNER

**BRIDGE DESCRIPTION:** A 760-ft-long concrete bridge featuring a 340-ft-long, asymmetric, three-span cable stayed section with fanned stays. The 170-ft-long main span uses partial-depth precast concrete deck panels with cast-in-place composite topping having a combined maximum thickness of 1 ft 2¼ in., which is post-tensioned together with adjacent, cast-in-place concrete spans.

**STRUCTURAL COMPONENTS:** 15 precast concrete deck panels, 10 ft long and 18 ft 11 in. wide; precast pylon legs, 86 ft long and 4 ft 0 in. by 2 ft 5¾ in.; 14 cast-in-place concrete approach slabs 30 ft long; fifteen 4-ft-diameter concrete drilled shafts support 2-ft 7-in.-square pier columns; one 8-ft-diameter shaft supports the pylon.

**BRIDGE CONSTRUCTION COST:** \$3.9 million

**AWARDS:** 2011 Federal Highway Administration Environmental Excellence Award; 2011 American Council of Engineering Companies, Oregon Engineering Excellence Honor Award



The structure's concrete V-shaped pylon tower is an impressive sight for bikers and pedestrians as they cross the Delta Ponds Pedestrian Bridge.

crossing under the bridge and limiting foundation options. Additionally, an existing storm water system crosses under the highway immediately adjacent to the pylon.

The presence of these elements confirmed the tower would require a small footprint. A pylon leg angle of just less than 8 degrees from vertical accomplished this goal, shaving more than 6 ft from the width of the foundation and allowing the use of a single, 8-ft-diameter drilled shaft.

Inconveniently, the pylon had to be located between a busy highway and a slough. Fabricating the pylon legs on site didn't seem manageable, given the limited staging area. The design team specified the use of precast concrete pylon legs. The pylon legs connect to the foundation using plates welded to steel anchors and connect to the deck using threaded inserts to attach reinforcement.

The length of each pylon leg is 86 ft. Its cross section is an irregular shape with outside plan dimensions of 4 ft 0 in. by 2 ft 5¾ in. for almost the full length. The leg tapers to a 4-ft-long knife edge in its upper 3 ft. The use of a precast concrete pylon had several advantages. Tighter controls on concrete mix design, concrete placement, and curing allowed the use of higher-strength concrete in the pylon legs. The specified concrete compressive strength was 6000 psi. Precasting meant higher confidence

for concrete consolidation in the congested areas at the stay connections, deck connections, and tower base. To enhance the strength of the pylon legs without increasing their dimensions, two 1¾-in.-diameter, ASTM A722 post-tensioning bars extended from the base of the legs approximately 60 ft to almost the stay anchorages. The bars were tensioned in the precast fabrication plant to a total force per leg of 332 kips.

### Over Traffic

Much of the Delta Ponds Pedestrian Bridge could be constructed on falsework, but this wasn't an option over Delta Highway because of the highway's heavy traffic. Building on previous experience on similar bridges (see *ASPIRE™* Fall 2010), a construction sequence was developed

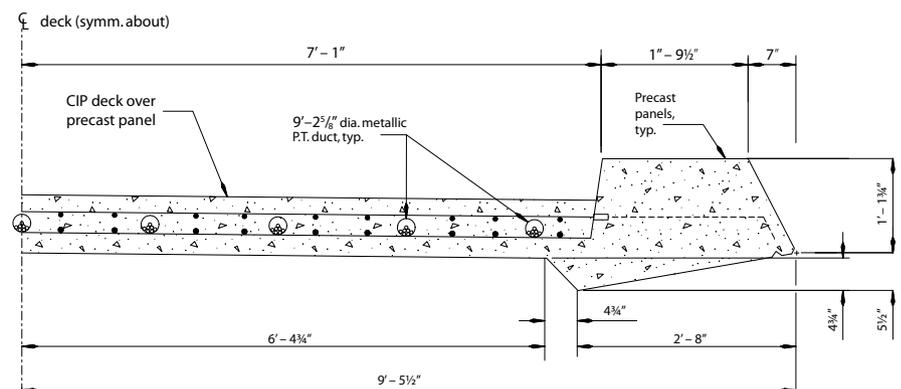
that cantilevered precast concrete deck panels over the highway. This sequence eliminated the need for daytime lane closures on Delta Highway, minimizing impacts to public traffic.

The back spans and 10 ft of the main span were constructed on falsework in advance of construction over Delta Highway. Precast panels were placed during lane closures at night. The stays were then connected and adjusted during the day. The 15 deck panels were partial depth to limit the handling weight and allow for a cast-in-place topping that provides a smooth riding surface. Precast deck panels were 10 ft long, 18 ft 11 in. wide, and 1 ft 7¼ in. thick at the curbs. The specified concrete compressive strength was 6000 psi.

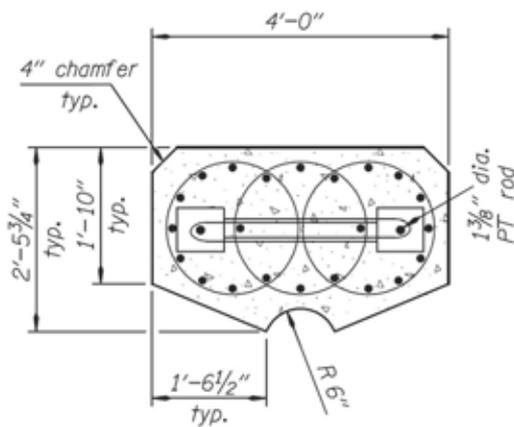
As deck construction advanced, deck grades and stay stresses were checked regularly. Forces in the stays were small, and a simple hydraulic jack system allowed for unloading the lower portion of a stay so that a coupling nut could be turned to adjust the stay length.

### Topping It Off

The cast-in-place concrete topping compressive strength was specified to be 5000 psi, the same as the cast-in-place spans. The topping contains a longitudinal post-tensioning system to control stresses in the deck panel joints. The panel joints are designed as they would be in a precast segmental structure, with zero tension under design service loads. This post-tensioning extends just over half the total bridge length, terminating



Half section of the precast deck panel with cast-in-place topping slab and post-tensioning shown. The deck cross-sectional dimensions were constant throughout the bridge.



Section through a pylon leg between the bottom and the first stay anchor.

at a deck joint in span 11. The post-tensioning consisted of nine tendons each with seven 0.6-in.-diameter strands evenly distributed across the deck.

### Finishing Touches

Late in the project development, the city of Eugene secured additional funding through the American Reinvestment and Recovery Act (ARRA), which led to the installation of energy-efficient LED luminaires to replace the planned incandescent bulbs.

In addition to the energy-efficient luminaires, the ARRA funds allowed

additional aesthetic touches to be added, including red LED rope lights on the deck edge and top stay of the main spans that make the bridge a strong visual experience day and night, pushing the bridge toward “landmark” status within the community.

In November 2010, the Delta Ponds Pedestrian Bridge opened for use. Long awaited by the public, the bridge was instantly appreciated for its graceful form and has become a beacon for bicyclists and pedestrians, adding to Eugene’s reputation for accommodating environmentally friendly commuting options.

*Andrew Howe is senior project engineer with OBEC Consulting Engineers in Salem, Ore.*

**For additional photographs or information on this or other projects, visit [www.aspirebridge.org](http://www.aspirebridge.org) and open Current Issue.**



Daytime closures on Delta Highway were out of the question, so crews erected the precast concrete pylon tower and placed the precast deck panels at night.



Placing the main span topping slab on the precast panels. The longitudinal post-tensioning ducts can be seen between the curbs of the precast panels.

## AESTHETICS COMMENTARY

by Frederick Gottemoeller



This bridge is an excellent example of how a community can get more use out of a favored and well-loved park. The alignment itself reminds one of a stroll through the woods. It curves around obstacles and over conflicting uses like a meandering park walkway, but in the air.

On its way it creates a dramatic landmark for the community and the park. The tower and cable planes impose an easily understood geometric silhouette on the sky. The tower’s arms are simple, thin rectangular prisms. The angle of the tower’s arms is well chosen. The tower recalls the triumphant “Touchdown” gesture well known in football. Bracing of the arms at their base is achieved not by thickening the arms, but by thin triangular walls, leaving a V-shaped slot that preserves the view through the tower. The arms end equally well, with a simple diagonal slice.

The semi-harp stay pattern is also well chosen. The stays create a fascinating moiré pattern of interacting lines that shift and change as drivers move under the bridge. The red color brings out the pattern on both sunny and cloudy days. The lighting of the upper stay preserves the bridge’s memorable image at night.

Finally, the short spans on the approach allow the thin deck of the cable-supported span to continue unchanged to the abutment, giving the whole structure a unified appearance. Short spans allow thin columns. Even though there are many of them, their thinness and their simple shape means that the views through the bridge are not significantly interrupted. Designers often assume that long spans are better for appearance. That is true in many cases, but this is not one of them. Plus, the economy of the short spans has allowed the community to obtain a signature bridge at a remarkably low price.

# THE BENSON ROAD BRIDGE OVER I-405

*Extending Precast Concrete Spans with Washington State's "Super Girders"*

by Paul Guenther, Ben C. Gerwick Inc. and Hong Guan, CH2M HILL

The I-405 Renton, Wash., Stage 2 design-build project provides improvements to accommodate high occupancy vehicles and new freeway connections to local arterials of the city of Renton. As part of this project, the existing 1970s vintage Benson Road Bridge over I-405 was replaced with a new, wider, longer bridge that enabled widening of the freeway below. The project was part of the Washington State Department of Transportation's (WSDOT's) I-405 Corridor Improvements Program.

## Superstructure Description

The replacement bridge provides for two traffic lanes, two bicycle lanes, and one sidewalk for a curb-to-curb width of 40 ft. The bridge consists of a three-span structure with spans of 132, 207, and 182 ft. The bridge was constructed with spliced precast, post-tensioned concrete girder technology.

Span 1 used single segment precast girders and Spans 2 and 3 used two-segment precast girders.

Four girder lines were used, with the multi-segment spans erected on temporary falsework bents. The field-cast girder and pier closure placements were constructed monolithically with the bridge deck placement. The bridge was then post-tensioned, followed by placement of the abutment end diaphragms. The girders were then jacked up at the abutments to re-set the elastomeric bearings to relieve short-term deformations caused by post-tensioning. The final result was a highly efficient, cost-effective, durable, fully composite structure. The bridge construction was completed ahead of schedule and was opened to traffic in July, 2010.

## Options Considered

The replacement for the existing Benson Road Bridge was conceptualized as a five-span curved steel plate girder bridge in the original request for proposal (RFP) documents. At 845 ft long, the RFP design represented a significant portion of the total project construction cost. The long lead time for the procurement of steel also posed a significant scheduling risk to the overall project.

During the proposal stage, the design-build team considered various alternatives. Most significant was changing the overcrossing alignment and the use of different structure types and materials. The final solution selected was a three-span alternative that would significantly shorten the overall bridge length to approximately 521 ft. The revised alignment also allowed the bridge structure to be

The Benson Road Bridge over I-405 in Renton, Wash., has spans of 132, 207, and 182 ft and at a 45-degree skew. All photos: CH2M HILL.



## profile

### BENSON ROAD BRIDGE / RENTON, WASHINGTON

**BRIDGE DESIGN ENGINEER:** CH2M HILL, Bellevue, Wash.

**PRIME CONTRACTOR:** I-405 Corridor Design Builders (a joint venture between CH2M HILL and Gary Merlino Construction Co.), Renton, Wash.

**BRIDGE SPECIALITY CONTRACTOR:** Mowat Construction Company, Woodinville, Wash.

**PRECASTER:** Concrete Technology Corporation, Tacoma, Wash., a PCI-certified producer

**POST-TENSIONING CONTRACTOR:** VSL, Wheat Ridge, Colo.

## The final solution would significantly shorten the overall bridge length.

placed along a tangent alignment, thus making a precast concrete option more feasible. The revision required an additional off-ramp flyover bridge over Benson Road that was also a precast concrete structure. It was needed to accommodate the new roadway alignment, but the reduction in total deck area and the change from steel to precast concrete reduced the total bridge cost by over \$700,000. The use of concrete in lieu of steel also reduced future maintenance requirements and was perceived as an advantage by the owner.

### Design Constraints

Located in an urban environment, the project site is geometrically constrained. The owner's requirement to maintain all lanes of traffic on Benson Road and the I-405 freeway below during construction added additional constraints. To avoid excessively long spans, one of the center piers (Pier 3) needed to be located in the median of mainline I-405 and was thus constrained by the existing freeway on both sides. In order to limit the disruption to traffic, all construction work for Pier 3 had to be performed within a 20-ft-wide work zone centered within the median. Carefully designed shoring was needed with construction tolerances limited to a few inches. The orientation of the I-405 median relative to the new bridge alignment also dictated that the bridge would have to be placed on piers with 45-degree skews.

The uneven terrain at the project site also played an important role in the design. In order to accommodate a future on-ramp near the south end of the bridge, one of the two intermediate piers had to be designed significantly taller than the other pier. This resulted

in a significant challenge to the seismic design of the bridge.

Although the project scope only involved widening existing I-405 to four lanes in each direction, the replacement bridge needed to accommodate a future widening adding a total of four more lanes. To meet this requirement, the longest span of the replacement bridge needed to be in excess of 200 ft.

### Girder Selection

Conventional prestressed concrete girders were first considered due to their lower cost and the contractor's familiarity with them. Prior to 2008, the longest spans achieved with conventional precast, prestressed concrete girder sections available in Washington State was approximately 180 ft, well short of the required span. Post-tensioned, precast spliced-girders quickly emerged as feasible for several reasons. First, span lengths in excess of 200 ft were readily achievable. Secondly, spliced-girders provide the designer with greater latitude in selecting the number and location of piers, segment lengths, and splice locations—an important requirement for this project due to the extremely constrained site. Lastly, although the span lengths for spliced-girder bridges may be comparable to those of typical box girder bridges, construction methods are more conventional and falsework requirements are reduced.

Shortly after the start of preliminary design in late 2008, a new series of WSDOT precast girder sections became available. Called the WF100G/PTG, the 100 is the depth in inches (8 ft 4 in.) and the PTG indicates a post-tensioned girder section. Together with the WF83G and WF95G standards, these



Pier 2 nears completion of its column beam. Seismic isolation casings can be seen around the columns just above the ground.



Pier 3 shown during construction in the confined area in the median of I-405.

precast sections are commonly referred to as "super girders." In the case of WF100G girders, the span capability exceeds 200 ft. Although conventional pretensioned WF100G girders could achieve the span length required for the Benson Road Bridge, the design team eventually chose post-tensioned spliced girders in order to minimize transportation concerns.

The locations of the girder splices were selected so that shoring towers could be constructed with minimal impact to traffic on I-405. The first span consisted of a single segment, 125 ft long. The center span used two 100-ft-long segments. In the third span, the girders were splayed to accommodate the

SPLICED, POST-TENSIONED PRECAST GIRDER BRIDGE / WASHINGTON STATE DEPARTMENT OF TRANSPORTATION, OWNER

**BRIDGE DESCRIPTION:** A 521-ft-long, three-span, spliced, post-tensioned precast concrete girder bridge with spans of 132, 207, and 182 ft and a width of 40 ft inside curbs

**STRUCTURAL COMPONENTS:** 20 WSDOT WF100G/PTG precast concrete girder segments with composite cast-in-place concrete deck with full length post-tensioning and cast-in-place concrete substructure

**BRIDGE CONSTRUCTION COST:** \$5.0 million (\$200/ft<sup>2</sup>)

**AWARDS:** 2010 American Society of Civil Engineers, Seattle Chapter, Project of the Year, Structures Category



The 8-ft 4-in.-deep girder is shown during production in the precast production building.



One of the longest girder segments at 125 ft is shown being transported to the site during nighttime erection to reduce impact to traffic.

deck flare at the northern end of the bridge. The longest segments were approximately 100 ft long and the shortest segments approximately 75 ft long. The closures between segments were 2 ft 0 in. long. Fabricating the two longer spans using two girder segments each provided for segment sizes that were more easily transported and erected. Each segment was pretensioned for handling, shipping, and erection.

## Post-Tensioning

After the girder segments were erected and the concrete at the closures, diaphragms, and deck had been placed, post-tensioning was applied to the full length of the bridge to connect all segments into a continuous, fully composite structure. Post-tensioning after deck placement allowed the full composite section to be utilized for a portion of the dead load, thus maximizing the structural efficiency.

A total of four 19-strand post-tensioning tendons were used for each girder, stressed to a maximum of 3400 kips per girder at the time of jacking. The tendons were composed of 0.6-in.-

diameter strands in 4-in.-diameter metal ducts. Post-tensioning was applied from one end, during which the girders lifted from their temporary supports on the shoring towers that were then removed. Then, the sidewalk and traffic barriers were installed. In addition to the enhanced structural efficiency of the resulting system, a fully composite, post-tensioned structure has the added benefit of being entirely in compression under service loads, thus eliminating flexural cracking in the deck and increasing the durability of the structure.

## Considerations for Deep Girders

Although conventional pretensioned WF100G sections can span to 220 ft, the significant size and weight of the girders pose concerns for shipping and handling. At 205 ft long, the shipping weight of a single WF100G girder is approximately 250 kips. Special trucking equipment is required to haul these larger girders within legal load limits. Although the precast industry is usually equipped with these vehicles, it was decided to use shorter girder segments.

The WF100G girders are also almost 9 ft tall including the height of the protruding shear stirrups. When on the haul truck carriage, the top of the girder is over 15 ft above the roadway surface, approaching the vertical clearance limit of many bridges currently in service. An adequate haul route to the site must be assured.

To use these larger beams, crane access, reach, and maneuverability must be carefully evaluated for each site. The girder segment weight and length are both significant factors. The girders require a well-planned erection scheme. In the case of the Benson Road Bridge, a Sicklesteel 650-ton wheeled crane was used for girder erection—one of the largest wheeled cranes available in the United States.

## Broader Applications

The precast concrete bridge industry is continuing to make advancements that result in more cost-efficient solutions. Advances reduce material quantities and speed construction, making better use of today's limited capital project dollars. The application of precast "super girders," combined with spliced construction techniques, is a prime example of these advancements. Once

used primarily for larger and more exotic long-span bridges, this technology is quickly becoming more mainstream, with fabricators, construction contractors, and design engineers all becoming increasingly comfortable with their routine applications.

Effective use of precast concrete spliced super girders requires special design and construction considerations that may limit their use at some sites. However, with proper foresight and planning, these obstacles can be overcome at many sites, making this an effective solution for a wide range of bridge projects, from smaller grade separations and stream crossings to major bridges.

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*Paul Guenther is area manager with Ben C. Gerwick Inc. in Seattle, Wash. He was the engineer of record with CH2M HILL during the project. Hong Guan is structural engineer with CH2M HILL in Bellevue, Wash.*

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A 125-ft-long segment is being erected in Span 1.



Epoxy-coated reinforcing steel was used to extend the life of the cast-in-place concrete deck.

# Little Cedar Creek Bridge— Big Innovation

by Brian P. Moore, Wapello County



The underside of the completed Little Cedar Creek Bridge showing ultra-high-performance concrete (UHPC) waffle panels on conventional precast, prestressed concrete I-beams. All photos: Wapello County.

**B**ridge engineers are seeking new ways to build better bridges, reduce work zone travel delays, and reduce maintenance costs. Agencies are challenged with replacing critical bridge components with minimal disruption to the traveling public. Using ultra-high-performance concrete (UHPC) for precast panels and connections is a new system that offers great potential for both new and rehabilitation bridge projects.

In the fall of 2011, Wapello County, Iowa, used UHPC two-way-ribbed, modular deck panels (waffle panels) and UHPC field-cast, continuity connections to construct the Little Cedar Creek Bridge. All connections from panel to panel and from panel to beam used UHPC. The bridge consists of 14 waffle panels. The panels are 15 ft long, 8 ft wide, and 8 in. deep, with the top flange portion of the “waffle” squares only 2½ in. thick. The waffle panels sit on conventional precast, prestressed concrete I-beams, 39 in. deep, spanning 63 ft. The bridge is 32 ft 2 in. wide. The panels are connected to the beams by reinforcement extending from the beams into the space between the ribs of the panels and the tops of the beams. This reinforcement is encapsulated with UHPC.

This first-of-its-kind bridge has proven very successful. The design of the bridge and

initial testing was by the Iowa Department of Transportation. The design was relatively straight forward and utilized the unique properties of UHPC. Production of the panels was by Coreslab Structures Inc. in Omaha, Neb., and was completed with ease, with very few adjustments to existing technologies or processes. The UHPC was furnished by Lafarge North America Inc. Construction moved quickly due to the use of the modular panels and readily available equipment, materials, and techniques. The UHPC field casting process was new to the contractor, Bloomfield Bridge & Culvert, and required some additional early instruction, but the process went quickly and smoothly.

Overall the Little Cedar Creek Bridge project was a huge success exceeding all expectations of Wapello County. It shows how UHPC can change the way bridge decks are constructed and can significantly extend the service life of highway infrastructure in this country. Wapello County believes that UHPC has not only performed well in this project but shows great promise for innovation in the future.

*Brian P. Moore is the Wapello County engineer in Ottumwa, Iowa*



The Little Cedar Creek Bridge in Wapello County, Iowa.



Short extended reinforcing bars are shown in the longitudinal and transverse joints prior to placing the UHPC field-cast closures.

## EDITOR'S NOTE

More articles that mention this project or UHPC field-cast connection techniques, can be found in these issues of ASPIRE:™

- Fall 2009, “Route 31 Bridge over Canandaigua Outlet,” pp. 28-30.
- Summer 2010, FHWA: “Deployment of Ultra-High-Performance Concrete Technology,” pp. 50-51.
- Fall 2010, FHWA: “The Highways for LIFE Pilot Program,” pp. 42-43; Winter 2011, Wapello County, p. 46.

# THE BRIDGE AT PITKINS CURVE

## *One Less Bend in the Road*

by Mike Van de Pol and Pete Norboe,  
California Department of Transportation

The California Department of Transportation (Caltrans) is currently making improvements to Highway 1 along the rugged Big Sur Coast in Monterey County. The Pitkins Curve project site, located north of Limekiln State Park, is characterized by steep slopes high above the Pacific Ocean and is one of many geologically dynamic sections on this remarkable highway. Noted for its spectacular views of the rocky coastline, the road is both a state scenic highway and a national scenic byway. Seven graceful concrete spandrel arch bridges, rock masonry retaining walls and parapets, and drinking fountains along the 75-mile corridor form memorable features of the Carmel-San Simeon Highway Historic District. Construction of the two-lane highway in the 1920s and 1930s was a remarkable engineering feat; maintaining it in the twenty-first century is another.

Besides its historical and scenic values, Highway 1 is the only direct link

between numerous small communities and isolated residences dotting the Big Sur coast. The Pitkins Curve project will restore highway reliability, decrease maintenance expenditures, and improve safety for motorists and highway workers alike. To accomplish these goals, a new bridge is being constructed that addresses the challenging geologic instabilities found at the site.

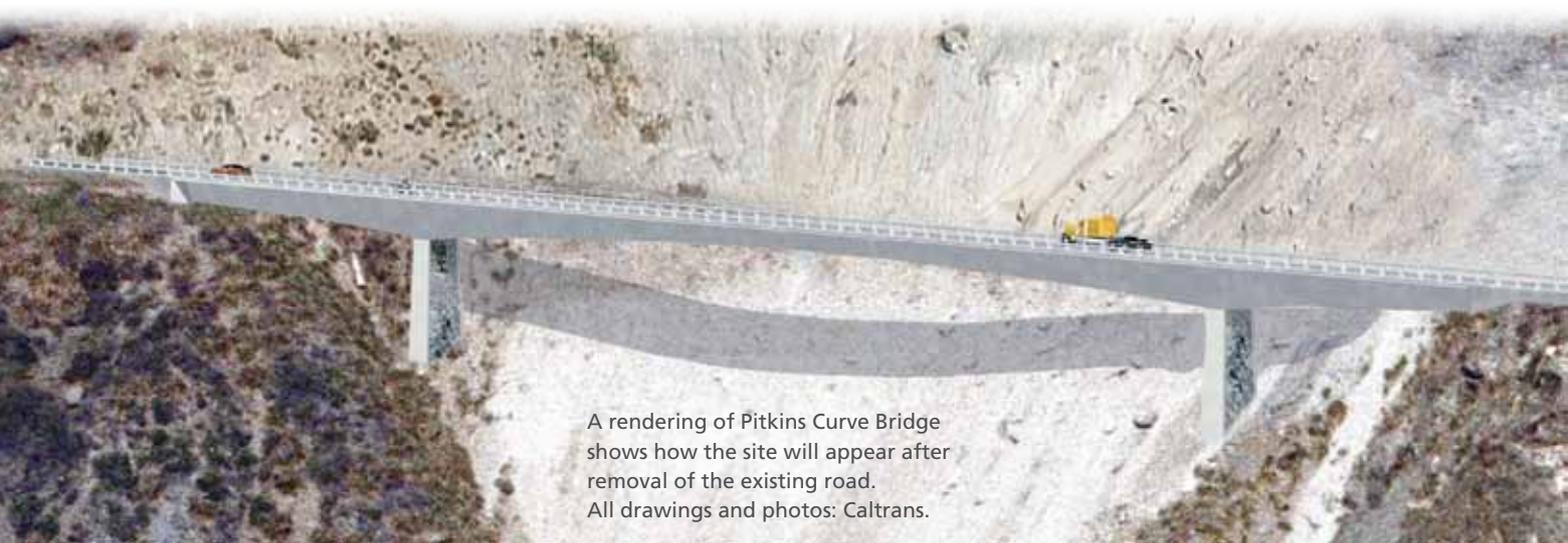
### Understanding the Risk

Unstable geology and winter storms cause unpredictable and extensive landslides and rock falls at Pitkins Curve, regularly reducing or interrupting travel for months at a time, and creating significant hardship for travelers and the coastal communities. Highway restoration is generally conducted under emergency conditions, which increases the risk to highway workers, elevates costs, restricts the range of restoration methods available, and limits ways to avoid or minimize impacts to traffic movement, the economy, and the environment. Even routine management

of landslides at this location is riskier and has higher maintenance costs than other locations on the Big Sur Coast Highway. Caltrans geologists and geotechnical engineers studied the slopes at Pitkins Curve, concluding that the hillside would continue to slide, rocks would continue to fall, and the highway would continue to be damaged and severed repeatedly unless mitigation measures were taken.

### The Solution Becomes Apparent

The design selected for the Pitkins Curve Bridge is founded on geologically stable rock formations and spans the unstable slide region. The three-span, 620-ft-long structure carries two-way traffic. The structure has end spans of 154 ft 6 in. and a main span of 311 ft. The structure width at the deck level is 35 ft 6 in., with the roadway section carrying two 12-ft-wide lanes and two 4-ft shoulders. The traveled way is bounded by Type 80 concrete barriers with steel pipe hand railings affixed to the barriers for



A rendering of Pitkins Curve Bridge shows how the site will appear after removal of the existing road. All drawings and photos: Caltrans.

## profile

**THE BRIDGE AT PITKINS CURVE / HIGHWAY 1 NORTH OF LIMEKILN STATE PARK, MONTEREY COUNTY, CALIFORNIA**

**BRIDGE DESIGN ENGINEER:** California Department of Transportation, Sacramento, Calif.

**GENERAL CONTRACTOR:** Golden State Bridge Inc. (GSB), Martinez, Calif.

**CONTRACTOR'S CONSTRUCTION ENGINEER:** NRV Bridge Design, Gualala, Calif.

**POST-TENSIONING SUPPLIER:** CMC Rebar Company, Fresno, Calif.

**READY-MIX CONCRETE SUPPLIER:** Graniterock, Watsonville, Calif.

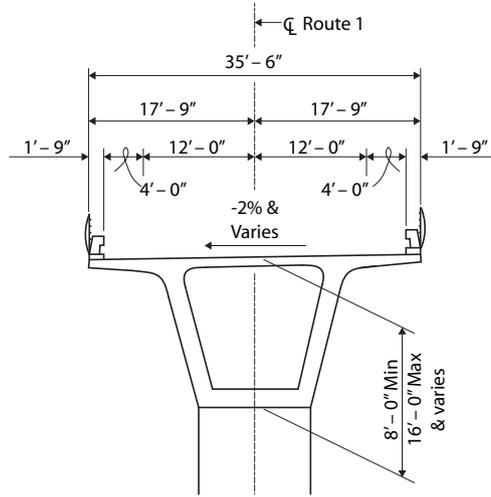
pedestrian and bicyclist safety. Different elements of the barriers have imprinted architectural treatments and all will have staining that includes flecking to match the colors of the local environment.

### The Bridge Geometry and Siting

The structure follows a tangential alignment. The vertical change in deck profile grade between one end of the bridge and the other is 39 ft. The profile consists of two vertical curves followed by a straight 7% grade portion. Superelevation of the deck is a constant 2%. Because of the inherent site complexities and geologic instabilities, it was considered not feasible to employ falsework in the main span located over the slide area. Consequently, segmental construction was used. The proximity of the abutments to the main bridge piers and the stability of the geology at these locations did, however, allow the end spans to be constructed on falsework.

### Superstructure

The superstructure is a cast-in-place, post-tensioned concrete, variable-depth box girder with inclined webs supported by single-column piers. The main span was constructed segmentally with a single form traveler working from each end. The form traveler was launched from the pier cantilevers that extend 35 ft 9 in. from the centerline of the piers. In addition, there are sixteen 14-ft-long girder segments plus an 11-ft 6-in.-long closure segment in the main span. The variable depth follows a parabolic curve in all spans. The typical box section complies with the American Segmental Bridge Institute standard guidelines for its configuration. Overall box girder depth varies from 16 ft at the faces of pier caps to 8 ft near the abutments and at midspan. Deck overhangs are 8 ft wide, tapering from 1 ft 7 in. thick at the web to 10 in. at the edge. The minimum deck thickness is 10 in. The soffit of the box girder varies in



Girder cross section.

thickness from 24 in. at the faces of the pier caps to 9 in. within the spans.

The superstructure is supported on the abutment seats by two polytetrafluoroethylene bearing assemblies. The superstructure end diaphragms are thicker than usual to act as counterweights against uplift potential due to the short end spans. No vertical tie down anchors are used. The movement expected at the abutments due to thermal and other factors is 4 in. Full-width approach slabs are 30 ft long.

With the closure segment completed, the form traveler is being removed from the north end of the bridge. Bridge railings remain to be constructed and falsework under the end spans removed.



### Substructure and Abutments

The piers are slightly tapered rectangular, cast-in-place concrete single columns, varying from 9 ft 0 in. by 12 ft 3 in. at the top to 12 ft 0 in. by 12 ft 3 in. at the bottom. Due to the variation in site and substrata conditions, the columns are 45 and 61 ft tall. The tops of the columns employ slight parabolic flares in two directions. The columns are reinforced with two interlocking circles of No. 14 bundled continuous bars. These bars extend from full footing embedment to full cap embedment. The columns are made integral with the pier cap at the superstructure level. The pier caps are 16 ft deep, 12 ft long, and of variable width to match the box girder sections.

The columns are supported by and integral with concrete footings, which are 8 by 25 by 25 ft, highly reinforced and founded on four, 5-ft 6-in.-diameter, cast-in-drilled-hole piles socketed into competent rock. Vertical tie downs, which are near full pile length, and which have external anchorages at the top of the pier footings, are employed within all pier piles. The tie downs comprise ten 0.6-in.-diameter strands in a single 2¾-in.-diameter duct that are splayed

## CAST-IN-PLACE, POST-TENSIONED, CONCRETE BOX GIRDER BRIDGE WITH CAST-IN-PLACE RECTANGULAR COLUMN PIERS, CAST-IN-PLACE FOOTINGS, AND CAST-IN-DRILLED HOLE PILES / CALIFORNIA DEPARTMENT OF TRANSPORTATION, OWNER

**BRIDGE DESCRIPTION:** A 620-ft-long, cast-in-place concrete, variable-depth, box girder bridge with main span of segmental construction and side spans cast on falsework. The side span lengths are 154.5 ft and the main span is 311 ft long. The substructure column piers are 12 ft 0 in. by 12 ft 3 in. at the base and are 45 or 61 ft tall.

**BRIDGE CONSTRUCTION COST:** \$11.5 million



A form traveler was used to cast the 14-ft-long segments. After completing the south cantilever, shown here, the traveler was relocated to the north span cantilever.

at the bottom, each with an anchor head. Permanent steel casings 5 ft 6 in. in diameter are employed at all pier pile locations. Overall pile lengths vary from 69 to 95 ft; steel casing lengths vary from 19 to 35 ft; and rock sockets vary in depth from 50 to 60 ft. Extensive shoring was required to construct the main bridge piers.

The abutments are traditional cast-in-place, concrete seat type abutments, 6 ft thick, and varying from 14 to 18 ft in height. Traditional wingwalls at each end of the abutments are from 24 to 30 ft long. The abutments are founded typically on twin, 5-ft-diameter, cast-in-drilled-hole piles, socketed into competent rock at depths ranging from 32 to 44 ft. The finished grade adjacent to the pier columns and Abutment 1 is contoured for passage of slide debris and rocks dislodged from the adjacent rock shed.

## Concrete and Reinforcement

The specified 28-day concrete compressive strengths were as follows:

- Main pier footings and piles, 5000 psi
- Pier columns, 6000 psi
- Integral pier caps and superstructure, 7000 psi
- All abutment components, except the piles, 3600 psi

Due to the size of the pier caps, columns, and footings, mass concrete temperature control systems were designed and implemented. This included plastic tubing with circulated water and a monitoring system that was successful in controlling curing temperatures to prevent cracking.

All nonprestressed steel reinforcement in the concrete barriers, approach

slabs, bridge deck, box girder stirrups, pier cap stirrups and top bars, and top reinforcement and stirrups in the abutment diaphragm are epoxy coated due to the marine environment. The remaining box girder reinforcement is uncoated, except for those additional longitudinal bars close to the deck. None of the reinforcement in the columns or abutments is epoxy coated.

## Post-tensioning

All post-tensioning used 0.6-in.-diameter 270 ksi strands. The specified concrete strength at stressing was 5500 psi.

In the end spans, three draped tendons in each web extend from the abutment diaphragms through the pier table cantilevers. The force in each of these tendons was 867 kips for a total force of 2600 kips per web. There are approximately 20 strands per tendon and the post-tensioning was done in two stages.

Another group of nine tendons is located within the deck adjacent to the webs. Three tendons extend from the abutment diaphragm and six

from deck mounted deviator blocks in the end spans. They extend over the piers and terminate at the various construction joints in the main span. The post-tensioning force was 700 kips per tendon, with approximately 16 strands per duct. One duct per web was designated for additional stressing if needed. These ducts are made continuous over the three spans of the structure. They were not used and were filled with grout, after the closure pour was completed.

The continuity post-tensioning is composed of two groups of six main span tendons, located within the soffit adjacent to each web. These extend between soffit-mounted deviator blocks located at varying distances from the closure segment. The force is 800 kips per tendon using approximately 19 strands per duct. One duct at each web was designated for additional stressing if needed. These ducts were not used and were filled with grout, after the closure pour was completed.

The fourth post-tensioning group is designated for future post-tensioning. Allowance is made for a single 4½-in.-diameter duct adjacent to each web. Internal diaphragms and deviator blocks are employed to provide the anchorage and directional change points for these ducts.

---

*Mike Van de Pol is senior bridge engineer and Pete Norboe is structures engineer, both with the California Department of Transportation, in Sacramento, Calif.*

**For additional photographs or information on this or other projects, visit [www.aspirebridge.org](http://www.aspirebridge.org) and open Current Issue.**

With segment casting completed on the south cantilever, the form traveler approaches completion of the north cantilever leading to the closure placement to complete the bridge.





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# A GRAND CONNECTIVITY IMPROVEMENT IN THE GRAND VALLEY

## THE 29 ROAD BRIDGE AND I-70B RAMP

by Jeff Mehle, Jacobs Engineering Group Inc.

The 29 Road Bridge and I-70B Ramp project is the most recent infrastructure improvement in Grand Junction, Colo., to enhance transportation connectivity in the Grand Valley. Earlier improvements for mobility and access included the Riverside Parkway along the southern end of Grand Junction in 2008 and the 29 Road crossing of the Colorado River in 2006. The 29 Road and I-70B improvement is a joint effort by the city of Grand Junction and Mesa County to extend and connect 29 Road from these earlier infrastructure improvements north to I-70 Business Loop (I-70B). The project includes nearly 4 miles of roadway and a bridge that crosses over the Union Pacific Railroad (UPRR) switchyard and mainline tracks, Fruitvale Irrigation Ditch, and I-70B. A ramp structure on the west side of the 29 Road Bridge provides access from eastbound I-70B.

### Spanning the UPRR

A significant challenge was how to design the bridge to span over UPRR's nine active tracks and accommodate five future tracks while maintaining the required roadway access and vertical and horizontal clearances. The minimum required vertical clearance over the rail tracks is 23 ft 6 in. and over I-70B is 16 ft 6 in. Mechanically stabilized earth (MSE) retaining walls support

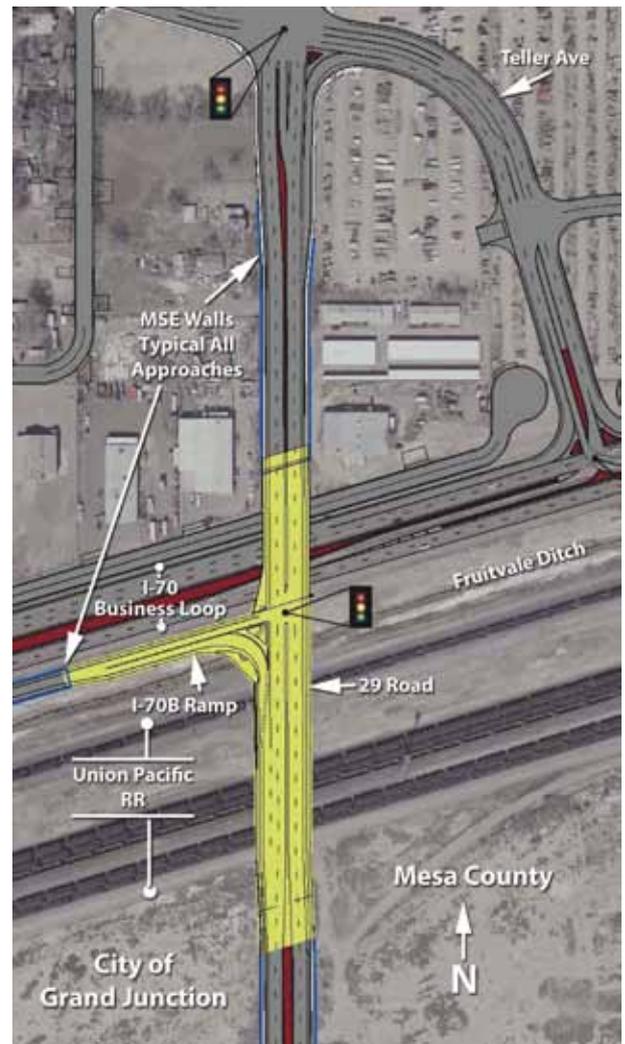
the roadway approach fill at both ends of the bridge. The designers determined the limits of the bridge structure and roadway approaches by balancing the cost of the bridge with the cost of the tall walls at each end. The design solution used 67,000 ft<sup>2</sup> of MSE retaining walls with a maximum wall height of 30 ft on the south end of the bridge.

### Spliced Girder Design

A life-cycle cost analysis for the bridge examined the initial cost, construction constraints, and long-term maintenance cost before arriving at the splice-girder design as the optimum solution to span the rail yard. To minimize the structure depth while meeting the vertical clearance over the UPRR tracks, three spans over the UPRR right-of-way were designed as precast, pretensioned and post-tensioned spliced girders. Post-tensioning made the girders continuous over the piers prior to the deck placement, thereby optimizing the design. This allowed the structure depth and wall heights to be

reduced, and the girder spacing to be increased, which reduced the number of girders needed.

The three span lengths over the UPRR are 135, 157, and 138 ft with the pier columns placed between the existing and future tracks and access roads. The 72-in.-deep Colorado Department of Transportation (CDOT) bulb-tee girder was modified with end blocks for the coupling of post-tensioning ducts and to accommodate the tendon



Location of the 29 Road Bridge and I-70B Ramp in Grand Junction, Colo. Illustration: Jacobs Engineering Group Inc.

## profile

### 29 ROAD BRIDGE AND I-70B RAMP / GRAND JUNCTION, COLORADO

**BRIDGE DESIGN ENGINEER:** Jacobs Engineering Group Inc., Denver, Colo.

**PRIME CONTRACTOR:** Lawrence Construction, Littleton, Colo.

**PRECASTER:** Plum Creek Structures, Littleton, Colo., a PCI-certified producer

**CONCRETE SUPPLIER:** United Companies, Grand Junction, Colo.

**POST-TENSIONING CONTRACTOR:** VSL, Wheat Ridge, Colo.

**REINFORCEMENT SUPPLIER:** CMC Banner Rebar Inc., Denver, Colo.

## The bridge spans over nine active and five future railroad tracks.

anchorages. With a maximum girder spacing of 10 ft 3 in., the spliced girders allowed the design team to eliminate at least two girder lines and reduce the structure depth by over 1 ft compared to a conventional girder design. This shallower structure depth also allowed the roadway profile to be lowered an equal amount, resulting in reduced costs for approach fill and MSE walls.

The remainder of the 29 Road Bridge and the ramp structure were constructed using conventional 72-in. and 63-in.-deep precast, prestressed concrete bulb-tee girders with a design concrete compressive strength of 8500 psi. The width of the 29 Road Bridge varies from 95 ft 3 in. at the connection to the I-70B Ramp to 79 ft 0 in. on the north approach end, accommodating two travel lanes, a bicycle lane and a sidewalk in each direction, and a right turn acceleration lane from the ramp access. The four spans north of the UPRR tracks over Fruitvale Ditch and I-70B measure 118, 69, 104, and 58 ft. The total length of the 29 Road crossing is 779 ft.

The ramp structure from I-70B tees into 29 Road and is 320 ft long with a span configuration of 70, 80, 75, 47, and 48 ft. The ramp has a minimum width



The completed 29 Road Bridge and the intersection of the I-70B Ramp on the left. Photo: Paul Jagim, City of Grand Junction, Colo.

of 30 ft 10 in. to carry two lanes of traffic with shoulders. The ramp flares to a maximum width of 110 ft 6 in. at the connection with the 29 Road structure to provide left and right turn movements. The geometry at the end of the ramp was challenging because the last span is flared wider on each side. It spans between skewed supports and the final deck cross-slope had to match the profile of the center span on the 29 Road Bridge. To solve the span geometry, additional flared girders were added to the cross section, and the ramp span deck was not cast until the center span was constructed to help match the elevations.

### Fabrication and Shipment of Girders

The girders were fabricated in Littleton, Colo., southwest of Denver and shipped 250 miles to Grand Junction on I-70. At the Continental Divide, I-70 passes through the Eisenhower Tunnel, which has a limited vertical clearance. Depending on the transport equipment used, deeper girders, such as an 84-in.-deep bulb-tee section, would have difficulty with the limitations of the tunnel. The alternate route to

Delivery of a precast, prestressed concrete spliced girder section at the site.

bypass the tunnel over Loveland Pass, adds time and cost, not to mention uncertainty with inclement weather. Working within other design requirements, the design team chose a spliced girder solution with 72-in.-deep girders. On a trailer, the girders are tall, but a 72-in.-deep bulb-tee girder with its projected reinforcement, just passes beneath the top of the tunnel. In the end, all girders were easily transported by truck through the Eisenhower Tunnel.

### No Falsework Required

Once on site, the girders were erected by crane. The spliced girders were designed to span from pier to pier with no temporary falsework supports. The girders were pretensioned to control stresses during handling and shipping, which allowed the girders to be transported and erected as simple spans. The elimination of falsework was important to minimize impacts in the UPRR right-of-way. Once erected, the post-tensioning ducts were coupled, reinforcement placed, and the integral pier diaphragm concrete placed. Two tendons containing nine 0.6-in.-diameter strands in 3-in.-diameter ducts were installed in each girder and stressed to 395 kips each. Stressing from each end achieved the proper force along the parabolic tendon path.

PRECAST, PRESTRESSED CONCRETE SPLICED-GIRDER BRIDGE AND RAMP CONNECTOR USING PRECAST, PRESTRESSED CONCRETE, PARTIAL-DEPTH DECK PANELS AND CAST-IN-PLACE CONCRETE SUBSTRUCTURE / CITY OF GRAND JUNCTION AND MESA COUNTY, COLORADO, OWNERS

**BRIDGE DESCRIPTION:** Seven-span, 779-ft-long precast, prestressed, spliced girder bridge (span lengths are 118, 69, 104, 58, 135, 157, and 138 ft) and a five-span, 320-ft-long precast, prestressed concrete girder ramp (span lengths are 70, 80, 75, 47, and 48 ft). Both have a cast-in-place concrete composite deck cast on precast, prestressed concrete deck panels. The structures are supported on cast-in-place concrete column bents and abutments.

**STRUCTURAL COMPONENTS:** Bridge: 30 CDOT 72-in.-deep, precast, prestressed concrete, modified bulb-tees, 10 CDOT 72-in.-deep, standard bulb-tees, 27 CDOT 63-in.-deep bulb tees, and 3½-in.-thick precast, prestressed concrete deck panels; Ramp: 53 CDOT 63-in.-deep bulb-tees, and 3½-in.-thick precast, prestressed concrete deck panels

**BRIDGE CONSTRUCTION COST:** Total project \$34 million; Bridge cost \$7.5 million (\$107/ft<sup>2</sup>)



Construction of the spliced-girder unit over the UPRR showing the MSE approach retaining walls. Photo: Kristin Winn, City of Grand Junction, Colo.



A 3½-in.-thick, precast, prestressed concrete, stay-in-place deck panel form being lowered to the bridge during installation. Photo: Kristin Winn, City of Grand Junction, Colo.

The pier design is conventional with multi-column piers, cast-in-place with 3-ft 2-in.-square columns supporting 4 by 4 ft caps. To address the soft soils in the Grand Valley, 377 individual steel piles with an average length of 50 ft, were driven to support the substructure. The piers in the UPRR right-of-way had crash protection walls designed to absorb collision loading from adjacent tracks. The piers were offset the minimum horizontal clearance of 18 ft from existing and proposed future tracks in compliance with UPRR requirements.

### Precast Deck Panels Assist Schedule

The 8-in.-thick bridge deck utilized partial depth precast, prestressed concrete deck panels. The 3.5-in.-thick panels span between girder flanges and form the bottom of the composite deck. The top 4.5 in. of the deck is cast-in-place concrete with the epoxy-coated deck reinforcement placed directly on

the roughened surface of the precast deck panels. Upon curing, the cast-in-place portion of the deck, the precast deck panels, and the precast girders act compositely. The precast deck panels helped minimize the project schedule and demonstrate a method of accelerating bridge construction.

The project was built in four phases. The first three phases in 2009 addressed irrigation, utilities, roadway, and infrastructure improvements on the north and south ends of the project. These smaller phases yielded a construction opportunity for local contractors on the Western Slope of Colorado. They advanced the total project while creating the necessary time to obtain final approval from the UPRR and Public Utilities Commission for the

bridge crossing. The final phase—the bridge construction—was awarded in 2010.

The project was completed on schedule and opened with great public anticipation with a ribbon-cutting ceremony on November 19, 2011. The next planned transportation improvement for the Grand Valley is to extend 29 Road further north to I-70, including an interchange that will complete the beltway around Grand Junction for both local and regional mobility needs.

*Jeff Mehle is the structures manager for Jacobs Engineering Group Inc. in Denver, Colo.*

**For additional photographs or information on this or other projects, visit [www.aspirebridge.org](http://www.aspirebridge.org) and open Current Issue.**

### Environmental Sensitivity

The new 29 Road and I-70B crossing provides a more direct south-north connection in the Grand Valley of Grand Junction, Colo. It eliminates over 2 miles of transit route and travel time for 30,000 commuters. The reduced vehicle miles provide environmental benefits through reduced vehicle emissions. The crossing also improves emergency response time for police, fire, and ambulance providers to less than 5 minutes to residents and two schools on the south side of the UPRR tracks, which is a reduction of over 2 minutes. The corridor provides a more efficient bus route for Grand Valley Transit and multi-modal access for bicyclists and pedestrians on both sides of 29 Road that lead to Riverside Parkway and the 29 Road Colorado River crossing.

The project received a \$3.2 million energy grant award from the Colorado Department of Local Affairs. Aesthetically, the bridge and walls were colored with a concrete coating. Sand beige was used for the walls, abutments, monuments, pier cap, curb, and portions of the piers. Dark brown was used for the exterior girders and portions of the pier columns. The colors match those used on the Riverside Parkway, which includes eight bridges. The project provided a context-sensitive solution, which met the transportation need with an environmentally sensitive design that is an asset to the community.



The cast-in-place pier columns are shown with crash protection wall and striated surface that will be stained. Photo: Kristin Winn, City of Grand Junction, Colo.

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\*Available May 2012

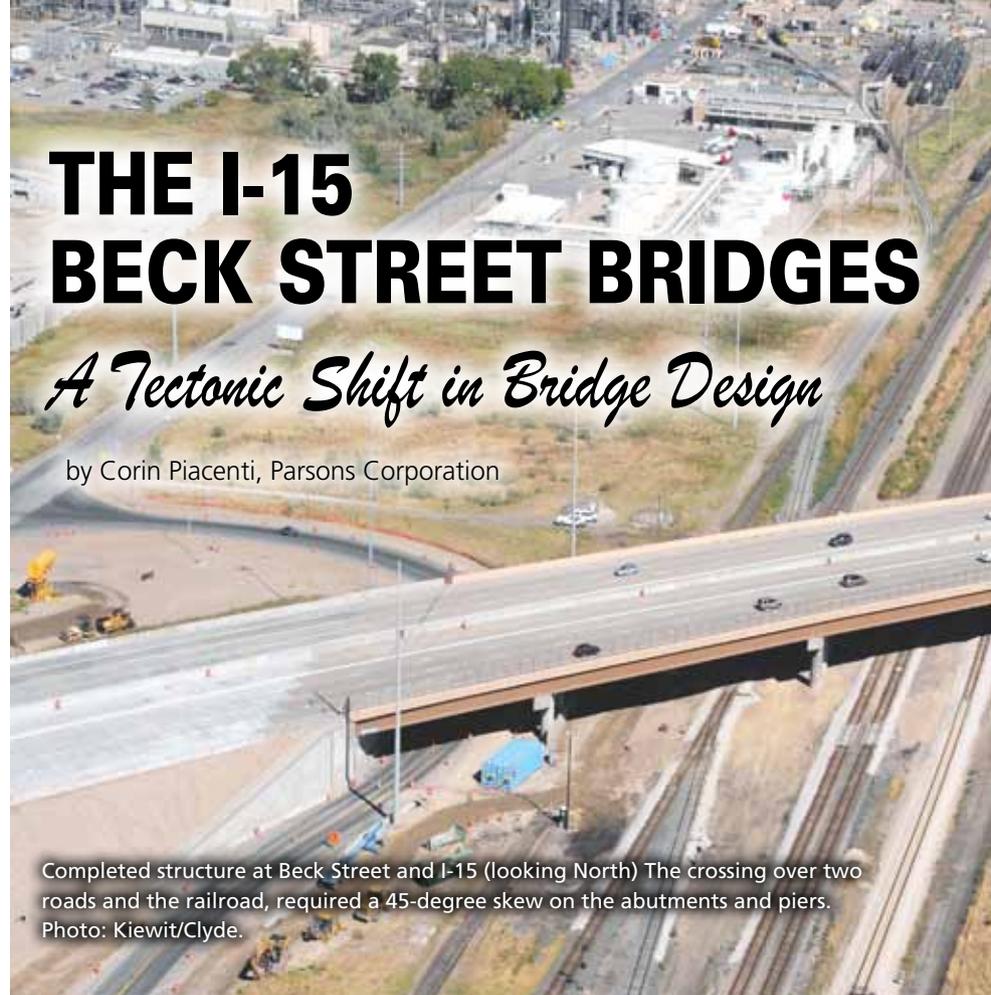
Designed to remain fully functional after the anticipated maximum seismic event.

The \$115 million I-15 widening project from 500 North in Salt Lake City, Utah, to the I-215 junction in Davis County, added 4 miles of northbound and southbound express lanes to I-15. As part of the design-build project, the existing six-lane Beck Street Bridge was removed and replaced with twin, four-span bridges to carry a total of 10 lanes of traffic on I-15. The bridge replacement, including additional lanes, eased the heavily used commuter route.

The northbound and southbound I-15 Beck Street Bridges are the Utah Department of Transportation's (UDOT's) first bridges designed to remain fully functional after the anticipated maximum seismic event. At the time of construction, they also used the longest precast, prestressed concrete girders ever fabricated and erected in the United States.

### Improved Layout from Original Concept Plans

The project team redesigned the concept plans for the I-15 Beck Street Bridges to reduce costs and complete the project 3 months ahead of UDOT's initial schedule. Warm Springs Road, the westernmost feature crossed by the I-15 Beck Street Bridges, was realigned 50 ft east, and vertical abutments were used instead of slope protection, resulting in a reduction of the overall length of the bridge by more than 200 ft. The reduction of the overall bridge length and the adjustment of the locations of the bents reduced the maximum span length to just less than 195 ft, allowing the use of precast, prestressed concrete



# THE I-15 BECK STREET BRIDGES

*A Tectonic Shift in Bridge Design*

by Corin Piacenti, Parsons Corporation

Completed structure at Beck Street and I-15 (looking North) The crossing over two roads and the railroad, required a 45-degree skew on the abutments and piers. Photo: Kiewit/Clyde.

girders rather than steel girders. The project team worked with the precaster during the proposal stage to select the girder section that could handle the long span. At the time, the standard Utah bulb-tee girders were still in development, but the precaster already had the data and the forms available for the metric, 2400-mm (94.5-in.) -deep, bulb-tee girder, which was selected for the project.

The bridges cross Union Pacific Railroad (UPRR) tracks, Utah Transit Authority (UTA) commuter rail tracks, Warm Springs Road, U.S. 89/Beck Street, residential and commercial structures, pressurized natural gas and hydrogen

lines, and two 10-in.-diameter crude-oil pipelines, and pass under a transmission power line. The geometric layout required approximately 45-degree skews at the abutments and bents. The bridges are on vertical and horizontal curves and featured a varying superelevation.

The northbound bridge is 591 ft 8.25 in. long between centers of bearings. The approximate span lengths are 114.6, 185.5, 196.5, and 95.1 ft. The bridge width varies from 84 ft 10 in. to 92 ft 11 in. The southbound bridge is 603 ft 7.1 in. long between bearings. Its span lengths are 124.6, 175.6, 196.5, and 107 ft. and its width varies from 72 ft 10 in. to 77 ft 0.25 in.

## profile

### I-15 BECK STREET BRIDGES / SALT LAKE CITY, UTAH

**BRIDGE DESIGN ENGINEER:** Parsons Corporation, Pasadena, Calif.

**GEOTECHNICAL/FOUNDATION DESIGN ENGINEERS:** Dan Brown and Associates PC, Sequatchie, Tenn., and Shannon & Wilson Inc., Seattle, Wash.

**PRIME CONTRACTOR:** Kiewit/Clyde (a joint venture between Kiewit Western Co., American Fork, Utah, and W.W. Clyde, Springville, Utah)

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

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

**SHAFT CONSTRUCTION:** Malcolm Drilling Company Inc., San Francisco, Calif.



## The use of long precast concrete girders was vital in accelerating the schedule, minimizing impact to the railroads, and reducing costs.

guide the girder designs. The girders required 8500 psi compressive strength concrete to reach the desired span length. The specified strength of the concrete at prestress transfer was 6500 psi. The girder bearings are 5¼-in.-thick reinforced elastomeric pads. The use of the long precast, prestressed concrete girders was vital in accelerating the schedule, minimizing impact to the railroads, and reducing costs.

The girders were shipped 18 miles to the construction site supported on each end by trailers specifically constructed for their transport. They were then lifted from the trailers and walked into place using two 250-ton crawler cranes. The precaster placed three monostrands in each edge of the top flanges of the girders. These helped to improve stability and mitigate tensile stresses in the girders' flanges during stripping, shipping, and erection. The monostrands eliminated the need for external bracing and were cut to detention them following erection.

Keeping with UDOT's commitment to incorporating accelerated bridge construction elements during design,



Each girder weighed up to 242 kips.  
Photo: Hanson Structural Precast.

partial-depth precast concrete panels were used in the 8½-in.-thick composite bridge deck. The 3.5-in.-thick, precast concrete panels, ranging from 3 ft 7 in. to 4 ft 7¾ in. wide and from 3 to 8 ft long, span between the girders and serve as stay-in-place forms for the bridges' cast-in-place concrete deck. These allowed the project to avoid installation and removal of forms over the railroad and was estimated to have saved an additional 6 to 8 weeks of construction time. The design compressive strength of the panel concrete was 5000 psi.

### Use of Precast Elements

The bridges use 194-ft 5-in.-long bulb-tee girders with shipping weights of approximately 242 kips. The 92 girders have a depth of 7 ft 10½ in. and are flared in the end spans to accommodate a varying roadway width. The center-to-center spacing of the girders varies from approximately 6 ft 9 in. to 7 ft 7 in. Steel was used for the intermediate diaphragms. The girders are heavily pretensioned, using up to sixty-eight 0.6-in.-diameter prestressing strands. The total jacking force was 2988 kips—791 kips in the 18 harped strands and 2197 kips in the 50 straight strands. The engineer used prestress bed capacity information from the precaster to



A precast, prestressed concrete bulb-tee girder during transport to the project. At 194 ft 5 in., the girders were the longest used in the United States at the time. Photo: Hanson Structural Precast.

## TWIN, PRECAST, PRESTRESSED CONCRETE BULB-TEE GIRDER BRIDGES WITH COMPOSITE, CAST-IN-PLACE CONCRETE DECK ON PRECAST CONCRETE DECK PANELS / UTAH DEPARTMENT OF TRANSPORTATION, OWNER

**DEEP SOIL MIXING:** Hayward-Baker AGC, Odenton, Md.

**BRIDGE DESCRIPTION:** Twin, four-span precast, prestressed concrete bulb-tee girder bridges with partial-depth precast concrete deck panels and cast-in-place concrete piers, abutments, wing walls, and foundations

**STRUCTURAL COMPONENTS:** Ninety-two 7-ft 10½-in.-deep bulb-tee girders with a maximum girder length of 194 ft 5 in., 48,333 ft<sup>2</sup> of precast 3½-in.-thick deck panels made composite with 5-in.-thick cast-in-place concrete, and twenty-four 9-ft 2-in.-diameter drilled shafts with a maximum depth of 122 ft

**AWARDS:** 2011 PCI Design Awards, Honorable Mention, Main Spans Greater than 150 Ft, 2011 American Council of Engineering Companies, Utah Chapter, Structural Systems Grand Award; 2010 *Roads & Bridges*, No. 9 Top Ten Road Projects; 2010 Utah Department of Transportation, Urban Project of the Year.

## Durability and Maintainability

The project team evaluated and selected material alternatives based on their ability to meet and exceed the project criteria, constructability, cost, aesthetic value, maintainability, and durability. Maintenance-free or low-cost maintenance components and a design that enabled easy access for maintenance crews were prime objectives. The design incorporated several components with specific durability and maintainability benefits, including:

- Precast, prestressed concrete girders that eliminate the need for painting.
- Partial-depth precast concrete deck panels that provide a PCI-certified, plant-produced, dense concrete in the bottom half of the bridge deck.
- Polymer concrete deck overlay that has proven highly effective in Utah's environment for at least 15 years.
- Deck designed with a ½-in.-thick sacrificial wearing layer and design for a 40 lb/ft<sup>2</sup> future wearing surface.
- Expansion joints only at abutments; no expansion joints at piers.
- UDOT maximum amount of fly ash in the concrete mixtures.
- Epoxy-coated reinforcement in all elements except the drilled shafts and piles.



The girders are 7 ft 10½ in. deep and are shown in the fabrication plant. Photo: Hanson Structural Precast.

## Seismic Design

The Beck Street Bridges are the first UDOT structures to be designed with the performance level category of "operational" using MCEER/ATC-49 *Recommended LFRD Guidelines for the Seismic Design of Highway Bridges* and the UDOT *Structures Design Manual*. UDOT classifies these bridges as "critical" because north and south mobility is constricted at this location by I-15, U.S. 89, and the UPRR and UTA tracks. The bridges provide a vital connection between Salt Lake County and Davis County.

Structures that UDOT classifies as "critical" must remain operational after the maximum considered earthquake (MCE). The MCE is defined as the earthquake response corresponding to a 2% probability of exceedance (PE) in 50 years (a return period of 2500 years), which is also equivalent to the MCEER 3% PE in 75 years. Per UDOT seismic design requirements, "critical" bridges must meet the displacement and detailing requirements for

Seismic Design Category D with a ductility demand equal to the maximum allowed. For a bridge with a performance level defined as "operational," UDOT requires that the damage sustained must be negligible and full service available for all vehicles after the inspection and clearance of debris. Any damage to the bridge must be repairable, without interruption to traffic.

The abutment is isolated from the approach embankment to reduce loading effects from the lateral spread of the embankment in an earthquake. The abutment embankment is protected through the use of deep-soil mixing.



Column reinforcement cage in a 9-ft 2-in.-diameter drilled shaft. Photo: Kiewit/Clyde.

## Bridges Open to Traffic

After 6 months of design and 20 months of construction, the I-15 Beck Street Bridges were completed and opened to traffic on August 16, 2010. With the completion of the project, the commute from and to the communities north of Salt Lake City was eased due to the increased capacity of I-15.

*Corin Piacenti is a structure design engineer with Parsons Corporation's South Jordan office, near Salt Lake City, Utah.*

**For additional photographs or information on this or other projects, visit [www.aspirebridge.org](http://www.aspirebridge.org) and open Current Issue.**



Precast concrete partial-depth deck panels provide a high-performance concrete, stay-in-place form and all of the positive moment reinforcement between beams in the bottom of the 8½-in.-thick composite deck. Photo: Hanson Structural Precast.



Completed twin bridges at Beck Street and I-15 (looking North-East). Photo: Kiewit/Clyde.



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## Silica Fume Association

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

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

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

- The publication of a *Silica Fume User's Manual*—the manual is a comprehensive guide for specifiers, ready mixed and precast concrete producers, and contractors that describes the best practice for the successful use of silica fume in the production of high performance concrete (HPC).
- The introduction of a Standard Reference Material (SRM)<sup>®</sup> 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](http://www.silicafume.org).



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# Concrete Bridges in Michigan— PAST, PRESENT, FUTURE



by Rebecca Curtis, Michigan Department of Transportation

**C**oncrete structures are an important part of the bridge inventory of the Michigan Department of Transportation (MDOT). Several reinforced concrete arch structures built prior to the 1900s are still in service today. One example is I-69 BR over the Battle Creek River in Eaton County, an earth-filled spandrel arch constructed in 1921, which remains in fair condition 90 years later.

By the 1920s, simple-span reinforced concrete T-beams were the most common concrete structure type being constructed. In the 1950s, a significant portion of the reinforced concrete T-beams built were continuous spans, and in the mid 1950s, precast, prestressed concrete side-by-side box beams were common in Michigan. In 1959, precast, prestressed concrete I-beam bridges were introduced and, within a few years,

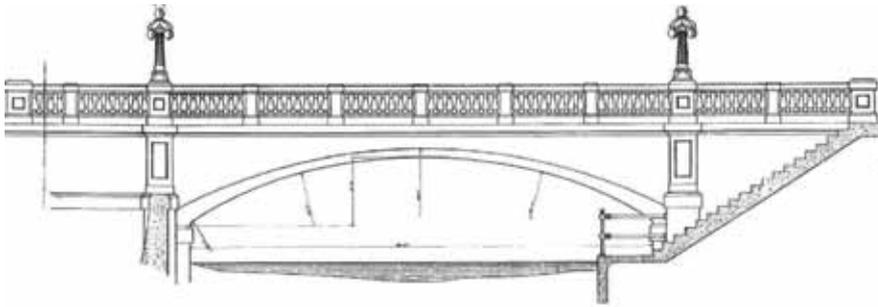
prestressed concrete box beam and I-beam bridges dominated new concrete construction.

## The Zilwaukee Bridge

When discussing concrete bridges in Michigan, one that must be mentioned is the Zilwaukee Bridge. MDOT made the decision to replace the existing I-75 bascule bridge over the Saginaw River in 1970, after it became apparent that a bascule bridge in an interstate freeway did not fit the purpose and need of the system. The decision to replace the drawbridge led to consideration of many alternatives. A tunnel under the Saginaw River would have cost about two and one-half times as much as a high-level bridge. Major alternatives for relocation of the freeway were also studied, but rejected as too costly and impractical. Closing the river to navigation at Zilwaukee also was considered but was opposed by the city of Saginaw and others with vested interests in maintaining port activity and its associated economic impacts upstream from I-75. Rerouting the traffic onto I-675 Business Loop through downtown Saginaw would have required extensive reconstruction well above the cost of a new bridge.

A high-level bridge was identified as the preferred option. Due to the Saginaw River being a strategic navigable waterway, the minimum height required over the waterway was 125 ft as dictated by the United States Coast Guard. The maximum highway longitudinal slope allowed in Michigan is 3%. These geometric factors contribute to the structure's grand size and length.

The twin precast, segmental concrete bridges are approximately 8085 ft long and the segments are 73 ft 6 in. wide between the tips of their



*Battle Creek River Bridge is an earth-filled spandrel arch constructed in 1921 and remains in fair condition 90 years later. All photos and drawing: Michigan Department of Transportation except where shown.*



*A typical parabolic reinforced concrete T-beam bridge built commonly in the 1950s.*



*Following the 1950s, adjacent precast, prestressed concrete box beam bridges were very common in Michigan as shown in these elevation and underside photos.*





*The twin structures of the Zilwaukee Bridge over the Saginaw River are shown during construction about 1987.*

cantilevers. The depth of the bridges varies from 8 ft 0 in. at midspan to 20 ft 0 in. at the piers. The precast segments were some of the largest used in segmental construction. A total of 1592 segments comprise the northbound and southbound structures. The northbound structure consists of 25 spans and the southbound structure consists of 26 spans, the longest of which is 392 ft over the Saginaw River.

Completed in 1988, the Zilwaukee Bridge has been in service for almost 24 years, and is currently in good to fair condition. The structure carries roughly 21.6 million vehicles each year, with the peak being between the July 4th and Labor Day holidays. A major rehabilitation project is scheduled for 2013, which will replace all pier, abutment, and expansion hinge bearings.

## Concrete Today

In 2011, reinforced and prestressed concrete bridges made up nearly 52% of the more than 10,800 highway bridges in Michigan. Of these bridges, 3955 are prestressed concrete and 1652 are reinforced concrete. Generally, the concrete structures being constructed in Michigan today use precast, side-by-side box beams, spread box beams, or I-beams. Reinforced concrete

**Concrete structures outperform the average for structures over 50 years old.**

is generally used for culverts, many of which are long enough to exceed the 20-ft limitation on the National Bridge Inventory inspection length. Current inspections find that concrete structures in Michigan are performing near the same or better than the average for bridges constructed during equivalent periods, with concrete structures outperforming the average for structures over 50 years old.

Advancements in concrete technology along with renewed emphasis on quality provide opportunities for MDOT to improve long-term durability and reduce the potential for

uncontrolled random cracking in concrete structures. Given Michigan's harsh and often unforgiving wet, freeze-thaw climate, it is essential that concrete exposed to the elements be highly impervious to moisture and resistant to freeze-thaw deterioration. Acknowledging characteristics of high-performance concrete, MDOT is focusing its efforts on incorporating innovative performance features, such as, optimizing the gradation of aggregates, reducing the total cement content, utilizing higher volumes of supplemental cementitious materials such as ground-granulated blast-furnace slag, reducing the water-cementitious materials ratio to reasonable levels via chemical admixtures, and instituting upfront testing for and remediation of alkali-silica reactivity. In addition, MDOT recognizes that it is of utmost importance that the highest practical quality, freeze-thaw resistant



*The Parkview Avenue Bridge uses five different types of precast components. Full-depth deck panels are shown after installation before grout placement in the joints and pockets.*



*The Parkview Avenue Bridge was designed as a total precast concrete structure to explore the concepts of accelerated bridge construction.*



A scaled model of a deck bulb-tee bridge, 40 ft long and 14 in. deep, is shown in the structures laboratory of Lawrence Technological University and following testing to failure. The bridge uses carbon fiber prestressing strands, all nonmetallic reinforcement, and UHPC in the longitudinal joints. Photo: Lawrence Technological University.

aggregates are used in conjunction with a properly air-entrained, very low permeable matrix. Finally, in order to ensure a first line of defense against long-term deterioration of concrete bridge decks, MDOT requires that all exposed, freshly finished concrete surfaces be immediately covered with a saturated, highly absorptive burlap material, and kept continuously wet for at least 7 days using soaker hoses beneath plastic sheeting.

## The Parkview Avenue Bridge

In 2008, MDOT began construction of the Parkview Avenue Bridge replacement using multiple prefabricated elements. The existing bridge was a two-lane county road over a four-lane freeway in Kalamazoo, Mich. The new bridge incorporated five prefabricated elements in lieu of the traditional cast-in-place construction. The project allowed MDOT to reduce the estimated construction time from 7 months to 2½ months. The successes and challenges of this project have laid the foundation for additional development of accelerated bridge construction technology in the state of Michigan.

The goal was to replace the existing bridge with a 249-ft-long, four-span bridge with a 23-degree skew in just 12 weeks. The prefabricated components consisted of four abutment segments, 12 round pier columns, 3 pier caps, prestressed I-beams, and 48 full-depth concrete deck panels. A 1½-in.-thick asphaltic overlay on a waterproofing membrane complete the bridge. The precast deck panels included a 250-sensor data collection system designed and monitored by Western Michigan University (WMU).

Due to alignment issues in the precast components, the bridge took nearly 6 months to complete, compared to the goal of 2½ months. The total project costs were within 2.5% of the

as-bid amount. The monitoring system installed by WMU indicates that the bridge deck is performing as a unified segment and that the joints between panels remain properly tensioned in efforts to ensure that the composite design is being maintained. MDOT gained valuable experience on precast elements in construction and embraces the growing national movement toward accelerated bridge construction.

## A Look Ahead

As MDOT looks toward the future of concrete bridges in Michigan, a clear vision is the necessity to develop a bridge preservation strategy that targets a 100-year service life. This is critical to maximize resources while minimizing the traffic impacts of maintenance and rehabilitation. A bridge designed for a 100-year service life must be able to meet the design, management, and inspection standards in practice today. Precast, prestressed concrete box-beams are advantageous because they have structural advantages over typical T-beam or I-beam sections. However, in the past, there have been issues with corrosion and inspectability with these sections. Through a Transportation Pooled Fund project (Solicitation Number: 1264), MDOT is pursuing a beam solution that incorporates the positive aspects of adjacent box beams while allowing for inspection access between the beams. This beam will facilitate accelerated bridge construction because the top flange serves as the deck surface, thus eliminating any cast-in-place forming. The beam is expected to be very long lasting because it will use noncorroding reinforcement including carbon fiber, stainless steel, and stainless steel-clad materials.

MDOT is currently conducting research through Lawrence Technological University in Southfield, Mich., to study the development and evaluation of a precast, side-by-side, deck bulb-tee beam bridge, which consists of the following:

- Precast deck bulb-tee beams prestressed and reinforced with non-corrosive strands and stirrups
- Integral transverse diaphragms precast monolithically with the deck bulb-tee beams and post-tensioned with unbonded noncorrosive tendons
- Ultra-high-performance concrete (UHPC) with the 28-day design compressive strength of 24,000 psi, used to fill the joints between the adjacent deck bulb-tee beams

The proposed research describes the deck bulb-tee beams as similar to shallow I-shape beams, except that the top flange is slightly wider than the bottom. This deck bulb-tee beam bridge allows proper inspection with the available space between the bottom flanges as compared to the box-beam bridge type.

Concrete bridges of all kinds are very important to the state of Michigan and have been for more than 100 years. These bridges have proven to be cost effective and durable. There have been significant advancements in technology in recent years including concrete, innovative designs, and noncorroding reinforcement. These, together with diligent quality control and preservation activities, lead engineers at MDOT to believe that the capability exists to build bridges very rapidly and achieve service lives of 100 years.

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*Rebecca Curtis is bridge management engineer at the Michigan Department of Transportation in Lansing, Mich.*

**For more information about the Transportation Pooled Fund Research project, contact Dave Juntunen, bridge development engineer at [juntunend@michigan.gov](mailto:juntunend@michigan.gov), or call (517) 335-2993.**



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## CREATIVE CONCRETE CONSTRUCTION

# A New Face for Fort Benning

## Freestanding precast concrete façades and huge columns provide new gateway

by George Spence,  
Metromont Corp.



*Left: To dress up the gateway to Fort Benning, Ga., designers created freestanding precast concrete façades that hide the existing steel bridge and added a precast concrete column pedestal at each corner topped with a bronze statue.*

*Below: The precast concrete façades at Fort Benning, Ga., were funded through the American Recovery and Reinvestment Act (ARRA) through the Georgia Department of Transportation and private funds from the Gateway Foundation of Columbus.*

Officials at Fort Benning in Columbus, Ga., wanted to project a more dramatic face for visitors to the fort, one of the Army's busiest. To achieve that, designers created freestanding precast concrete façades that hide the existing steel bridge and added round precast concrete column pedestals at each corner, topped with an imposing statue.

The key challenge for precaster Metromont Corp. in Hiram, Ga., was to combine the highly finished aesthetic design with a structural concept that would allow the sculptural elements—essentially narrow bridge beams in their own right—to provide an integrated solution.

The \$6.8-million design features column piers on each end with a supporting pier in the highway median. The façades on each side of the bridge were created as two prestressed panels, each approximately 89 ft long and weighing 100,000 lb. The panels bear on new foundations and have metal lettering attached to them to spell "Fort Benning Georgia" on the north façade and "Columbus, Georgia" on the south façade.

The structures' finish consists of a white/buff mix of aggregates with a moderate sandblast. A total of 238 pieces, comprising 30,439 ft<sup>2</sup> of architectural precast concrete were erected using a crane positioned on each side of the interstate. Traffic only needed to be stopped for the short time when a panel was being set over the highway.

The erector also placed the four piers, which each support four tall, round precast columns topped with a precast concrete column cap—a total of 50 ft tall. Bronze statues were placed atop



the pillars by the precast erector. Two feature American bald eagles, while the others showcase statues representing the Armor and Infantry schools that train at the post.

"It's magnificent," said Maj. Gen. Robert Brown, commander of Fort Benning and the Maneuver Center of Excellence. Others agree: The project, completed in October 2011, was awarded first place in the design awards competition of the Georgia Chapter of the American Concrete Institute.

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*George Spence is the sales and business development manager for Metromont Corp. in Dalton, Ga.*

*Statues atop the column pedestals reflect the units that train at the post.*



# PRESTRESSED CONCRETE BRIDGES



PHOTO OF ROUTE 70 OVER MANASQUAN RIVER IN NEW JERSEY (PHOTO COURTESY ARORA ASSOCIATES).

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# Enhanced Stability of Bridge Column Reinforcing Bar Cages

by Ahmad M. Itani, University of Nevada, Reno



Close-up of a collapsed cage on a jobsite. All photos and drawings: University of Nevada in Reno.



View of test Specimen II having a 34 ft height and 3 ft 8 in. diameter.

The collapse of reinforcing bar cages during construction causes schedule delays, cost overruns, and sometimes injuries and deaths. A series of experimental and analytical studies on the stability of bridge column cages was conducted at the University of Nevada, Reno (UNR) through a research project funded by the California Department of Transportation (Caltrans). The purpose of the study was to develop guidelines to enhance the stability of bridge reinforcing bar cages, and minimize their instability during placement or potential for full collapse.

The project included designing and testing two full-scale reinforcing bar cages under lateral loads in addition to testing hundreds of tie wire connections under various types of loading conditions. The height of both test specimens was 34 ft, with an outside diameter of 3 ft 8 in. Specimen I had the longitudinal and transverse reinforcement ratios equal to 1% while Specimen II had the longitudinal and transverse reinforcement ratios equal to 2%. Internal X-type braces were used in Specimen I and square-type braces were used in Specimen II. The X-type was made of four No. 8 bars, while the square-type was made of eight No. 8 bars. The height of the braces was equal to



Test Specimen II following collapse.

9 ft 4 in. and 9 ft 8 in. for the X-type and square-type, respectively. Clear spacing for both types was 10 ft 6 in. along the height of the cage.

A series of nonlinear finite element analyses were carried out on various reinforcing bar cage configurations (height, diameter, reinforcement ratios, and braces) to determine the stability of cages under accidental dynamic loading. It was concluded that internal braces in cages play an important role in stability and lateral stiffness. Without these braces, reinforcing bar cages have low lateral stiffness and are vulnerable to significant instability or even collapse.

The following photos show recommendations that are proposed to improve the stability of bridge column cages during construction:

### Acknowledgements

Dr. Saad El-Azazy, Mr. John Drury, and Ajay Sehgal of Caltrans provided valuable information throughout the project. The author acknowledges J.C. Builes-Mejia former UNR graduate student and Hassan Sedarat of SC Solutions Inc. for their assistance throughout the investigation.

Ahmad M. Itani is professor of Civil and Environmental Engineering at the University of Nevada in Reno, Nev.

### EDITOR'S NOTE

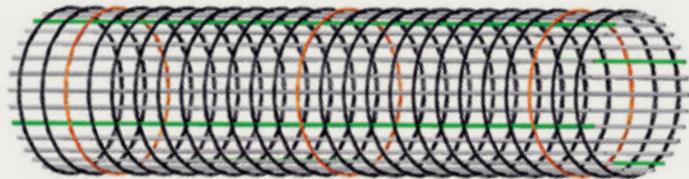
This article is a condensed summary of the report "Stability of Bridge Rebar Cages," (CCEER Report No. 10-07) by J.C. Builes-Mejia, A. Itani, and H. Sedarat, published in 2010 by the University of Nevada, Reno, and is available at <http://go.hw.net/cc-rebar-cages>.

A PDF file of a detailed PowerPoint presentation on this work by Dr. Ahmad M. Itani may be downloaded from the *ASPIRE*™ website, [www.aspirebridge.org](http://www.aspirebridge.org), click on "Resources" and select "Referenced Papers."

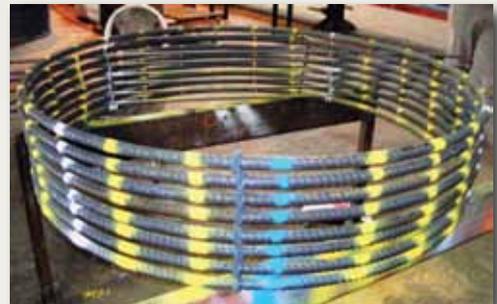


All tie wire connections should use 15-gauge, soft annealed black steel with a minimum tensile strength of 40 ksi.

Four longitudinal bars around the perimeter of a circular cage form the corners of a square shape and are typically identified as the "pick-up" bars. These four vertical bars should be tied at every intersection with double-wire ties. They are indicated with green markings.



Template hoops or rings, which maintain the circular shape of the cage, should be provided at a maximum of 10 ft increments and tied at every intersection with double-wire ties. The hoops are shown marked with paint to position the longitudinal bars. Above, hoop bars are indicated in orange.



Between the template hoop bars, at least 20% of the remaining reinforcement intersections should be tied with at least single-wire ties. Ties should be staggered from adjacent ties.



Internal braces with box configurations should be provided at a maximum of 10 ft increments using eight bars (minimum No. 8) tied to the "pick-up" bar and to the interlocking hoops at their ends.



# Resilience of Concrete Highway Bridges

by M. Myint Lwin,  
Federal Highway Administration



The new I-35W Bridge across the Mississippi River in Minnesota provides continuity throughout the bridge and state-of-the-art smart bridge technology that monitors bridge behavior in real time. Photo: FIGG Bridge Engineers.

Highway and transportation agencies are adopting innovative methods, technologies, and materials. They are using systematic preventive maintenance, bridge management systems, and asset management principles to balance demands and resources, while maintaining a high level of safety in highway bridges. This article summarizes a framework to achieve more resilient highway bridges.

## Resilient Highway Bridges

Resilient concrete highway bridges have the capability to withstand unusual or extreme forces without collapse or loss of lives. They are able to recover from distress or major damage with minimal disruption to traffic and essential services. Three key factors affect the resilience of highway bridges: ductility, redundancy, and operational importance.

- Ductility in a structural system is characterized by development of significant and visible inelastic deformations before failure.
- Redundancy may be defined as the capability to continue to carry loads after the failure of one of its components. In other words, a redundant bridge system has multiple-load paths for distributing the loads when a component fails.

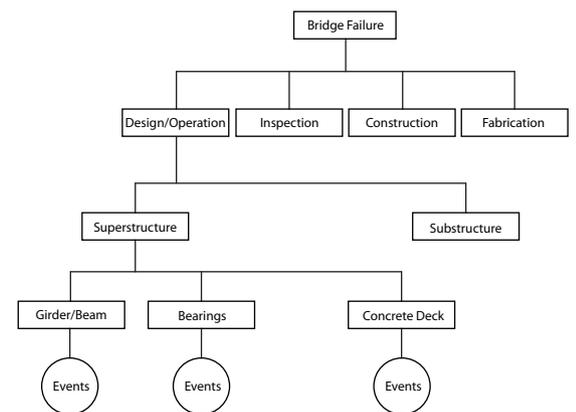
- Operational importance relates to the consequences of loss of use of the bridge. Rapid emergency response is important for the survival of people and the security of the incident scene.

The *AASHTO LRFD Bridge Design Specifications* recognizes the significant effects of ductility, redundancy, and operational importance on the resilience of concrete highway bridges. The *LRFD Specifications* accounts for these effects on the load side of the limit states equation. It recommends the use of multiple load paths and continuous bridges, unless there are compelling reasons for not doing so. The National Cooperative Highway Research Program (NCHRP) Reports 406 and 458 contain discussions and recommendations on quantifying redundancy in highway bridge superstructures and substructures, respectively. There is an ongoing NCHRP Project 12-86 “Bridge System Safety and Redundancy” for developing a methodology to quantify bridge system reliability for redundancy. The project is scheduled for completion in July 2012 with recommendations for updating the *LRFD Specifications* and the *AASHTO Manual for Condition Evaluation*.

The FHWA publication titled *Framework for Improving Resilience of Bridge Design*, Publication No. FHWA-IF-11-016, introduces the fault-tree methodology for performing failure analysis during design. A bridge designer goes through a fault-tree analysis mentally in making sure that the design is devoid of weaknesses or trouble spots that could lead to bridge closure or failure. This is generally adequate for simpler and more common types of concrete bridges. For more complex bridges, it is desirable to perform a fault-tree analysis to systematically determine all potential contributing factors or events that could lead to a bridge failure. The contributing factors or events can then be considered and carefully addressed in the design.

## Fault-Tree Analysis

A fault-tree analysis can be carried out using a fault-tree diagram. The diagram is a graphic model that shows parallel and sequential failure paths that can lead to an undesirable outcome; in this case a bridge failure. The fault-tree diagram is helpful in determining potential failure modes and their interactions. A fault-tree diagram is developed in a top-down direction. In this application, the top event is the failure of the bridge. The events immediately beneath the top event lead to the execution of the top



Portion of the girder bridge fault tree. Diagram: Federal Highway Administration.

event. Successor events and conditions that most directly lead to the predecessor events are then determined. This process is repeated at each successive level of the fault tree until the diagram is complete.

Utilizing a fault-tree diagram, a bridge is modeled to determine the critical failure paths. The fault-tree diagram illustrates the structural component interactions, redundancy, actions/causes, and environmental impacts. The failure paths depicted in the fault-tree diagram are intended to provide bridge designers with a means to improve bridge designs. If bridge designers understand critical failure modes related to the particular bridge, they will be able to employ additional analyses to assess and rectify issues not typically addressed during the design phase.

## Girder Bridge Failure Analysis Framework

A general fault tree for the case of a bridge failure is developed and presented in this section. Failure may be considered as a total collapse of the bridge system or an event that results in a critical defect.

The fault tree is established with the top event, the Bridge Failure. The failure can develop from four different categories: Design/Operation, Inspection, Construction, or Fabrication. Not all of the conditions will necessarily apply to the bridge designer, but the designer should be aware of all of the events on the fault tree. These aspects are presented here so bridge designers understand and take into account the whole process of the design, fabrication, construction, inspection, and operation of the bridge.

The *Design/Operations* category alludes to the fact that a failure, either a collapse or critical defect, can occur while the bridge is in service. *Inspection* refers to the fact that there may be a problem with the routine inspection such that the design does not permit inspection of some of the bridge components. A failure can also occur during the *construction* of the concrete girder bridge. The *fabrication* process is also subject to errors and omissions. The bridge designer should be aware of, and give due consideration to the events in these categories.

### Design/Operation Category

While in service, a bridge failure can result from either a failure of the superstructure or substructure.

A failure of the concrete girder superstructure can be caused by a failure in any one of the



*The Don E. Wickstrom Bridge over the Green River in Kent, Wash., features fully continuous, post-tensioned spans and integral piers. Photo: BergerABAM.*

superstructure components, but mainly the girders, bearings, or concrete deck. A failure of the superstructure will trigger an operational failure of the bridge. After identifying the critical events or components, the bridge designer can take steps to ensure the resilience of the design for safety, durability, and economy. Detailed discussions of each of the main components and events are given in the FHWA Publication No. FHWA-IF-11-016, *Framework for Improving Resilience of Bridge Design*.

### Closing Remarks

The fault-tree analysis is applicable to highway bridges of all types of construction materials. Fortunately, concrete has a track

record of high performance. The application of fault-tree analysis in the design and evaluation of major and complex concrete highway bridges will further enhance the design of resilient concrete highway bridges.

### EDITOR'S NOTE

*The FHWA Publication No. FHWA-IF-11-016, Framework for Improving Resilience of Bridge Design may be downloaded from [www.fhwa.dot.gov/bridge/pubs/hif11016/hif11016.pdf](http://www.fhwa.dot.gov/bridge/pubs/hif11016/hif11016.pdf).*



*An accident caused by an over height load on I-29 in Iowa, resulted in the destruction of all bottom flanges of this precast, prestressed concrete I-girder bridge without its collapse, illustrating the redundancy in these concrete structures. Photo: Iowa Department of Transportation.*

## CREATIVE CONCRETE CONSTRUCTION

# Geosynthetic Reinforced Soil Bridge Abutments in Defiance County, Ohio

by Warren Schlatter, Defiance County



*The Bowman Road Bridge was the first GRS bridge constructed by Defiance County in 2005. It uses an 80-ft-long beam. The bridge is 34 ft wide with a 24-degree skew and 7.6-degree superelevation. The abutments are 43.6 ft long and 15.25 ft tall.*

**D**efiance County, Ohio, was introduced to geosynthetic reinforced soil (GRS) at a county engineers' conference in 2004. The presentation reported research conducted by the Federal Highway Administration (FHWA) on layers of aggregate reinforced with closely spaced sheets of geotextile using a concrete masonry block facing. The presentation advocated this technology for bridge abutments resulting in lower costs and possibly better performance than traditional methods.

The construction begins with the excavation to a competent soil layer. A GRS foundation is created by laying a large piece of geotextile on the bottom of the excavation, filling it with compacted aggregate approximately 8 to 10 in. thick, then folding the fabric over the top of the carefully leveled and compacted surface. The facing course is laid out on this foundation—in our case a row of split face, 8-in.-high concrete masonry blocks. Aggregate is placed, leveled, and compacted behind the facing in additional 8-in. lifts and the aggregate and facing covered with more layers of geotextile. This is repeated to achieve the desired wall height.

In 2005, Defiance County began using this technology to construct wingwalls on culverts followed by the first bridge abutments. In this initial installation, the vertical load-bearing abutments allowed the use of beam spans of about 80 ft instead of 110 ft, and perhaps eliminated an additional pier that traditional

spill-through slopes would have required. Even though it was a first project of sizeable scale, it went well, was installed as predicted, and at 6 years old, continues to demonstrate how well this type of bridge substructure performs. The adjacent, precast, prestressed concrete box beams sit directly on a layer of fabric on the GRS fill. The backfill at the ends of the beams is also GRS with no bearing slab or special approach slab. Despite, or perhaps because of this simple construction, there is no pavement crack or “bump at the end of the bridge.” All the materials are easy to obtain, handle, and store.

Defiance County has subsequently constructed over 20 more bridges using GRS abutments. Ranging from a 10 ft to a 130 ft span, they have all performed well. The small abutments can be substantially completed in a day as the crew gets more proficient with the method of construction. Several bridges have been built by contractors with similar results.

Defiance County encourages others to investigate how GRS may help save them money and build substantial bridges in these difficult economic times. The FHWA has chosen this technology to promote as part of its Every Day Counts initiative and has recently published new design and construction guidance that can help interested designers. Links to these documents and additional pictures of completed bridges can be found at [www.defiance-county.com/engineer/GRS.htm](http://www.defiance-county.com/engineer/GRS.htm).



*A geosynthetic reinforced soil (GRS) abutment is constructed in 8-in.-high lifts with a layer of geotextile between each lift.*



*A close view of the 8-in. concrete masonry units forming the face of the abutment and the geotextile between layers.*



*Adjacent precast, prestressed concrete box beams are placed directly on the geotextile covering the compacted granular backfill.*

**Warren Schlatter is the Defiance County engineer in Defiance, Ohio.**

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*See you in Nashville!*

# 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](http://www.aspirebridge.org).

## IN THIS ISSUE

### [www.pppcouncil.ca](http://www.pppcouncil.ca)

Additional information about Public-Private Partnerships in Canada, as mentioned on page 13, is available at this website of The Canadian Council for Public Private Partnerships.

### [www.vappta.org](http://www.vappta.org)

Visit this website for more information about Virginia's Office of Public-Private Partnerships. The guidance document mentioned on page 15 is available under Publications.

### <http://go.hw.net/cc-rebar-cages>

The full report titled *Stability of Bridge Rebar Cages* summarized in the Safety and Serviceability article on page 49 is available to download from this website.

### [www.fhwa.dot.gov/bridge/pubs/hif11016/hif11016.pdf](http://www.fhwa.dot.gov/bridge/pubs/hif11016/hif11016.pdf)

The publication titled *Framework for Improving Resilience of Bridge Design* referenced in the FHWA article on page 51 may be downloaded from this website.

### [www.defiance-county.com/engineer/GRS.htm](http://www.defiance-county.com/engineer/GRS.htm)

Additional information about the geosynthetic reinforced soil projects in Defiance County, Ohio, mentioned on page 52, is available at this website.

### [www.fhwa.dot.gov/everydaycounts/technology/grs\\_ibs/](http://www.fhwa.dot.gov/everydaycounts/technology/grs_ibs/)

This FHWA website contains information about geosynthetic reinforced soil integrated bridge system technology, which is part of the FHWA Every Day Counts initiative.

## Environmental

### <http://environment.transportation.org/>

The Center for Environmental Excellence by AASHTO's Technical Assistance Program offers a team of experts to assist transportation and environmental agency officials in improving environmental performance and program delivery. *The Practitioner's Handbooks* provide practical advice on a range of environmental issues that arise during the planning, development, and operation of transportation projects.

### [www.environment.transportation.org/teri\\_database](http://www.environment.transportation.org/teri_database)

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

## Sustainability

### <http://sustainablehighways.org>

The Federal Highway Administration has launched an internet-based resource designed to help state and local transportation agencies incorporate sustainability best practices into highway and other roadway projects. The Sustainable Highways Self-Evaluation Tool, currently available in beta form, is a collection of best practices that agencies can use to self-evaluate the performance of their projects and programs to determine a sustainability score in three categories: system planning, project development, and operations and maintenance.

## Bridge Technology

### [www.aspirebridge.org](http://www.aspirebridge.org)

Previous issues of *ASPIRE*<sup>TM</sup> 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](http://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](http://www.hpcbridgeviews.org)

This website contains 68 issues of *HPC Bridge Views*, an electronic newsletter published jointly by the FHWA and the NCBC to provide relevant, reliable information on all aspects of high-performance concrete in bridges.

### **NEW** [www.fhwa.dot.gov/bridge/abc/docs/abcmanual.pdf](http://www.fhwa.dot.gov/bridge/abc/docs/abcmanual.pdf)

The FHWA report titled *Accelerated Bridge Construction: Experience in Design, Fabrication, and Erection of Prefabricated Bridge Elements and Systems* may be downloaded from this website.

### [www.fhwa.dot.gov/bridge/abc/prefab.cfm](http://www.fhwa.dot.gov/bridge/abc/prefab.cfm)

If you missed the FHWA webinars about Prefabricated Bridge Elements and Systems, held in four sessions on August 16 and 17, 2011, the webinar is now available at this website. Under Webinars, click on one of the four sessions. The concrete industry role is included in Session 3.

### [www.abc.fiu.edu](http://www.abc.fiu.edu)

This website contains information from the Accelerated Bridge Construction (ABC) Center of Florida International University about upcoming and previous webinars.

## Bridge Research

### [www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/nrcc52661.pdf](http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/nrcc52661.pdf)

A research report by the National Research Council of Canada about the benefits of internal curing on service life and life-cycle costs of high-performance concrete bridge decks is available at this website.

### [www.fhwa.dot.gov/research/publications/technical](http://www.fhwa.dot.gov/research/publications/technical)

Searching for transportation infrastructure-related reports, fact sheets, and other publications? For a list of FHWA research reports and technical publications, visit this website.

### **NEW** [www.fhwa.dot.gov/pavement/concrete/asr/reference.cfm](http://www.fhwa.dot.gov/pavement/concrete/asr/reference.cfm)

The online alkali-silica reactivity (ASR) Reference Center developed under the FHWA ASR Development and Deployment Program has been updated to provide engineers and practitioners with the most current and pertinent information related to ASR. Over 300 references are posted.

### [www.trb.org/Publications/](http://www.trb.org/Publications/)

### [PubsNCHRPResearchResultsDigests.aspx](http://PubsNCHRPResearchResultsDigests.aspx)

Research Results Digest 355 summarizing key findings from NCHRP Project 10-71 titled *Cast-in-Place Concrete Connections for Precast Deck Systems* is available from this National Cooperative Highway Research Program website.

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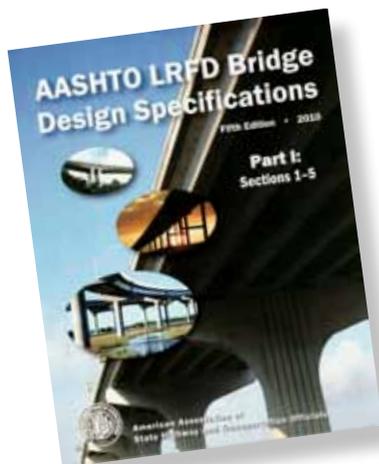
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# A Question of Application and Interpretation



by Dr. Dennis R. Mertz



**T**he question in the Reader Response on page 6 about the best methodology to calculate the effects of superstructure creep (CR) and shrinkage (SH) on substructure design of a multi-span, continuous concrete bridge structure, raises broader issues regarding the nature of design standards.

The *AASHTO LRFD Bridge Design Specifications* represents minimum requirements and in some cases, such as live-load distribution, acceptable simplifications. At times, the *LRFD Specifications* asks the designer to consider various effects but is not explicit about how. For example, LRFD Article 3.4.1, cited by the reader, states,

“All relevant subsets of the load combinations shall be investigated. For each load combination, every load that is indicated to be taken into account and that is germane to the component being designed, including all significant effects due to distortion, shall be multiplied by the appropriate load factor . . .”

My interpretation of this specification passage, and its intent, is to allow the designer to apply expertise to eliminate effects that are deemed insignificant. As the reader correctly indicates, creep and shrinkage are included in each of the strength and service limit-state load combinations of LRFD Article 3.4.1. A quick look at any of the published design examples developed by various reputable sources, including the newly revised *PCI Bridge Design Manual*, reveals that many of the loads indicated in LRFD Table 3.4.1-1, are

not explicitly included in the calculations. The bridge engineers who developed these examples used their expertise and experience to selectively eliminate insignificant effects based upon the type and geometry of the bridge components under investigation.

Similarly, the *LRFD Specifications* does not necessarily tell the designer how to calculate all force effects, especially those principally dependent upon the bridge type and configuration, such as those due to superimposed deformations including creep and shrinkage. This calculation is best left to the judgment of the engineer, who may need to use a global structure response model or a time-step analysis depending on the complexity of the structural system.

In my mind, the specifications are becoming too prescriptive, and thus potentially limiting to experienced designers. The *LRFD Specifications* does not tell how to determine creep and shrinkage effects in complex structures. The bridge designer should have a more intimate knowledge of the behavior of the specific bridge, more than any specification writer can possibly anticipate. I believe it is up to a designer to apply the art and science of bridge design satisfying the minimum requirements represented by the *LRFD Specifications*, but not driven by these specifications. Unfortunately, the *LRFD Specifications* is becoming too much like a cookbook for bridge design and is being used as such. The panel of state

bridge engineers who oversaw the development of the first edition of the *LRFD Specifications* dictated that the essence of the specifications should not be that of a textbook but that users of the specifications must bring knowledge of highway bridge design to the specifications. Unfortunately, we seem to be losing this essence.

## EDITOR'S NOTE

*The topic of pier design for bridges with integral connections between the superstructure and substructure is addressed in the PCI State-of-the-Art of Precast/Prestressed Integral Bridges, PCI publication No. IB-01-02.*

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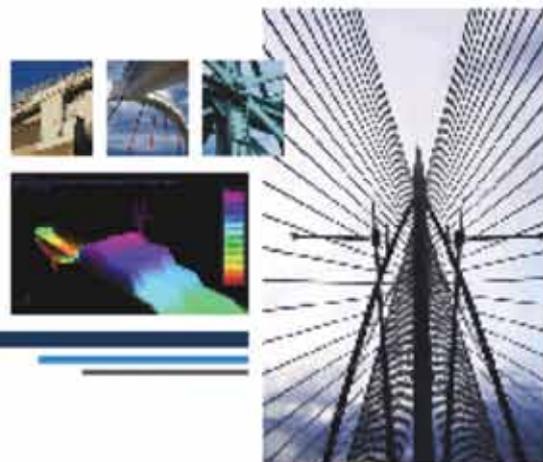
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